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Input Files and Procedures for Analysis of SMA Hybrid Composite Beams in MSC.Nastran and ABAQUS

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Abstract

A thermoelastic constitutive model for shape memory alloys (SMAs) and SMA hybrid composites (SMAHCs) was recently implemented in the commercial codes MSC.Nastran and ABAQUS. The model is implemented and supported within the core of the commercial codes, so no user subroutines or external calculations are necessary. The model and resulting structural analysis has been previously demonstrated and experimentally verified for thermoelastic, vibration and acoustic, and structural shape control applications. The commercial implementations are described in related documents cited in the references, where various results are also shown that validate the commercial implementations relative to a research code. This paper is a companion to those documents in that it provides additional detail on the actual input files and solution procedures and serves as a repository for ASCII text versions of the input files necessary for duplication of the available results.

Introduction

Shape memory alloys (SMAs) are being considered for an ever-increasing number and variety of applications. While practical knowledge of SMAs has increased significantly in recent years, no practical modeling tool has been made available to engineers and researchers. Furthermore, SMA hybrid composite (SMAHC) structures, conventional composite structures with embedded SMA actuators, are receiving significant interest. SMAHC structures present even greater numerical modeling difficulties because of the complex interactions between the constituents.

A thermoelastic constitutive model for such SMAHC material systems and structures was previously developed by Turner.[1] This model is based upon definition of a nonlinear, effective coefficient of thermal expansion (CTE) and is relatively intuitive, simple to use, and requires only fundamental engineering properties of the constituent materials. A research finite element (FE) code was developed around this constitutive model. The research code has been used for numerical studies and for experimental validation of the model.[2-5] The model was recently implemented in the commercial finite element codes MSC.Nastran and ABAQUS, as reported by Turner and Patel.[6-7] The model is supported within the core of current releases of both codes, so no user subroutines or external calculations during solution are necessary. Details of the theory behind the model are presented in reference 1. An overview of the manner in which the model can be used in the commercial codes is given in references 6 and 7, followed by results for thermal post-buckling and random vibration control of clamped SMAHC beams and deflection control of cantilevered SMAHC beams. The results show excellent agreement between the commercial codes and the research code in all cases. A web link is cited in references 6 and 7 (and below) that provides all of the input files necessary to duplicate the results presented in those papers.

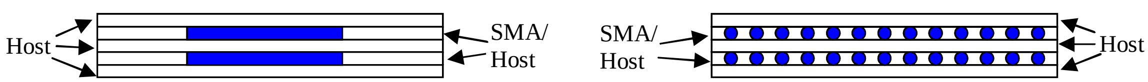
The objectives of this paper are to describe the specific input files in more detail than is possible in the other publications, describe the solution processes in more detail, and serve as a repository for ASCII listings of all of the files necessary to regenerate the results in references 6 and 7. It is hoped that the information in references 6 and 7, the additional detail in this publication, and the input files in electronic or text form (in this document) will enable the reader to rapidly understand the usage of the model in MSC.Nastran and ABAQUS and enable adaptation of these methods to a wide variety of research and industrial applications.

General Comments

The input files necessary to regenerate the results in references 6 and 7 are available online at http://stabserv.larc.nasa.gov. There are three subfolders in this distribution including "deflection_control," "post-buckling," and "random_vibration." The subfolder names indicate their respective content necessary to duplicate the deflection control, thermal post-buckling, and random vibration results from references 6 and 7. In the event that these files are ever unavailable, they are presented in ASCII text form in Appendices A–F. The remainder of this section is dedicated to general comments on the files in the distribution. Some filename suffix definitions are as follows.

*.bdf MSC.Nastran analysis input file (bulk data file)
*.dat Material property data file, ABAQUS data file (ASCII), or results comparison data file
*.fil ABAQUS results file (binary)
*.f06 MSC.Nastran output file (ASCII)
*.inp ABAQUS analysis input file
*.odb ABAQUS output database file (binary)
*.pch MSC.Nastran punch file (ASCII)
*.py ABAQUS Python script

Two beam configurations are considered in this study including a 18×1 inch beam clamped at both ends and a 9×1 inch cantilever beam. Two SMAHC laminates are analyzed for each beam configuration. The SMAHC laminates include one having single wide ribbon Nitinol inclusions along the centerline of the beam in specific layers and the other having uniformly distributed Nitinol inclusion over the extent of specific layers. Schematics of a representative beam cross section for the two laminates are shown in Figure 1a and b, where unrealistically few layers are shown for clarity.



(a) (b)

Figure 1: Representative beam cross sections for the *mon* (a) and *mix0* (b) SMAHC laminate types.

The FE mesh used in this study has 4 elements across the width of the beam cross sections. Application of the mesh to the laminate in Figure 1a results in the outer two rows of elements consisting of host material only and the inner elements have layers that alternate between 100% Nitinol (monolithic Nitinol inclusion) and 100% host composite. In contrast, the same FE mesh applied to the laminate in Figure 1b results in identical lamination for all elements with layers consisting of host composite only or mixtures of Nitinol and host composite (mixture Nitinol inclusion with 0° orientation). These laminates will be referred to as *mon* and *mix0* SMAHC laminate types, indicating the respective monolithic and mixture Nitinol content in representative finite element cross sections. The *mon* laminates considered in this study have differing glass-epoxy and Nitinol layer thicknesses of 0.004875 and 0.006 inches, respectively. Thus, the necessary material properties for elements of the *mon* laminate type include those to characterize the constituents alone and the resulting two element types (glass-epoxy only and SMAHC) have differing thickness but the same mid-plane. Elements of the *mix0* laminate type require material properties to characterize the host material alone and in combination with Nitinol. Also, all layers have the same thickness (0.004875 inches) for the *mix0* laminates analyzed in this study. These two attributes result in uniform element thickness and properties for elements of the *mix0* laminate type. The MSC.Nastran and ABAQUS input files associated with the two material types are distinct, as indicated by the presence of the string "mix0" in the root of the file name for analyses involving the SMAHC laminates with the mixture layers (*mix0* laminates). The material property data files have the following naming convention.

materialcode_1dir2dir75.dat

- material – glep, niti, or smahcmix0 indicating that the material property data is representative of glass-epoxy, Nitinol, or of a SMAHC mixture layer with Nitinol in the 0° direction, respectively.
- code – nast or abaq indicating that the material property data is in a format consistent with MSC.Nastran or ABAQUS input, respectively.
- 1dir and 2dir – sec, tan, or stn indicating that the thermal expansion data in the material property data file is secant CTE values, tangent CTE values, or thermal strain values, respectively. The data type indication is given for both the 1 and 2 principal material coordinate directions.
- 75 – indicates that the material property data is specific to a reference temperature of 75°F.

The properties given for the SMAHC mixture (smahcmix0) were evaluated using the relations for effective material properties in Equations (7) of references 6 and 7. Note that the native form for the thermal expansion properties of Nitinol is thermal strain in the 1-direction and tangent CTE in the 2-direction. That for glass-epoxy is tangent CTE in both the 1- and 2-directions. These native forms are dictated by the corresponding experimental measurement(s) and subsequent data processing. Thermal strain for Nitinol in the 2-direction was calculated by integrating the tangent CTE values. Secant CTEs for Nitinol were calculated from the corresponding thermal strain values. Similarly, thermal strain values for glass-epoxy were calculated by integrating the tangent CTE data and secant CTE values were subsequently calculated from the thermal strain data.

The root names of the MSC.Nastran analysis input files end with "_n" or "_in" and the root names of the ABAQUS analysis input files end with "_a". This was done because the two commercial codes automatically generate several auxiliary files during each run and this distinction avoids the potential for the two codes to write to the same auxiliary file name. The distinction between the "_n" and "_in" root names for the MSC.Nastran analyses is explained below. The ASCII text versions of the input and associated data files have the following organization in the appendices.

- Appendices A, C, E – MSC.Nastran analysis input files, FE mesh "include" files, and material property "include" files, respectively
- Appendices B, D, F – ABAQUS analysis input files, FE mesh "include" files, and material property "include" files, respectively

The following sections further describe the files and procedures associated with performing thermal post-buckling, linear random response, and deflection control simulations of the SMAHC beams. Specific file names associated with the example problems are indicated in **bold type**.

Thermal Post-Buckling Control

The files associated with thermal post-buckling analysis of SMAHC beams are contained in the folder "post-buckling." The beams have a length and width of 18×1 inches with clamped boundary conditions at both ends and a spatially uniform temperature of 250°F is taken as the thermal load. The lamination stacking sequence is $(45/0/\text{-}45/90)_{2s}$ with the Nitinol actuators in the 0° layers, giving an overall thickness of 0.0825 and 0.078 inches for the *mon* and *mix0* laminates, respectively. All of the analysis input files have "include" statements to incorporate the common files specifying the nodal coordinates, element connectivity, and material properties. The nonlinear static solutions in both commercial codes require some "perturbation" to avoid convergence on the trivial solution. This requirement is accommodated in these analyses by first performing a static solution under gravity load and using the resulting deflections as geometric imperfections in the thermal post-buckling analyses. Descriptions of the solution process in each of the commercial codes are given in the following subsections.

MSC.Nastran Analysis

The MSC.Nastran input files associated with the gravity load analyses for the *mon* and *mix0* laminates are **smahcbeamg_n.bdf** and **smahcbeammix0g_n.bdf**, respectively. Note that **smahcbeamg_n.bdf** uses the unperturbed nodal coordinates in **nodes.bdf** and element properties associated with the *mon* laminate, which consists of glass-epoxy elements in the outer rows (**glep_outer_elem.bdf**) and SMAHC elements in the inner rows (**smahc_inner_elem.bdf**). The element properties for the *mon* laminate are determined from the independent constituent properties in **glepnast_secsec75.dat** and **nitinast_secsec75.dat**. The *mix0* laminate found in **smahcbeammix0g_n.bdf** also uses the unperturbed nodal coordinates in **nodes.bdf** and has uniform properties for all elements in **smahc_all_elem.bdf**, as defined by **glepnast_secsec75.dat** and **smahcmix0nast_secsec75.dat**. The gravity deflections from the MSC.Nastran runs were extracted from the output files **smahcbeamg_n.f06** and **smahcbeammix0g_n.f06** and used to perturb the nodal coordinates in **nodes.bdf** to create the "imperfect" geometry represented in **nodes_imon.bdf** and **nodes_imix0.bdf**, respectively. There are many ways in which the gravity deflection data might be extracted from the "f06" files and used to alter the nodal coordinates. The provided utility **bdf_node_alter.f** was used in the present work. The gravity analysis input and supporting files are summarized as follows.

- **smahcbeamg_n.bdf** – gravity load analysis for *mon* laminate case
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **nitinast_secsec75.dat**
- **smahcbeammix0g_n.bdf** – gravity load analysis for *mix0* laminate case
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **smahcmix0nast_secsec75.dat**
- **bdf_node_alter.f** – utility to alter unperturbed nodal coordinates with gravity deflections
  - *mon* laminate case
    - input files: **smahcbeamg_n.f06** and **nodes.bdf**
    - output file: **nodes_imon.bdf**
  - *mix0* laminate case
    - input files: **smahcbeammix0g_n.f06** and **nodes.bdf**
    - output file: **nodes_imix0.bdf**

The thermal post-buckling input files for the *mon* laminate case are **smahcbeamr_in.bdf**, **smahcbeams_in.bdf**, and **smahcbeamt_in.bdf.** The three input files are identical except for the manner in which thermal expansion data is included in the model. Tangent CTE data is used for glass-epoxy and a combination of thermal strain and tangent CTE data is used for Nitinol in **smahcbeamr_in.bdf**; "included" from **glepnast_tantan75.dat** and **nitinast_stntan75.dat**. Thermal strain data is used for both glass-epoxy and Nitinol in **smahcbeams_in.bdf**; "included" from **glepnast_stnstn75.dat** and **nitinast_stnstn75.dat**. Finally, secant CTE data is used for both glass-epoxy and Nitinol in **smahcbeamt_in.bdf**; "included" from **glepnast_secsec75.dat** and **nitinast_secsec75.dat**. A similar description applies for the *mix0* laminate case input files **smahcbeammix0r_in.bdf**, **smahcbeammix0s_in.bdf**, and **smahcbeammix0t_in.bdf**. Note that all of the thermal post-buckling input files require geometric imperfections, which are provided by incorporation of the nodal coordinates in **nodes_imon.bdf** and **nodes_imix0.bdf** for the *mon* and *mix0* laminate cases, respectively. Also, note that this is the source for the distinction between the MSC.Nastran analysis input file root names ending in "_n" and "_in", meaning the absence and presence of geometric imperfections, respectively. For cases when imperfections are required for the analysis, the "_n" input files are included for reference only. The thermal post-buckling input and supporting files for the *mon* laminate case are summarized as follows.

- **smahcbeamr_in.bdf** – thermal post-buckling analysis with tangent CTE/thermal strain data
  - nodal coordinates: **nodes_imon.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_tantan75.dat**, **nitinast_stntan75.dat**
- **smahcbeams_in.bdf** – thermal post-buckling analysis with all thermal strain data
  - nodal coordinates: **nodes_imon.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_stnstn75.dat**, **nitinast_stnstn75.dat**
- **smahcbeamt_in.bdf** – thermal post-buckling analysis with all secant CTE data
  - nodal coordinates: **nodes_imon.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **nitinast_secsec75.dat**

The corresponding summary for the *mix0* laminate case follows similarly.

- **smahcbeammix0r_in.bdf** – thermal post-buckling analysis w/ tangent CTE/thermal strain data
  - nodal coordinates: **nodes_imix0.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_tantan75.dat**, **smahcmix0nast_stntan75.dat**
- **smahcbeammix0s_in.bdf** – thermal post-buckling analysis with all thermal strain data
  - nodal coordinates: **nodes_imix0.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_stnstn75.dat**, **smahcmix0nast_stnstn75.dat**
- **smahcbeammix0t_in.bdf** – thermal post-buckling analysis with all secant CTE data
  - nodal coordinates: **nodes_imix0.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **smahcmix0nast_secsec75.dat**

MSC.Nastran "punch" files of mid-span deflection versus load factor are requested in each thermal post-buckling input file. The resulting punch files were read into Microsoft Excel. Equations were introduced to normalize the load factor to temperature (i.e., 0–1 $\rightarrow$ 75°F–150°F and 1–2 $\rightarrow$ 150°F–250°F) and to add the initial imperfection (mid-span gravity deflection from **smahcbeamg_n.f06** or **smahcbeammix0g_n.f06**) to the thermal post-buckling deflection. The results of this process are contained in the files **smahcbeam_in.xls** and **smahcbeammix0_in.xls**.

ABAQUS Analysis

The ABAQUS input files associated with the gravity load analyses for the *mon* and *mix0* laminate cases are **smahcbeamg_a.inp** and **smahcbeammix0g_a.inp**, respectively. Analogously to the MSC.Nastran analyses, these input files make use of the unperturbed nodal coordinates in **nodes.inp** and the corresponding material and element property definitions. The gravity analysis input and supporting files are summarized as follows.

- **smahcbeamg_a.inp** – gravity load analysis for *mon* laminate case
  - nodal coordinates: **nodes.inp**
  - element properties and connectivity: **glep_outer_elem.inp**, **smahc_inner_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **nitiabaq_secsec75.dat**
- **smahcbeammix0g_a.inp** – gravity load analysis for *mix0* laminate case
  - nodal coordinates: **nodes.inp**
  - element properties and connectivity: **smahc_all_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **smahcmix0abaq_secsec75.dat**

The "results files" from the ABAQUS gravity load analyses (i.e., **smahcbeamg_a.fil** and **smahcbeammix0g_a.fil**) are used directly as geometric imperfection input using the *IMPERFECTION option in the corresponding post-buckling analyses **smahcbeamt_a.inp** and **smahcbeammix0t_a.inp**, respectively. The thermal post-buckling analysis input and supporting files are summarized as follows.

- **smahcbeamt_a.inp** – thermal post-buckling analysis for *mon* laminate case
  - nodal coordinates: **nodes.inp**
  - geometric imperfections: **smahcbeamg_a.fil**
  - element properties and connectivity: **glep_outer_elem.inp**, **smahc_inner_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **nitiabaq_secsec75.dat**
- **smahcbeammix0t_a.inp** – thermal post-buckling analysis for *mix0* laminate case
  - nodal coordinates: **nodes.inp**
  - geometric imperfections: **smahcbeammix0g_a.fil**
  - element properties and connectivity: **smahc_all_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **smahcmix0abaq_secsec75.dat**

Note that thermal post-buckling analysis in ABAQUS is performed using secant CTE data only. Analysis in ABAQUS is also possible with thermal strain data by employing the USER parameter on the *EXPANSION option and defining the user subroutine UEXPAN, but this is not explored in this study. Analysis in ABAQUS is not possible using tangent CTE values.

The Python scripts **smahcbeamt_a.py** and **smahcbeammix0t_a.py** extract the output from the thermal post-buckling output databases **smahcbeamt_a.odb** and **smahcbeammix0t_a.odb**, respectively. The scripts extract mid-span displacement versus "time" from the output databases, normalize time to temperature (i.e., 0–1 → 75°F–150°F and 1–2 → 150°F–250°F), add the initial imperfection (gravity deflection from **smahcbeamg_a.dat** or **smahcbeammix0g_a.dat**) at the mid-span to the thermal post-buckling deflection, and to write results to **smahcbeamt_a.wvt** and **smahcbeammix0t_a.wvt**, respectively. The scripts are run via the command "abaqus python 'script name'."

The mid-span deflection versus temperature data from all MSC.Nastran and ABAQUS post-buckling analyses, as well as the results from the research code, were compiled for the *mon* and *mix0* laminate beams in the ASCII data files (formatted for Tecplot) **smahcbeam_wvtcmp.dat** and **smahcbeammix0_wvtcmp.dat**, respectively. These data were used to generate the plots of mid-span deflection versus temperature in references 6 and 7.

Random Vibration Control

The files necessary for simulation of the random vibration response of SMAHC beams are in the folder "random_vibration." The beam model of the previous section is used, i.e., 18×1 inch beam clamped at both ends and subjected to a uniform thermal load of 250°F, but only the *mon* laminate case and only the secant CTE thermal expansion data are considered in this part of the study. The excitation is taken to be band-limited white noise inertial load (base acceleration) with a bandwidth of 0–400 Hz and a RMS value of 0.25g. This RMS load corresponds to a spectral level of approximately 23.32 $(\text{in/s}^2)^2$/Hz. The modal approach is used in all dynamic analyses incorporating the first 10 modes and a uniform critical damping ratio of 0.5% for all modes. All of the analysis input files have "include" statements to incorporate the common files specifying the nodal coordinates, element connectivity, and material properties. The intent of these random vibration analyses is to examine the dynamic response of the beams at various thermoelastic equilibrium states throughout the thermal post-buckling range, the solution to which was described in the Thermal Post-Buckling Response section. Thus, the thermal post-buckling solutions must be performed prior to or in series with the dynamic solutions.

MSC.Nastran Analysis

In the case of MSC.Nastran, the thermal post-buckling solution is performed prior to the dynamic analyses. Recall that the post-buckling solution requires a perturbation, which is accomplished by performing a static solution to gravity load. Thus, the solution sequence and input files necessary to arrive at the thermal post-buckling solution are summarized as follows.

- **smahcbeamg_n.bdf** – gravity load analysis for *mon* laminate case
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **nitinast_secsec75.dat**

The utility **bdf_node_alter.f** is used to extract the gravity deflections from **smahcbeamg_n.f06** and alter the unperturbed nodal coordinates in **nodes.bdf** to create the "imperfect" geometry in **nodes_imon.bdf**.

- **smahcbeamt_in.bdf** – thermal post-buckling analysis for *mon* laminate case
  - nodal coordinates: **nodes_imon.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **nitinast_secsec75.dat**

The random response at ambient temperature (75°F) is determined using the "imperfect" geometry, but with no thermal load and, consequently, no reference or dependence on the thermal post-buckling solution.

- **smahcbeamd75_in.bdf** – random vibration analysis for *mon* laminate case at 75°F
  - nodal coordinates: **nodes_imon.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **nitinast_secsec75.dat**

The random response at elevated temperature requires information from the thermal post-buckling solution. This was accomplished by using the RESTART command in the File Management Section to assign the logical name for the "MASTER" from the thermal post-buckling analysis, i.e., **smahcbeamt_in.MASTER**. Furthermore, the parameter NMLOOP was used to select the system state at specific analysis temperatures in the post-buckling solution. For example, the random response solution at the three conditions examined (150°F, 200°F, and 250°F) queried thermoelastic equilibrium conditions at thermal load increments 300, 305, and 310, respectively. Note that the input files **smahcbeamd150_in.bdf**, **smahcbeamd200_in.bdf**, and **smahcbeamd250_in.bdf** only require input information specific to the random analysis and the corresponding PARAM, NMLOOP, # card because all other model and system information is conveyed from the restart. Also, the dependency of these dynamic analyses on the imperfect geometry, as indicated by the "_in" in the root of the input file names, is implicit through the restart from **smahcbeamt_in.MASTER.**

The mid-span displacement power spectral density (PSD) is output in each case to a "punch" file. The punch files were read into Microsoft Excel, the results of which are contained in **smahcbeamd75-250_in.xls**.

ABAQUS Analysis

The thermal post-buckling and random response solutions are performed sequentially in ABAQUS. Again, geometric imperfection for the thermal post-buckling solution is provided by a gravity load analysis in **smahcbeamg_a.inp**. The sequential post-buckling and random response analysis procedure is accomplished in the single analysis input file **smahcbeamt+d_a.inp** by introducing a series of analysis steps according to the following sequence.

- Linear perturbation STEPs for the eigensolution and random response at 75°F
- Nonlinear static STEP for thermal post-buckling response from 75°F to 150°F
- Linear perturbation STEPs for the eigensolution and random response at 150°F
- Nonlinear static STEP for thermal post-buckling response from 150°F to 200°F
- Linear perturbation STEPs for the eigensolution and random response at 200°F
- Nonlinear static STEP for thermal post-buckling response from 200°F to 250°F
- Linear perturbation STEPs for the eigensolution and random response at 250°F

Thus, the solution sequence and input files necessary to arrive at the random response solution at the three elevated temperatures (150°F, 200°F, and 250°F) are summarized as follows.

- **smahcbeamg_a.inp** – gravity load analysis for *mon* laminate case
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **glep_outer_elem.inp**, **smahc_inner_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **nitiabaq_secsec75.dat**

The "results file" from the gravity load analysis **smahcbeamg_a.fil** is used directly as geometric imperfections in the combined thermal post-buckling and random response input file using the *IMPERFECTION option. The input and supporting files necessary to determine the required thermoelastic equilibrium conditions and corresponding random responses are as follows.

- **smahcbeamt+d_a.inp** – thermal post-buckling and random response for *mon* laminate case
  - nodal coordinates: **nodes.bdf**
  - geometric imperfections: **smahcbeamg_a.fil**
  - element properties and connectivity: **glep_outer_elem.inp**, **smahc_inner_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **nitiabaq_secsec75.dat**

The Python script **smahcbeamt+d_a.py** extracts the ABAQUS random response output (mid-span displacement PSDs) from the output database **smahcbeamt+d_a.odb** and writes the results to the ASCII file **smahcbeamt+d_a.psd**. The command "abaqus python smahcbeamt+d_a.psd" is used to execute the script.

The mid-span displacement PSDs from all MSC.Nastran and ABAQUS analyses, as well as the results from the research code, were compiled in the ASCII data file **smahcbeam_psdcmp.dat**, which is formatted for Tecplot input. These data were used to generate the plots of mid-span displacement power spectral density in references 6 and 7.

Deflection Control

Attention is now turned to static analysis of the 9×1 inch cantilever SMAHC beams. The Nitinol actuators are embedded only on one side of the mid-plane in this case, so a spatially uniform elevated temperature produces a thermal moment and out of plane deflection. The files necessary for simulation of the deflection control cases are in the folder "deflection_control." Both the *mon* and *mix0* laminate cases are considered in this section. The same lamination sequence is used as in the previous sections except the Nitinol content is restricted to the second 0° layer only, which results in overall thicknesses of 0.079 and 0.078 inches for the *mon* and *mix0* laminates, respectively. Again, all of the analysis input files have "include" statements to incorporate the common files specifying the nodal coordinates, element connectivity, and material properties. The nonlinear static solutions in the commercial codes do not require a "perturbation" in this case because of the development of a thermal moment. Thus, no previous gravity load solutions are required. Descriptions of the solution process in each of the commercial codes are given in the following subsections.

MSC.Nastran Analysis

The MSC.Nastran nonlinear static deflection analysis input files for the *mon* laminate case are **smahccantileverr_n.bdf**, **smahccantilevers_n.bdf**, and **smahccantilevert_n.bdf**. As before, these input files are identical except for the manner in which thermal expansion data is included in the model. Tangent CTE data is used for glass-epoxy and a combination of thermal strain and tangent CTE data is used for Nitinol in **smahccantileverr_n.bdf**; "included" from **glepnast_tantan75.dat** and **nitinast_stntan75.dat**. Thermal strain data is used for both glass-epoxy and Nitinol in **smahccantilevers_n.bdf**; "included" from **glepnast_stnstn75.dat** and **nitinast_stnstn75.dat**. Finally, secant CTE data is used for both glass-epoxy and Nitinol in **smahccantilevert_n.bdf**; "included" from **glepnast_secsec75.dat** and **nitinast_secsec75.dat**. A similar description applies for the *mix0* laminate case input files **smahccantmix0r_n.bdf**, **smahccantmix0s_n.bdf**, and **smahccantmix0t_n.bdf**. Note that all of these analyses require the new, unperturbed nodal coordinates in **nodes.bdf** and new element connectivity files as outlined subsequently, where "new" refers to the 9x1 inch geometry. The input supporting files for the *mon* laminate case analyses are summarized as follows.

- **smahccantileverr_n.bdf** – nonlinear static analysis with tangent CTE/thermal strain data
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_tantan75.dat**, **nitinast_stntan75.dat**
- **smahccantilevers_n.bdf** – nonlinear static analysis with all thermal strain data
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_stnstn75.dat**, **nitinast_stnstn75.dat**
- **smahccantilevert_n.bdf** – nonlinear static analysis with all secant CTE data
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **glep_outer_elem.bdf**, **smahc_inner_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **nitinast_secsec75.dat**

The input files and dependencies for the *mix0* laminate case follow similarly.

- **smahccantmix0r_n.bdf –** nonlinear static analysis with tangent CTE/thermal strain data
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_tantan75.dat**, **smahcmix0nast_stntan75.dat**
- **smahccantmix0s_n.bdf** – nonlinear static analysis with all thermal strain data
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_stnstn75.dat**, **smahcmix0nast_stnstn75.dat**
- **smahccantmix0t_n.bdf** – nonlinear static analysis with all secant CTE data
  - nodal coordinates: **nodes.bdf**
  - element properties and connectivity: **smahc_all_elem.bdf**
  - material properties: **glepnast_secsec75.dat**, **smahcmix0nast_secsec75.dat**

The MSC.Nastran "punch" files of the tip deflection versus load factor from each analysis were read into Microsoft Excel. Equations were introduced to normalize the load factor to temperature (i.e., 0–1 $\rightarrow$ 75°F–250°F), the results of which are contained in the files **smahcbeam_in.xls** and **smahcbeammix0_in.xls**.

ABAQUS Analysis

The ABAQUS input files associated with the nonlinear static deflection analyses for the *mon* and *mix0* laminate cases are **smahccantilevert_a.inp** and **smahccantmix0t_a.inp**, respectively. Analogously to the MSC.Nastran analyses, these input files make use of the unperturbed nodal coordinates in **nodes.inp** and the corresponding material and element property definitions as follows.

- **smahccantilevert_a.inp** – nonlinear static analysis for *mon* laminate case
  - nodal coordinates: **nodes.inp**
  - element properties and connectivity: **glep_outer_elem.inp**, **smahc_inner_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **nitiabaq_secsec75.dat**
- **smahccantmix0t_a.inp** – nonlinear static analysis for *mix0* laminate case
  - nodal coordinates: **nodes.inp**
  - element properties and connectivity: **smahc_all_elem.inp**
  - material properties: **glepabaq_secsec75.dat**, **smahcmix0abaq_secsec75.dat**

Note that thermal deflection analysis in ABAQUS is performed using secant CTE data only. Analysis in ABAQUS is also possible with thermal strain data by employing the USER parameter on the *EXPANSION option and defining the user subroutine UEXPAN, but this is not explored in this study. Analysis in ABAQUS is not possible using tangent CTE values.

The Python scripts **smahccantilevert_a.py** and **smahccantmix0t_a.py** extract the output from the static deflection output databases **smahccantilevert_a.odb** and **smahccantmix0t_a.odb**, respectively. The scripts extract tip displacement versus "time" from the output databases, normalize time to temperature (i.e., 0–1 → 75°F–250°F), and to write the results to the ASCII files **smahccantilevert_a.wvt** and **smahccantmix0t_a.wvt**, respectively. The scripts are run via the command "abaqus python 'script name'."

The mid-span deflection versus temperature data from all MSC.Nastran and ABAQUS nonlinear static deflection analyses were compiled for the *mon* and *mix0* laminate beams in the ASCII data files (formatted for Tecplot) **smahccantilever_wvtcmp.dat** and **smahccantmix0_wvtcmp.dat**, respectively. These data were used to generate the plots of tip deflection versus temperature in references 6 and 7.

Summary

A thermoelastic model for SMAs and SMAHCs was recently implemented in the commercial finite element codes MSC.Nastran and ABAQUS. The model is relatively intuitive, simple to use, and requires only fundamental material properties. The model is also very versatile for analysis of structures involving SMA actuators, particularly when they are integrated within the structure as is the case for SMAHC structures, and it has been validated against experimental results for the applications of thermal post-buckling control, random vibration control, and deflection/shape control. The form of the constitutive model allowed it to be implemented and supported within the core of the commercial codes, so no user subroutines or external calculations are necessary. This is a companion document to two more formal documents cited in the reference list. The web link http://stabserv.larc.nasa.gov provides electronic versions of the files necessary for simulation of thermal post-buckling, random vibration, and deflection control of SMAHC beams and duplication of the results in the related documents. This paper describes the various input files necessary for accomplishing these simulations within MSC.Nastran and ABAQUS and details of the solution process. This paper also serves as a repository for the ASCII text versions of all of the input files necessary for these simulations, which are available in the appendices of this document. The information in this paper and either of the two directly related documents cited in this paper should be sufficient to introduce the reader to analysis of SMA actuators and SMAHC structures within MSC.Nastran and ABAQUS.

References

1. T. L. Turner, “A New Thermoelastic Model for Analysis of Shape Memory Alloy Hybrid Composites,” *Journal of Intelligent Material Systems and Structures*, **11**, 382-394, May 2000.
2. T. L. Turner, “SMA Hybrid Composites for Dynamic Response Abatement Applications,” *7th Inter. Conference on Recent Advances in Structural Dynamics*, **1**, 453-465, ISVR, University of Southampton, Southampton, UK, 2000.
3. T. L. Turner, “Experimental Validation of a Thermoelastic Model for SMA Hybrid Composites,” in *Smart Structures and Materials: Modeling, Signal Processing, and Control in Smart Structures*, V. S. Rao, Editor, Proceedings of SPIE Vol. 4326, 208-219 (2001).
4. T. L. Turner, “*Thermomechanical Response of Shape Memory Alloy Hybrid Composites*,” NASA/TM-2001-210656, 2001.
5. T. L. Turner, R. H. Buehrle, R. J. Cano, and G. A. Fleming, “Design, Fabrication, and Testing of SMA Enabled Adaptive Chevrons for Jet Noise Reduction,” in *Smart Structures and Materials: Smart Structures and Integrated Systems*, A. B. Flatau, Editor, Proceedings of SPIE Vol. 5390, 297-308 (2004).
6. T. L. Turner and H. D. Patel, “Analysis of SMA Hybrid Composite Structures Using Commercial Codes,” in *Smart Structures and Materials 2004: Modeling, Signal Processing, and Control*, R. C. Smith, Editor, Proceedings of SPIE Vol. 5383, 82–93 (2004).
7. T. L. Turner and H. D. Patel, “Analysis of SMA Hybrid Composite Structures in MSC.Nastran and ABAQUS,” submitted to *Computers and Structures*, January 2005.

Appendix A
MSC.Nastran Analysis Input Files (Bulk Data Files)

<u>18x1 inch SMAHC Beam Clamped at Both Ends</u>

smahcbeamg_n.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2003 ) on June      19, 2003 at 10:12:57.
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
SOL 106
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 19-Jun-03 at 10:10:01
ECHO = NONE
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : gravity
   SUBTITLE=gravity
   NLPARM = 1
   SPC = 2
   LOAD = 2
   DISPLACEMENT(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM    LGDISP  1
PARAM    K6ROT   100.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
PARAM    NLTOL   0
NLPARM   1       1               ITER    1       25              YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : smahclam
$ Composite Material Description :
PCOMP    1                                       75.     0.
*        1               .004875         45.             YES
*        2               .006            0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         45.             YES
*        2               .006            0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .006            0.              YES
*        1               .004875         45.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .006            0.              YES
*        1               .004875         45.             YES
INCLUDE 'smahc_inner_elem.bdf'
$
```

```
$ Elements and Element Properties for region : glepelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : gleplam
$ Composite Material Description :
PCOMP    2                                       75.     0.
*        1              .004875         45.              YES
*        1              .004875         0.               YES
*        1              .004875        -45.              YES
*        1              .004875         90.              YES
*        1              .004875         45.              YES
*        1              .004875         0.               YES
*        1              .004875        -45.              YES
*        1              .004875         90.              YES
*        1              .004875         90.              YES
*        1              .004875        -45.              YES
*        1              .004875         0.               YES
*        1              .004875         45.              YES
*        1              .004875         90.              YES
*        1              .004875        -45.              YES
*        1              .004875         0.               YES
*        1              .004875         45.              YES
INCLUDE 'glep_outer_elem.bdf'
$
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'nitinast_secsec75.dat'
$
$ Nodes of the Entire Model
INCLUDE 'nodes.bdf'
$
$ Loads for Load Case : gravity
SPCADD   2       1
LOAD     2       1.      1.      1
$ Displacement Constraints of Load Set : cccc
SPC1     1       123456  1       37      38      74      75      111
         112     148     149     185
$ Contact Table for Load Case: gravity
$ Gravity Loading of Load Set : gravity
GRAV     1       0       386.4   0.      0.      1.
$ Referenced Coordinate Frames
ENDDATA 738b1768
```

smahcbeamt_n.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2003 ) on June      19, 2003 at 10:14:09.
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
$
PROJ='SMAHC beam post-buckling/random response'
$
SOL 106
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 19-Jun-03 at 10:10:01
ECHO = NONE
$ Direct Text Input for Global Case Control Data
TEMPERATURE(INITIAL) = 1
SUBCASE 1
$ Subcase name : thermal
   SUBTITLE=thermal
```

```
   NLPARM = 1
   SPC = 2
   TEMPERATURE(LOAD) = 3
   DISPLACEMENT(SORT1,REAL)=ALL
SUBCASE 2
$ Subcase name : thermal
   SUBTITLE=thermal
   NLPARM = 2
   SPC = 2
   TEMPERATURE(LOAD) = 4
   DISPLACEMENT(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
OUTPUT(XYOUT)
XYPRINT DISP / 93(T3)
XYPUNCH DISP / 93(T3)
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM    LGDISP  1
PARAM    K6ROT   100.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
PARAM   NLTOL    0
NLPARM   1       300             ITER    1       100             YES
NLPARM   2       10              ITER    1       100             YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : smahclam
$ Composite Material Description :
PCOMP    1                                       75.     0.
*        1               .004875         45.             YES
*        2               .006            0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         45.             YES
*        2               .006            0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .006            0.              YES
*        1               .004875         45.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .006            0.              YES
*        1               .004875         45.             YES
INCLUDE 'smahc_inner_elem.bdf'
$
$ Elements and Element Properties for region : glepelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : glepla m
$ Composite Material Description :
PCOMP    2                                       75.     0.
*        1               .004875         45.             YES
*        1               .004875         0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         45.             YES
*        1               .004875         0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
```

```
*        1               .004875        90.             YES
*        1               .004875       -45.             YES
*        1               .004875        0.              YES
*        1               .004875        45.             YES
*        1               .004875        90.             YES
*        1               .004875       -45.             YES
*        1               .004875        0.              YES
*        1               .004875        45.             YES
INCLUDE 'glep_outer_elem.bdf'
$
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'nitinast_secsec75.dat'
$
$ Nodes of the Entire Model
INCLUDE 'nodes.bdf'
$
$ Loads for Load Case : thermal
SPCADD   2       1
$ Displacement Constraints of Load Set : cccc
SPC1     1       123456  1       37      38      74      75      111
         112     148     149     185
$ Default Initial Temperature and Load Temperature
TEMPD    1       75.     3       150.    4       250.
$ Referenced Coordinate Frames
ENDDATA d7666e0d
```

smahcbeamt_in.bdf

Identical to smahcbeamt_n.bdf except replace “INCLUDE ‘nodes.bdf’” with “INCLUDE ‘nodes_imon.bdf’”.

smahcbeamr_in.bdf

Identical to smahcbeamt_in.bdf except add “PARAM,EPSILONT,INTEGRAL” in parameter block and replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE nitinast_secsec75.bdf’” with “INCLUDE ‘glepnast_tantan75.dat” and “INCLUDE ‘nitinast_stntan75.dat’”, respectively.

smahcbeams_in.bdf

Identical to smahcbeamt_in.bdf except replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘nitinast_secsec75.bdf’” with “INCLUDE ‘glepnast_stnstn75.dat” and “INCLUDE ‘nitinast_stnstn75.dat’”, respectively.

smahcbeammix0g_n.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2003 ) on June      19, 2003 at 10:12:57.
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
SOL 106
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 19-Jun-03 at 10:10:01
ECHO = NONE
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : gravity
   SUBTITLE=gravity
   NLPARM = 1
```

```
   SPC = 2
   LOAD = 2
   DISPLACEMENT(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM    LGDISP  1
PARAM    K6ROT   100.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
PARAM    NLTOL   0
NLPARM   1       1               ITER    1       25              YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : smahclam
$ Composite Material Description :
PCOMP    1                                       75.     0.
*        1              .004875         45.              YES
*        2              .004875         0.               YES
*        1              .004875        -45.              YES
*        1              .004875         90.              YES
*        1              .004875         45.              YES
*        2              .004875         0.               YES
*        1              .004875        -45.              YES
*        1              .004875         90.              YES
*        1              .004875         90.              YES
*        1              .004875        -45.              YES
*        2              .004875         0.               YES
*        1              .004875         45.              YES
*        1              .004875         90.              YES
*        1              .004875        -45.              YES
*        2              .004875         0.               YES
*        1              .004875         45.              YES
INCLUDE 'smahc_all_elem.bdf'
$
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'smahcmix0nast_secsec75.dat'
$
$ Nodes of the Entire Model
INCLUDE 'nodes.bdf'
$
$ Loads for Load Case : gravity
SPCADD   2       1
LOAD     2       1.      1.      1
$ Displacement Constraints of Load Set : cccc
SPC1     1       123456  1       37      38      74      75      111
         112     148     149     185
$ Contact Table for Load Case: gravity
$ Gravity Loading of Load Set : gravity
GRAV     1       0       386.4   0.      0.      1.
$ Referenced Coordinate Frames
ENDDATA 738b1768
```

smahcbeammix0t_n.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2003 ) on June      19, 2003 at 10:14:09.
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
```

```
SOL 106
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 19-Jun-03 at 10:10:01
ECHO = NONE
$ Direct Text Input for Global Case Control Data
TEMPERATURE(INITIAL) = 1
SUBCASE 1
$ Subcase name : thermal
   SUBTITLE=thermal
   NLPARM = 1
   SPC = 2
   TEMPERATURE(LOAD) = 3
   DISPLACEMENT(SORT1,REAL)=ALL
SUBCASE 2
$ Subcase name : thermal
   SUBTITLE=thermal
   NLPARM = 2
   SPC = 2
   TEMPERATURE(LOAD) = 4
   DISPLACEMENT(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
OUTPUT(XYOUT)
XYPRINT DISP / 93(T3)
XYPUNCH DISP / 93(T3)
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM    LGDISP  1
PARAM    K6ROT   100.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
PARAM   NLTOL    0
NLPARM   1       300             ITER    1       100             YES
NLPARM   2       10              ITER    1       100             YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : smahclam
$ Composite Material Description :
PCOMP    1                                       75.     0.
*        1               .004875         45.             YES
*        2               .004875         0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         45.             YES
*        2               .004875         0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .004875         0.              YES
*        1               .004875         45.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES

*        2               .004875         0.              YES
*        1               .004875         45.             YES
INCLUDE 'smahc_all_elem.bdf'
$
```

```
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'smahcmix0nast_secsec75.dat'
$
$ Nodes of the Entire Model
INCLUDE 'nodes.bdf'
$
$ Loads for Load Case : thermal
SPCADD   2       1
$ Displacement Constraints of Load Set : cccc
SPC1     1       123456  1       37      38      74      75      111
         112     148     149     185
$ Default Initial Temperature and Load Temperature
TEMPD    1       75.     3       150.    4       250.
$ Referenced Coordinate Frames
ENDDATA d7666e0d
```

smahcbeammix0t_in.bdf

Identical to smahcbeammix0t_n.bdf except replace “INCLUDE ‘nodes.bdf’” with “INCLUDE ‘nodes_imix0.bdf’”.

smahcbeammix0r_in.bdf

Identical to smahcbeammix0t_in.bdf except add “PARAM,EPSILONT,INTEGRAL” in parameter block and replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘smahcmix0nast_secsec75.bdf’” with “INCLUDE ‘glepnast_tantan75.dat” and “INCLUDE ‘smahcmix0nast_stntan75.dat’”, respectively.

smahcbeammix0s_in.bdf

Identical to smahcbeammix0t_in.bdf except replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘smahcmix0nast_secsec75.bdf’” with “INCLUDE ‘glepnast_stnstn75.dat” and “INCLUDE ‘smahcmix0nast_stnstn75.dat’”, respectively.

smahcbeamd75_n.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2001 r2a ) on January   24, 2004 at 08:12:07.
$ Direct Text Input for File Management Section
$ Frequency Response Analysis, Modal Formulation, Database
SOL 111
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 19-Jun-03 at 10:10:01
ECHO = NONE
LOADSET = 1
$ Direct Text Input for Global Case Control Data
SDAMPING = 1
RANDOM = 1
SUBCASE 1
$ Subcase name : inertial dynamic
   SUBTITLE=inertial dynamic
   METHOD = 1
   FREQUENCY = 1
   SPC = 2
   DLOAD = 2
   SET 1 = 93
   DISPLACEMENT(SORT1,REAL)=1
$ Direct Text Input for this Subcase
OUTPUT(XYOUT)
```

```
XYPUNCH DISP PSDF / 93(T3)
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
FREQ1    1       0.      0.25    1600
TABDMP1  1       CRIT
         0.      .005    10000.  .005    ENDT
EIGRL    1                       10      0
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : smahclam
$ Composite Material Description :
PCOMP    1                                       75.     0.
*        1               .004875         45.             YES
*        2               .006            0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         45.             YES
*        2               .006            0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .006            0.              YES
*        1               .004875         45.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        2               .006            0.              YES
*        1               .004875         45.             YES
INCLUDE 'smahc_inner_elem.bdf'
$
$ Elements and Element Properties for region : glepelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : gleplam
$ Composite Material Description :
PCOMP    2                                       75.     0.
*        1               .004875         45.             YES
*        1               .004875         0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         45.             YES
*        1               .004875         0.              YES
*        1               .004875        -45.             YES
*        1               .004875         90.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        1               .004875         0.              YES
*        1               .004875         45.             YES
*        1               .004875         90.             YES
*        1               .004875        -45.             YES
*        1               .004875         0.              YES
*        1               .004875         45.             YES
INCLUDE 'glep_outer_elem.bdf'
$
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'nitinast_secsec75.dat'
$
$ Nodes of the Entire Model
```

```
INCLUDE 'nodes.bdf'
$
$ Loads for Load Case : inertial dynamic
SPCADD   2       1
RLOAD1   4       5                       1
LSEQ     1       5       3
DLOAD    2       1.      1.      4
$ Displacement Constraints of Load Set : cfcf
SPC1     1       123456  1       37      38      74      75      111
         112     148     149     185
$ Gravity Loading of Load Set : gravity
GRAV     3       0       1.      0.      0.      1.
$ Referenced Dynamic Load Tables
$ Constant Load Table
TABLED1  1
         0.      1.      1000.   1.      ENDT
$ Random input spectrum (PSD)
RANDPS  1       1       1       1.      0.0     101
TABRND1 101
        0.0     23.33   400.    23.33   ENDT
$ Referenced Coordinate Frames
ENDDATA 5ff81f04
```

smahcbeamd75_in.bdf

Identical to smahcbeamd75_n.bdf except replace “INCLUDE ‘nodes.bdf’” with “INCLUDE ‘nodes_imon.bdf’”.

smahcbeamd150_in.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2001 r2a ) on January   24, 2004 at 08:12:07.
$ Direct Text Input for File Management Section
$ Frequency Response Analysis, Modal Formulation, Database
$
PROJ='SMAHC beam post-buckling/random response'
ASSIGN S250='smahcbeamt_in.MASTER'
RESTART VERSION=1 KEEP LOGICAL=S250
$
SOL 111
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 19-Jun-03 at 10:10:01
ECHO = NONE
LOADSET = 1
$ Direct Text Input for Global Case Control Data
SDAMPING = 1
RANDOM = 1
SUBCASE 1
$ Subcase name : inertial dynamic
   SUBTITLE=inertial dynamic
   METHOD = 1
   FREQUENCY = 1
   DLOAD = 2
   SPC = 2
   SET 1 = 93
   DISPLACEMENT(SORT1,REAL)=1
$ Direct Text Input for this Subcase
OUTPUT(XYOUT)
XYPUNCH DISP PSDF / 93(T3)
BEGIN BULK
```

```
$ select nonlinear state at 150 F
PARAM,NMLOOP,300
FREQ1    1       0.      0.25    1600
TABDMP1  1       CRIT
         0.      .005    10000.  .005    ENDT
EIGRL    1                       10      0
$ Direct Text Input for Bulk Data
RLOAD1   4       5                       1
LSEQ     1       5       3
DLOAD    2       1.      1.      4
$ Gravity Loading of Load Set : gravity
GRAV     3       0       1.      0.      0.      1.
$ Referenced Dynamic Load Tables
$ Constant Load Table
TABLED1  1
         0.      1.      1000.   1.      ENDT
$ Random input spectrum (PSD)
RANDPS  1       1       1       1.      0.0     101
TABRND1 101
        0.0     23.33   400.    23.33   ENDT
$ Referenced Coordinate Frames
ENDDATA 5ff81f04
```

smahcbeamd200_in.bdf

Identical to smahcbeamd150_in.bdf except replace “PARAM,NMLOOP,300” with “PARAM,NMLOOP,305”.

smahcbeamd250_in.bdf

Identical to smahcbeamd150_in.bdf except replace “PARAM,NMLOOP,300” with “PARAM,NMLOOP,310”.

9x1 inch SMAHC Cantilever Beam

smahccantilevert_n.bdf

```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2001 r2a ) on February  15, 2004 at 16:19:01.
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
SOL 106
TIME 600
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 15-Feb-04 at 16:08:48
ECHO = NONE
MAXLINES = 999999999
$ Direct Text Input for Global Case Control Data
TEMPERATURE(INITIAL) = 1
SUBCASE 1
$ Subcase name : nlstat
   SUBTITLE=Default
   NLPARM = 1
   SPC = 2
   TEMPERATURE(LOAD) = 3
   DISPLACEMENT(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
OUTPUT(XYOUT)
XYPUNCH DISP / 57(T3)
```

```
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM    LGDISP  1
PARAM    K6ROT   100.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
PARAM   NLTOL    0
NLPARM   1       10              ITER    1       100             YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : glepelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : gleplam
$ Composite Material Description :
PCOMP    1                                       75.     0.
*        1              .004875         45.             YES
*        1              .004875         0.              YES
*        1              .004875        -45.             YES
*        1              .004875         90.             YES
*        1              .004875         45.             YES
*        1              .004875         0.              YES
*        1              .004875        -45.             YES
*        1              .004875         90.             YES
*        1              .004875         90.             YES
*        1              .004875        -45.             YES
*        1              .004875         0.              YES
*        1              .004875         45.             YES
*        1              .004875         90.             YES
*        1              .004875        -45.             YES
*        1              .004875         0.              YES
*        1              .004875         45.             YES
INCLUDE 'glep_outer_elem.bdf'
$
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
$ record : smahclam
$ Composite Material Description :
PCOMP    2                                       75.     0.
*        1              .004875         45.             YES
*        1              .004875         0.              YES
*        1              .004875        -45.             YES
*        1              .004875         90.             YES
*        1              .004875         45.             YES
*        2              .006            0.              YES
*        1              .004875        -45.             YES
*        1              .004875         90.             YES
*        1              .004875         90.             YES
*        1              .004875        -45.             YES
*        1              .004875         0.              YES
*        1              .004875         45.             YES
*        1              .004875         90.             YES
*        1              .004875        -45.             YES
*        1              .004875         0.              YES
*        1              .004875         45.             YES
INCLUDE 'smahc_inner_elem.bdf'
$
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'nitinast_secsec75.dat'
$
$ Nodes of the Entire Model
INCLUDE 'nodes.bdf'
```

```
$
$ Loads for Load Case : Default
SPCADD   2       1
$ Displacement Constraints of Load Set : cfff
SPC1     1       123456  1       20      39      58      77
$ Default Initial Temperature
TEMPD    1       75.     3       250.
$ Referenced Coordinate Frames
ENDDATA e4091d30
```

smahccantileverr_n.bdf
Identical to smahccantilevert_n.bdf except add “PARAM,EPSILONT,INTEGRAL” in parameter block and replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘nitinast_secsec75.bdf’” with “INCLUDE ‘glepnast_tantan75.dat” and “INCLUDE ‘nitinast_stntan75.dat’”, respectively.

smahccantilevers_n.bdf
Identical to smahccantilevert_n.bdf except replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘nitinast_secsec75.bdf’” with “INCLUDE ‘glepnast_stnstn75.dat” and “INCLUDE ‘nitinast_stnstn75.dat’”, respectively.

smahccantmix0t_n.bdf
```
$ NASTRAN input file created by the MSC MSC.Nastran input file
$ translator ( MSC.Patran 2001 r2a ) on February  15, 2004 at 16:19:01.
$ Direct Text Input for File Management Section
$ Nonlinear Static Analysis, Database
SOL 106
TIME 600
$ Direct Text Input for Executive Control
CEND
SEALL = ALL
SUPER = ALL
TITLE = MSC.Nastran job created on 15-Feb-04 at 16:08:48
ECHO = NONE
MAXLINES = 999999999
$ Direct Text Input for Global Case Control Data
TEMPERATURE(INITIAL) = 1
SUBCASE 1
$ Subcase name : nlstat
   SUBTITLE=Default
   NLPARM = 1
   SPC = 2
   TEMPERATURE(LOAD) = 3
   DISPLACEMENT(SORT1,REAL)=ALL
$ Direct Text Input for this Subcase
OUTPUT(XYOUT)
XYPUNCH DISP / 57(T3)
BEGIN BULK
PARAM    POST    -1
PARAM   COUPMASS 1
PARAM    LGDISP  1
PARAM    K6ROT   100.
PARAM,NOCOMPS,-1
PARAM   PRTMAXIM YES
PARAM,COMPMATT,YES
PARAM   NLTOL    0
NLPARM   1       10              ITER    1       100             YES
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : smahcelem
$ Composite Property Record created from P3/PATRAN composite material
```

```
$ record : smahclam
$ Composite Material Description :
PCOMP    1                                      75.     0.
*        1               .004875         45.            YES
*        1               .004875         0.             YES
*        1               .004875        -45.            YES
*        1               .004875         90.            YES
*        1               .004875         45.            YES
*        2               .004875         0.             YES
*        1               .004875        -45.            YES
*        1               .004875         90.            YES
*        1               .004875         90.            YES

*        1               .004875        -45.            YES
*        1               .004875         0.             YES
*        1               .004875         45.            YES
*        1               .004875         90.            YES
*        1               .004875        -45.            YES
*        1               .004875         0.             YES
*        1               .004875         45.            YES
INCLUDE 'smahc_all_elem.bdf'
$
$ Referenced Material Records
INCLUDE 'glepnast_secsec75.dat'
INCLUDE 'smahcmix0nast_secsec75.dat'
$
$ Nodes of the Entire Model
INCLUDE 'nodes.bdf'
$
$ Loads for Load Case : Default
SPCADD   2       1
$ Displacement Constraints of Load Set : cfff
SPC1     1       123456  1       20      39      58      77
$ Default Initial Temperature
TEMPD    1       75.     3       250.
$ Referenced Coordinate Frames
ENDDATA e4091d30
```

smahccantmix0r_n.bdf
Identical to smahccantmix0t_n.bdf except add “PARAM,EPSILONT,INTEGRAL” in parameter block and replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘smahcmix0nast_secsec75.bdf’” with “INCLUDE ‘glepnast_tantan75.dat” and “INCLUDE ‘smahcmix0nast_stntan75.dat’”, respectively.

smahccantmix0s_n.bdf
Identical to smahccantmix0t_n.bdf except replace “INCLUDE ‘glepnast_secsec75.dat’” and “INCLUDE ‘smahcmix0nast_secsec75.bdf’” with “INCLUDE ‘glepnast_stnstn75.dat” and “INCLUDE ‘smahcmix0nast_stnstn75.dat’”, respectively.

Appendix B
ABAQUS Analysis Input Files

18x1 inch SMAHC Beam Clamped at Both Ends

smahcbeamg_a.inp

```
*HEADING
Gravity deflection analysis of a 18x1 SMAHC beam
**
** ------------------------------------------------------
** --- Nodal information ---
** ------------------------------------------------------
**
*INCLUDE, INPUT=nodes.inp
**
*NSET, NSET=CENTER
93,
**
** ------------------------------------------------------
** --- Temp. dependent material properties ---
** ------------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=nitiabaq_secsec75.dat
**
** ------------------------------------------------------
** --- SHELL elements (with directional properties) --
** ------------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
** total thickness = 0.0825
0.004875, 3, GLEP, 45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=smahc_inner_elem.inp
**
*SHELL SECTION, COMPOSITE, ELSET=GLEPELEM
** total thickness = 0.078
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
```

```
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=glep_outer_elem.inp
**
*ELSET, ELSET=ALL_ELEMENTS
SMAHCELEM,
GLEPELEM,
**
** --------------------------------------------------
** ------ STEP data for SUBCASE 1
** --------------------------------------------------
*STEP, NLGEOM, INC=1
**    SUBTITLE=gravity
*STATIC, DIRECT
1.0,1.0
*BOUNDARY
       1, 1,6, 0.
      37, 1,6, 0.
      38, 1,6, 0.
      74, 1,6, 0.
      75, 1,6, 0.
     111, 1,6, 0.

     112, 1,6, 0.
     148, 1,6, 0.
     149, 1,6, 0.
     185, 1,6, 0.
**
** Apply 1.0g gravity load to generate initial imperfection geometry
**
*DLOAD
ALL_ELEMENTS, GRAV, 386.4, 0., 0., 1.
**
** Write out deflection data at all nodes to the results file
**
*NODE, PRINT, NSET=CENTER
U3,
**
*NODE FILE, NSET=ALL_NODES
U,
**
*END STEP
```

smahcbeamt_a.inp

```
*HEADING
Thermal post-buckling response of a 18x1 SMAHC beam with initial imperfections
**
** --------------------------------------------------
** --- Nodal information ---
** --------------------------------------------------
**
*INCLUDE, INPUT=nodes.inp
**
*NSET, NSET=CENTER
93,
```

```
**
** Read geometric imperfection data from external file
**
*IMPERFECTION, FILE=smahcbeamg_a, STEP=1
1, 1.0
**
** -----------------------------------------------------
** --- Include temp. dependent material properties ---
** -----------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=nitiabaq_secsec75.dat
**
** -----------------------------------------------------
** --- SHELL elements (with directional properties) --
** -----------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
** total thickness = 0.0825
0.004875, 3, GLEP, 45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=smahc_inner_elem.inp
**
*SHELL SECTION, COMPOSITE, ELSET=GLEPELEM
** total thickness = 0.078
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=glep_outer_elem.inp
**
*ELSET, ELSET=ALL_ELEMENTS
SMAHCELEM,
GLEPELEM,
**
```

```
*INITIAL CONDITIONS, TYPE=TEMPERATURE
ALL_NODES, 75.
**
*BOUNDARY
       1, 1,6, 0.
      37, 1,6, 0.
      38, 1,6, 0.
      74, 1,6, 0.
      75, 1,6, 0.
     111, 1,6, 0.
     112, 1,6, 0.
     148, 1,6, 0.
     149, 1,6, 0.
     185, 1,6, 0.
**
** --------------------------------------------------
** ------ STEP data for post-buckling 75-150 F
** --------------------------------------------------
*STEP, NLGEOM, INC=300
Post-buckling solution 75-150 degrees F
**
*STATIC, DIRECT
0.00333333,1.0
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 150.
**
** Load deflection data at center node (propagates to subsequent static steps)
**
*OUTPUT, HISTORY
*NODE OUTPUT, NSET=CENTER
U3,
**
*END STEP
** --------------------------------------------------
** ------ STEP data for post-buckling 150-250 F
** --------------------------------------------------
*STEP, NLGEOM
Post-buckling solution 150-250 degrees F
**
*STATIC, DIRECT
0.1,1.0
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 250.
**
** Load deflection data at center node (carries forward from above)
**
*END STEP
```

smahcbeammix0g_a.inp

```
*HEADING
Gravity deflection analysis of a 18x1 SMAHC beam
**
** --------------------------------------------------
** --- Nodal Information ---
** --------------------------------------------------
**
```

```
*INCLUDE, INPUT=nodes.inp
**
*NSET, NSET=CENTER
93,
**
** ------------------------------------------------
** --- Temp. dependent material properties ---
** ------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=smahcmix0abaq_secsec75.dat
**
** ------------------------------------------------
** --- SHELL elements (with directional properties) --
** ------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
** total thickness = 0.0825
0.004875, 3, GLEP, 45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=smahc_all_elem.inp
**
** ------------------------------------------------
** ------ STEP data for SUBCASE 1
** ------------------------------------------------
*STEP, NLGEOM, INC=1
**    SUBTITLE=gravity
*STATIC, DIRECT
1.0,1.0
*BOUNDARY
       1, 1,6, 0.
      37, 1,6, 0.
      38, 1,6, 0.
      74, 1,6, 0.
      75, 1,6, 0.
     111, 1,6, 0.
     112, 1,6, 0.
     148, 1,6, 0.
     149, 1,6, 0.
     185, 1,6, 0.
**
** Apply 1.0g gravity load to generate initial imperfection geometry
**
*DLOAD
SMAHCELEM, GRAV, 386.4, 0., 0., 1.
**
** Write out deflection data at all nodes to the results file
**
```

```
*NODE PRINT, NSET=CENTER
U3,
**
*NODE FILE, NSET=ALL_NODES
U,
**
*END STEP
```

smahcbeammix0t_a.inp

```
*HEADING
Thermal post-buckling response of a 18x1 SMAHC beam with initial imperfections
**
** ---------------------------------------------------
** --- Nodal information ---
** ---------------------------------------------------
**
*INCLUDE, INPUT=nodes.inp
**
*NSET, NSET=CENTER
93,
**
** Read geometric imperfection data from external file
**
*IMPERFECTION, FILE=smahcbeammix0g_a, STEP=1
1, 1.0
**
** ---------------------------------------------------
** --- Include temp. dependent material properties ---
** ---------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=smahcmix0abaq_secsec75.dat
**
** ---------------------------------------------------
** --- SHELL elements (with directional properties) --
** ---------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
** total thickness = 0.0825
0.004875, 3, GLEP, 45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, SMAHCMIX0, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=smahc_all_elem.inp
**
*INITIAL CONDITIONS, TYPE=TEMPERATURE
ALL_NODES, 75.
**
** ---------------------------------------------------
```

```
** ------ STEP data for post-buckling 75-150 F -------
** -------------------------------------------------
*STEP, NLGEOM, INC=300
Post-buckling solution 75-150 degrees F
*STATIC, DIRECT
0.00333333,1.0
**
*BOUNDARY
       1, 1,6, 0.
      37, 1,6, 0.
      38, 1,6, 0.
      74, 1,6, 0.
      75, 1,6, 0.
     111, 1,6, 0.
     112, 1,6, 0.
     148, 1,6, 0.
     149, 1,6, 0.
     185, 1,6, 0.
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 150.
**
** Load deflection data at center node
**
*OUTPUT, HISTORY
*NODE OUTPUT, NSET=CENTER
U3,
**
*END STEP
**
** -------------------------------------------------
** ------ STEP data for post-buckling 150-250 F ------
** -------------------------------------------------
*STEP, NLGEOM
Post-buckling solution 150-250 degrees F
*STATIC, DIRECT
0.1,1.0
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 250.
**
** Load deflection data at center node carries forward from above
**
*END STEP
```

smahcbeamt+d_a.inp

```
*HEADING
Thermal post-buckling/random response of a 18x1 SMAHC beam with initial imperfections
**
** -------------------------------------------------
** --- Nodal information ---
** -------------------------------------------------
**
*INCLUDE, INPUT=nodes.inp
**
*NSET, NSET=CENTER
93,
**
```

```
** Read geometric imperfection data from external file
**
*IMPERFECTION, FILE=smahcbeamg_a, STEP=1
1, 1.0
**
** ------------------------------------------------------
** --- Include temp. dependent material properties ---
** ------------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=nitiabaq_secsec75.dat
**
** ------------------------------------------------------
** --- SHELL elements (with directional properties) --
** ------------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
** total thickness = 0.0825
0.004875, 3, GLEP, 45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.006, 3, NITI, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=smahc_inner_elem.inp
**
*SHELL SECTION, COMPOSITE, ELSET=GLEPELEM
** total thickness = 0.078
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, 45.
0.004875, 3, GLEP, 90.
0.004875, 3, GLEP, -45.
0.004875, 3, GLEP, 0.
0.004875, 3, GLEP, 45.
**
*INCLUDE, INPUT=glep_outer_elem.inp
**
*ELSET, ELSET=ALL_ELEMENTS
SMAHCELEM,
GLEPELEM,
**
*INITIAL CONDITIONS, TYPE=TEMPERATURE
```

```
ALL_NODES, 75.
**
*BOUNDARY
      1, 1,6, 0.
     37, 1,6, 0.
     38, 1,6, 0.
     74, 1,6, 0.
     75, 1,6, 0.
    111, 1,6, 0.
    112, 1,6, 0.
    148, 1,6, 0.
    149, 1,6, 0.
    185, 1,6, 0.
**
*PSD-DEFINITION, NAME=S10TO400, G=1.0, TYPE=BASE
0.233289E+02, , 0.
0.233289E+02, , 400.
**
** -----------------------------------------------------
** ------ STEP data for Eigensolution at 75 F
** -----------------------------------------------------
*STEP, PERTURBATION
Eigensolution for SMAHC beam at 75 F
**
*FREQUENCY, EIGENSOLVER=LANCZOS, NORMALIZATION=MASS
10, , 1500.
**
** Eigensolution output
**
***OUTPUT, FIELD
***NODE OUTPUT
**U,
*END STEP
**
** -----------------------------------------------------
** ------ STEP data for Linear Random Response at 75 F
** -----------------------------------------------------
*STEP, PERTURBATION
Linear random response of SMAHC beam at 75 F
**
** 0-400 Hz with 400 points between eigenfrequencies, 1.0 bias and linear frequency
**
*RANDOM RESPONSE
0., 400., 400, 1.0, 1
**
** This is only needed in the event that a subset of the modes
** from the *FREQUENCY card are used
**
*SELECT EIGENMODES, GENERATE
1, 10
**
*MODAL DAMPING, MODAL=DIRECT
1, 10, 0.005
**
*CORRELATION, PSD=S10TO400, COMPLEX=NO, TYPE=CORRELATED
2, 1.
**
*DLOAD
**
*BASE MOTION, DOF=3, LOAD CASE=2, TYPE=ACCELERATION
**

** Random response PSD at center node
```

```
**
*OUTPUT, FIELD
*NODE OUTPUT, NSET=CENTER
U,
**
*END STEP
** ----------------------------------------------------
** ------ STEP data for post-buckling 75-150 F
** ----------------------------------------------------
*STEP, NLGEOM, INC=300
Post-buckling solution 75-150 degrees F
**
*STATIC, DIRECT
0.00333333,1.0
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 150.
**
** Load deflection data at center node (propagates to subsequent static steps)
**
*OUTPUT, HISTORY
*NODE OUTPUT, NSET=CENTER
U3,
**
*END STEP
** ----------------------------------------------------
** ------ STEP data for Eigensolution at 150 F
** ----------------------------------------------------
*STEP, PERTURBATION
Eigensolution for SMAHC beam at 150 F
**
*FREQUENCY, EIGENSOLVER=LANCZOS, NORMALIZATION=MASS
10, , 1500.
**
** Eigensolution output
**
***OUTPUT, FIELD
***NODE OUTPUT
**U,
*END STEP
**
** ----------------------------------------------------
** ------ STEP data for Linear Random Response at 150 F
** ----------------------------------------------------
*STEP, PERTURBATION
Linear random response of SMAHC beam at 150 F
**
** 0-400 Hz with 400 points between eigenfrequencies, 1.0 bias and linear frequency
**
*RANDOM RESPONSE
0., 400., 400, 1.0, 1
**
** This is only needed in the event that a subset of the modes
** from the *FREQUENCY card are used
**
*SELECT EIGENMODES, GENERATE
1, 10
**
*MODAL DAMPING, MODAL=DIRECT
1, 10, 0.005
**
```

```
*CORRELATION, PSD=S10TO400, COMPLEX=NO, TYPE=CORRELATED
2, 1.
**
*DLOAD
**
*BASE MOTION, DOF=3, LOAD CASE=2, TYPE=ACCELERATION
**
** Random response PSD at center node
**
*OUTPUT, FIELD
*NODE OUTPUT, NSET=CENTER
U,
**
*END STEP
** ---------------------------------------------------
** ------ STEP data for post-buckling 150-200 F
** ---------------------------------------------------
*STEP, NLGEOM
Post-buckling solution 150-200 degrees F
**
*STATIC, DIRECT
0.2,1.0
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 200.
**
** Load deflection data at center node (carries forward from above)
**
*END STEP
** ---------------------------------------------------
** ------ STEP data for Eigensolution at 200 F
** ---------------------------------------------------
*STEP, PERTURBATION
Eigensolution for SMAHC beam at 200 F
**
*FREQUENCY, EIGENSOLVER=LANCZOS, NORMALIZATION=MASS
10, , 1500.
**
** Eigensolution output
**
***OUTPUT, FIELD
***NODE OUTPUT
**U,
*END STEP
**
** ---------------------------------------------------
** ------ STEP data for Linear Random Response at 200 F
** ---------------------------------------------------
*STEP, PERTURBATION
Linear random response of SMAHC beam at 200 F
**
** 0-400 Hz with 400 points between eigenfrequencies, 1.0 bias and linear frequency
**
*RANDOM RESPONSE
0., 400., 400, 1.0, 1
**
** This is only needed in the event that a subset of the modes
** from the *FREQUENCY card are used
**
*SELECT EIGENMODES, GENERATE
1, 10
```

```
**
*MODAL DAMPING, MODAL=DIRECT
1, 10, 0.005
**
*CORRELATION, PSD=S10TO400, COMPLEX=NO, TYPE=CORRELATED
2, 1.
**
*DLOAD
**
*BASE MOTION, DOF=3, LOAD CASE=2, TYPE=ACCELERATION
**
** Random response PSD at center node
**
*OUTPUT, FIELD
*NODE OUTPUT, NSET=CENTER
U,
**
*END STEP
** ----------------------------------------------------
** ------ STEP data for post-buckling 200-250 F
** ----------------------------------------------------
*STEP, NLGEOM
Post-buckling solution 200-250 degrees F
**
*STATIC, DIRECT
0.2,1.0
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 250.
**
** Load deflection data at center node (carries forward from above)
**
*END STEP
** ----------------------------------------------------
** ------ STEP data for Eigensolution at 250 F
** ----------------------------------------------------
*STEP, PERTURBATION
Eigensolution for SMAHC beam at 250 F
**
*FREQUENCY, EIGENSOLVER=LANCZOS, NORMALIZATION=MASS
10, , 1500.
**
** Eigensolution output
**
***OUTPUT, FIELD
***NODE OUTPUT
**U,
*END STEP
**
** ----------------------------------------------------
** ------ STEP data for Linear Random Response at 250 F
** ----------------------------------------------------
*STEP, PERTURBATION
Linear random response of SMAHC beam at 250 F
**
** 0-400 Hz with 400 points between eigenfrequencies, 1.0 bias and linear frequency
**
*RANDOM RESPONSE
0., 400., 400, 1.0, 1
**
** This is only needed in the event that a subset of the modes
```

```
** from the *FREQUENCY card are used
**
*SELECT EIGENMODES, GENERATE
1, 10
**
*MODAL DAMPING, MODAL=DIRECT
1, 10, 0.005
**
*CORRELATION, PSD=S10TO400, COMPLEX=NO, TYPE=CORRELATED
2, 1.
**
*DLOAD
**
*BASE MOTION, DOF=3, LOAD CASE=2, TYPE=ACCELERATION
**
** Random response PSD at center node
**
*OUTPUT, FIELD
*NODE OUTPUT, NSET=CENTER
U,
**
*END STEP
```

<u>9x1 inch SMAHC Cantilever Beam</u>

smahccantilevert_a.inp

```
*HEADING
Deflection analysis of a 9x1 SMAHC cantilever beam
**
** ---------------------------------------------------
** --- Nodal information ---
** ---------------------------------------------------
**
*INCLUDE, INPUT=nodes.inp
**
** ---------------------------------------------------
** --- SHELL elements (with directional properties) --
** ---------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=GLEPELEM
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,         45.
**
*INCLUDE, INPUT=glep_outer_elem.inp
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,          0.
```

```
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,         45.
       0.006,    3,    NITI,          0.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,         45.
**
*INCLUDE, INPUT=smahc_inner_elem.inp
**
** -----------------------------------------------------
** --- Temp. dependent material properties ---
** -----------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=nitiabaq_secsec75.dat
**
** Cantilevered boundary conditions
**
*BOUNDARY
CFFF, 1, 6, 0.
**
** Uniform initial temperature
**
*INITIAL CONDITIONS, TYPE=TEMPERATURE
ALL_NODES, 75.
**
*NSET, NSET=CFFF
1, 20, 39, 58, 77
*NSET, NSET=TIP
57,
**
** -----------------------------------------------------
** ------ STEP data for thermal deflection 75-250 F
** -----------------------------------------------------
**
*STEP, INC=10, NLGEOM
Thermal deflection solution 75-250 degrees F
**
*STATIC, DIRECT
0.1, 1.
**
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 250.
**
** Load deflection data at tip node
**
*OUTPUT, HISTORY
*NODE OUTPUT, NSET=TIP
U3,
*NODE PRINT, NSET=TIP
U3,
**
```

```
*OUTPUT, FIELD
*NODE OUTPUT
U,
**
*END STEP
```

smahccantmix0t_a.inp

```
*HEADING
Deflection analysis of a 9x1 SMAHC cantilever beam
**
** ---------------------------------------------------
** --- Nodal information ---
** ---------------------------------------------------
**
*INCLUDE, INPUT=nodes.inp
**
** ---------------------------------------------------
** --- SHELL elements (with directional properties) --
** ---------------------------------------------------
**
*SHELL SECTION, COMPOSITE, ELSET=SMAHCELEM
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,         45.
    0.004875,    3, SMAHCMIX0,        0.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,         45.
    0.004875,    3,    GLEP,         90.
    0.004875,    3,    GLEP,        -45.
    0.004875,    3,    GLEP,          0.
    0.004875,    3,    GLEP,         45.
**
*INCLUDE, INPUT=smahc_all_elem.inp
**
** ---------------------------------------------------
** --- Include temp. dependent material properties ---
** ---------------------------------------------------
**
*INCLUDE, INPUT=glepabaq_secsec75.dat
*INCLUDE, INPUT=smahcmix0abaq_secsec75.dat
**
** Cantilevered boundary conditions
**
*BOUNDARY
CFFF, 1, 6, 0.
**
** Uniform initial temperature
**
*INITIAL CONDITIONS, TYPE=TEMPERATURE
ALL_NODES, 75.
**
*NSET, NSET=CFFF
1, 20, 39, 58, 77
*NSET, NSET=TIP
57,
**
```

```
** ---------------------------------------------------
** ------ STEP data for thermal deflection 75-250 F
** ---------------------------------------------------
**
*STEP, INC=10, NLGEOM
Thermal deflection solution 75-250 degrees F
**
*STATIC, DIRECT
0.1, 1.
**
**
** Uniform thermal load
**
*TEMPERATURE
ALL_NODES, 250.
**
** Load deflection at tip node
**
*OUTPUT, HISTORY
*NODE OUTPUT, NSET=TIP
U3,
*NODE PRINT, NSET=TIP
U3,
**
*OUTPUT, FIELD
*NODE OUTPUT
U,
**
*END STEP
```

Appendix C
MSC.Nastran Finite Element Mesh "Include" Files

18x1 inch SMAHC Beam Clamped at Both Ends

nodes.bdf

```
$ Nodes of the Entire Model
GRID     1               0.      0.      0.
GRID     2               .5      0.      0.
GRID     3               1.      0.      0.
GRID     4               1.5     0.      0.
GRID     5               2.      0.      0.
GRID     6               2.5     0.      0.
GRID     7               3.      0.      0.
GRID     8               3.5     0.      0.
GRID     9               4.      0.      0.
GRID     10              4.5     0.      0.
GRID     11              5.      0.      0.
GRID     12              5.5     0.      0.
GRID     13              6.      0.      0.
GRID     14              6.5     0.      0.
GRID     15              7.      0.      0.
GRID     16              7.5     0.      0.
GRID     17              8.      0.      0.
GRID     18              8.5     0.      0.
GRID     19              9.      0.      0.
GRID     20              9.5     0.      0.
GRID     21              10.     0.      0.
GRID     22              10.5    0.      0.
GRID     23              11.     0.      0.
GRID     24              11.5    0.      0.
GRID     25              12.     0.      0.
GRID     26              12.5    0.      0.
GRID     27              13.     0.      0.
GRID     28              13.5    0.      0.
GRID     29              14.     0.      0.
GRID     30              14.5    0.      0.
GRID     31              15.     0.      0.
GRID     32              15.5    0.      0.
GRID     33              16.     0.      0.
GRID     34              16.5    0.      0.
GRID     35              17.     0.      0.
GRID     36              17.5    0.      0.
GRID     37              18.     0.      0.
GRID     38              0.      .275    0.
GRID     39              .5      .275    0.
GRID     40              1.      .275    0.
GRID     41              1.5     .275    0.
GRID     42              2.      .275    0.
GRID     43              2.5     .275    0.
GRID     44              3.      .275    0.
GRID     45              3.5     .275    0.
GRID     46              4.      .275    0.
GRID     47              4.5     .275    0.
GRID     48              5.      .275    0.
GRID     49              5.5     .275    0.
GRID     50              6.      .275    0.
GRID     51              6.5     .275    0.
GRID     52              7.      .275    0.
GRID     53              7.5     .275    0.
```

GRID	54	8.	.275	0.
GRID	55	8.5	.275	0.
GRID	56	9.	.275	0.
GRID	57	9.5	.275	0.
GRID	58	10.	.275	0.
GRID	59	10.5	.275	0.
GRID	60	11.	.275	0.
GRID	61	11.5	.275	0.
GRID	62	12.	.275	0.
GRID	63	12.5	.275	0.
GRID	64	13.	.275	0.
GRID	65	13.5	.275	0.
GRID	66	14.	.275	0.
GRID	67	14.5	.275	0.
GRID	68	15.	.275	0.
GRID	69	15.5	.275	0.
GRID	70	16.	.275	0.
GRID	71	16.5	.275	0.
GRID	72	17.	.275	0.
GRID	73	17.5	.275	0.
GRID	74	18.	.275	0.
GRID	75	0.	.5	0.
GRID	76	.5	.5	0.
GRID	77	1.	.5	0.
GRID	78	1.5	.5	0.
GRID	79	2.	.5	0.
GRID	80	2.5	.5	0.
GRID	81	3.	.5	0.
GRID	82	3.5	.5	0.
GRID	83	4.	.5	0.
GRID	84	4.5	.5	0.
GRID	85	5.	.5	0.
GRID	86	5.5	.5	0.
GRID	87	6.	.5	0.
GRID	88	6.5	.5	0.
GRID	89	7.	.5	0.
GRID	90	7.5	.5	0.
GRID	91	8.	.5	0.
GRID	92	8.5	.5	0.
GRID	93	9.	.5	0.
GRID	94	9.5	.5	0.
GRID	95	10.	.5	0.
GRID	96	10.5	.5	0.
GRID	97	11.	.5	0.
GRID	98	11.5	.5	0.
GRID	99	12.	.5	0.
GRID	100	12.5	.5	0.
GRID	101	13.	.5	0.
GRID	102	13.5	.5	0.
GRID	103	14.	.5	0.
GRID	104	14.5	.5	0.
GRID	105	15.	.5	0.
GRID	106	15.5	.5	0.
GRID	107	16.	.5	0.
GRID	108	16.5	.5	0.
GRID	109	17.	.5	0.
GRID	110	17.5	.5	0.
GRID	111	18.	.5	0.
GRID	112	0.	.725	0.
GRID	113	.5	.725	0.
GRID	114	1.	.725	0.
GRID	115	1.5	.725	0.
GRID	116	2.	.725	0.

```
GRID     117              2.5     .725    0.
GRID     118              3.      .725    0.
GRID     119              3.5     .725    0.
GRID     120              4.      .725    0.
GRID     121              4.5     .725    0.
GRID     122              5.      .725    0.
GRID     123              5.5     .725    0.
GRID     124              6.      .725    0.
GRID     125              6.5     .725    0.
GRID     126              7.      .725    0.
GRID     127              7.5     .725    0.
GRID     128              8.      .725    0.
GRID     129              8.5     .725    0.
GRID     130              9.      .725    0.
GRID     131              9.5     .725    0.
GRID     132              10.     .725    0.
GRID     133              10.5    .725    0.
GRID     134              11.     .725    0.
GRID     135              11.5    .725    0.
GRID     136              12.     .725    0.
GRID     137              12.5    .725    0.
GRID     138              13.     .725    0.
GRID     139              13.5    .725    0.
GRID     140              14.     .725    0.
GRID     141              14.5    .725    0.
GRID     142              15.     .725    0.
GRID     143              15.5    .725    0.
GRID     144              16.     .725    0.
GRID     145              16.5    .725    0.
GRID     146              17.     .725    0.
GRID     147              17.5    .725    0.
GRID     148              18.     .725    0.
GRID     149              0.      1.      0.
GRID     150              .5      1.      0.
GRID     151              1.      1.      0.
GRID     152              1.5     1.      0.
GRID     153              2.      1.      0.
GRID     154              2.5     1.      0.
GRID     155              3.      1.      0.
GRID     156              3.5     1.      0.
GRID     157              4.      1.      0.
GRID     158              4.5     1.      0.
GRID     159              5.      1.      0.
GRID     160              5.5     1.      0.
GRID     161              6.      1.      0.
GRID     162              6.5     1.      0.
GRID     163              7.      1.      0.
GRID     164              7.5     1.      0.
GRID     165              8.      1.      0.
GRID     166              8.5     1.      0.
GRID     167              9.      1.      0.
GRID     168              9.5     1.      0.
GRID     169              10.     1.      0.
GRID     170              10.5    1.      0.
GRID     171              11.     1.      0.
GRID     172              11.5    1.      0.
GRID     173              12.     1.      0.
GRID     174              12.5    1.      0.
GRID     175              13.     1.      0.
GRID     176              13.5    1.      0.
GRID     177              14.     1.      0.
GRID     178              14.5    1.      0.
GRID     179              15.     1.      0.
```

```
GRID     180              15.5    1.      0.
GRID     181              16.     1.      0.
GRID     182              16.5    1.      0.
GRID     183              17.     1.      0.
GRID     184              17.5    1.      0.
GRID     185              18.     1.      0.
```

nodes_imon.bdf

```
$ Nodes of the Entire Model
GRID     1                0.00000 0.00000 0.00000
GRID     2                0.50000 0.00000 0.00011
GRID     3                1.00000 0.00000 0.00046
GRID     4                1.50000 0.00000 0.00099
GRID     5                2.00000 0.00000 0.00166
GRID     6                2.50000 0.00000 0.00245
GRID     7                3.00000 0.00000 0.00331
GRID     8                3.50000 0.00000 0.00421
GRID     9                4.00000 0.00000 0.00513
GRID     10               4.50000 0.00000 0.00604
GRID     11               5.00000 0.00000 0.00691
GRID     12               5.50000 0.00000 0.00773
GRID     13               6.00000 0.00000 0.00848
GRID     14               6.50000 0.00000 0.00914
GRID     15               7.00000 0.00000 0.00969
GRID     16               7.50000 0.00000 0.01014
GRID     17               8.00000 0.00000 0.01046
GRID     18               8.50000 0.00000 0.01065
GRID     19               9.00000 0.00000 0.01071
GRID     20               9.50000 0.00000 0.01064
GRID     21              10.00000 0.00000 0.01043
GRID     22              10.50000 0.00000 0.01010
GRID     23              11.00000 0.00000 0.00965
GRID     24              11.50000 0.00000 0.00909
GRID     25              12.00000 0.00000 0.00842
GRID     26              12.50000 0.00000 0.00767
GRID     27              13.00000 0.00000 0.00684
GRID     28              13.50000 0.00000 0.00596
GRID     29              14.00000 0.00000 0.00505
GRID     30              14.50000 0.00000 0.00413
GRID     31              15.00000 0.00000 0.00323
GRID     32              15.50000 0.00000 0.00238
GRID     33              16.00000 0.00000 0.00160
GRID     34              16.50000 0.00000 0.00094
GRID     35              17.00000 0.00000 0.00042
GRID     36              17.50000 0.00000 0.00010
GRID     37              18.00000 0.00000 0.00000
GRID     38               0.00000 0.27500 0.00000
GRID     39               0.50000 0.27500 0.00013
GRID     40               1.00000 0.27500 0.00047
GRID     41               1.50000 0.27500 0.00099
GRID     42               2.00000 0.27500 0.00166
GRID     43               2.50000 0.27500 0.00244
GRID     44               3.00000 0.27500 0.00329
GRID     45               3.50000 0.27500 0.00419
GRID     46               4.00000 0.27500 0.00511
GRID     47               4.50000 0.27500 0.00601
GRID     48               5.00000 0.27500 0.00689
GRID     49               5.50000 0.27500 0.00771
GRID     50               6.00000 0.27500 0.00845
GRID     51               6.50000 0.27500 0.00911
GRID     52               7.00000 0.27500 0.00967
GRID     53               7.50000 0.27500 0.01011
```

GRID	54	8.00000	0.27500	0.01043
GRID	55	8.50000	0.27500	0.01063
GRID	56	9.00000	0.27500	0.01069
GRID	57	9.50000	0.27500	0.01062
GRID	58	10.00000	0.27500	0.01042
GRID	59	10.50000	0.27500	0.01010
GRID	60	11.00000	0.27500	0.00965
GRID	61	11.50000	0.27500	0.00909
GRID	62	12.00000	0.27500	0.00843
GRID	63	12.50000	0.27500	0.00768
GRID	64	13.00000	0.27500	0.00685
GRID	65	13.50000	0.27500	0.00598
GRID	66	14.00000	0.27500	0.00507
GRID	67	14.50000	0.27500	0.00416
GRID	68	15.00000	0.27500	0.00326
GRID	69	15.50000	0.27500	0.00241
GRID	70	16.00000	0.27500	0.00163
GRID	71	16.50000	0.27500	0.00097
GRID	72	17.00000	0.27500	0.00045
GRID	73	17.50000	0.27500	0.00012
GRID	74	18.00000	0.27500	0.00000
GRID	75	0.00000	0.50000	0.00000
GRID	76	0.50000	0.50000	0.00013
GRID	77	1.00000	0.50000	0.00047
GRID	78	1.50000	0.50000	0.00099
GRID	79	2.00000	0.50000	0.00165
GRID	80	2.50000	0.50000	0.00243
GRID	81	3.00000	0.50000	0.00328
GRID	82	3.50000	0.50000	0.00417
GRID	83	4.00000	0.50000	0.00509
GRID	84	4.50000	0.50000	0.00599
GRID	85	5.00000	0.50000	0.00687
GRID	86	5.50000	0.50000	0.00769
GRID	87	6.00000	0.50000	0.00844
GRID	88	6.50000	0.50000	0.00910
GRID	89	7.00000	0.50000	0.00965
GRID	90	7.50000	0.50000	0.01010
GRID	91	8.00000	0.50000	0.01043
GRID	92	8.50000	0.50000	0.01062
GRID	93	9.00000	0.50000	0.01069
GRID	94	9.50000	0.50000	0.01062
GRID	95	10.00000	0.50000	0.01043
GRID	96	10.50000	0.50000	0.01010
GRID	97	11.00000	0.50000	0.00965
GRID	98	11.50000	0.50000	0.00910
GRID	99	12.00000	0.50000	0.00844
GRID	100	12.50000	0.50000	0.00769
GRID	101	13.00000	0.50000	0.00687
GRID	102	13.50000	0.50000	0.00599
GRID	103	14.00000	0.50000	0.00509
GRID	104	14.50000	0.50000	0.00417
GRID	105	15.00000	0.50000	0.00328
GRID	106	15.50000	0.50000	0.00243
GRID	107	16.00000	0.50000	0.00165
GRID	108	16.50000	0.50000	0.00099
GRID	109	17.00000	0.50000	0.00047
GRID	110	17.50000	0.50000	0.00013
GRID	111	18.00000	0.50000	0.00000
GRID	112	0.00000	0.72500	0.00000
GRID	113	0.50000	0.72500	0.00012
GRID	114	1.00000	0.72500	0.00045
GRID	115	1.50000	0.72500	0.00097
GRID	116	2.00000	0.72500	0.00163

```
GRID     117          2.50000 0.72500 0.00241
GRID     118          3.00000 0.72500 0.00326
GRID     119          3.50000 0.72500 0.00416
GRID     120          4.00000 0.72500 0.00507
GRID     121          4.50000 0.72500 0.00598
GRID     122          5.00000 0.72500 0.00685
GRID     123          5.50000 0.72500 0.00768
GRID     124          6.00000 0.72500 0.00843
GRID     125          6.50000 0.72500 0.00909
GRID     126          7.00000 0.72500 0.00965
GRID     127          7.50000 0.72500 0.01010
GRID     128          8.00000 0.72500 0.01042
GRID     129          8.50000 0.72500 0.01062
GRID     130          9.00000 0.72500 0.01069
GRID     131          9.50000 0.72500 0.01063
GRID     132         10.00000 0.72500 0.01043
GRID     133         10.50000 0.72500 0.01011
GRID     134         11.00000 0.72500 0.00967
GRID     135         11.50000 0.72500 0.00911
GRID     136         12.00000 0.72500 0.00845
GRID     137         12.50000 0.72500 0.00771
GRID     138         13.00000 0.72500 0.00689
GRID     139         13.50000 0.72500 0.00601
GRID     140         14.00000 0.72500 0.00511
GRID     141         14.50000 0.72500 0.00419
GRID     142         15.00000 0.72500 0.00329
GRID     143         15.50000 0.72500 0.00244
GRID     144         16.00000 0.72500 0.00166
GRID     145         16.50000 0.72500 0.00099
GRID     146         17.00000 0.72500 0.00047
GRID     147         17.50000 0.72500 0.00013
GRID     148         18.00000 0.72500 0.00000
GRID     149          0.00000 1.00000 0.00000
GRID     150          0.50000 1.00000 0.00010
GRID     151          1.00000 1.00000 0.00042
GRID     152          1.50000 1.00000 0.00094
GRID     153          2.00000 1.00000 0.00160
GRID     154          2.50000 1.00000 0.00238
GRID     155          3.00000 1.00000 0.00323
GRID     156          3.50000 1.00000 0.00413
GRID     157          4.00000 1.00000 0.00505
GRID     158          4.50000 1.00000 0.00596
GRID     159          5.00000 1.00000 0.00684
GRID     160          5.50000 1.00000 0.00767
GRID     161          6.00000 1.00000 0.00842
GRID     162          6.50000 1.00000 0.00909
GRID     163          7.00000 1.00000 0.00965
GRID     164          7.50000 1.00000 0.01010
GRID     165          8.00000 1.00000 0.01043
GRID     166          8.50000 1.00000 0.01064
GRID     167          9.00000 1.00000 0.01071
GRID     168          9.50000 1.00000 0.01065
GRID     169         10.00000 1.00000 0.01046
GRID     170         10.50000 1.00000 0.01014
GRID     171         11.00000 1.00000 0.00969
GRID     172         11.50000 1.00000 0.00914
GRID     173         12.00000 1.00000 0.00848
GRID     174         12.50000 1.00000 0.00773
GRID     175         13.00000 1.00000 0.00691
GRID     176         13.50000 1.00000 0.00604
GRID     177         14.00000 1.00000 0.00513
GRID     178         14.50000 1.00000 0.00421
GRID     179         15.00000 1.00000 0.00331
```

```
GRID     180           15.50000 1.00000 0.00245
GRID     181           16.00000 1.00000 0.00166
GRID     182           16.50000 1.00000 0.00099
GRID     183           17.00000 1.00000 0.00046
GRID     184           17.50000 1.00000 0.00011
GRID     185           18.00000 1.00000 0.00000
```

nodes_imix0.bdf

```
$ Nodes of the Entire Model
GRID     1              0.00000 0.00000 0.00000
GRID     2              0.50000 0.00000 0.00012
GRID     3              1.00000 0.00000 0.00049
GRID     4              1.50000 0.00000 0.00106
GRID     5              2.00000 0.00000 0.00179
GRID     6              2.50000 0.00000 0.00263
GRID     7              3.00000 0.00000 0.00355
GRID     8              3.50000 0.00000 0.00452
GRID     9              4.00000 0.00000 0.00550
GRID     10             4.50000 0.00000 0.00648
GRID     11             5.00000 0.00000 0.00742
GRID     12             5.50000 0.00000 0.00830
GRID     13             6.00000 0.00000 0.00910
GRID     14             6.50000 0.00000 0.00981
GRID     15             7.00000 0.00000 0.01040
GRID     16             7.50000 0.00000 0.01088
GRID     17             8.00000 0.00000 0.01122
GRID     18             8.50000 0.00000 0.01143
GRID     19             9.00000 0.00000 0.01149
GRID     20             9.50000 0.00000 0.01141
GRID     21            10.00000 0.00000 0.01120
GRID     22            10.50000 0.00000 0.01084
GRID     23            11.00000 0.00000 0.01036
GRID     24            11.50000 0.00000 0.00975
GRID     25            12.00000 0.00000 0.00904
GRID     26            12.50000 0.00000 0.00823
GRID     27            13.00000 0.00000 0.00734
GRID     28            13.50000 0.00000 0.00640
GRID     29            14.00000 0.00000 0.00542
GRID     30            14.50000 0.00000 0.00444
GRID     31            15.00000 0.00000 0.00347
GRID     32            15.50000 0.00000 0.00255
GRID     33            16.00000 0.00000 0.00172
GRID     34            16.50000 0.00000 0.00101
GRID     35            17.00000 0.00000 0.00046
GRID     36            17.50000 0.00000 0.00011
GRID     37            18.00000 0.00000 0.00000
GRID     38             0.00000 0.27500 0.00000
GRID     39             0.50000 0.27500 0.00014
GRID     40             1.00000 0.27500 0.00050
GRID     41             1.50000 0.27500 0.00106
GRID     42             2.00000 0.27500 0.00178
GRID     43             2.50000 0.27500 0.00262
GRID     44             3.00000 0.27500 0.00353
GRID     45             3.50000 0.27500 0.00450
GRID     46             4.00000 0.27500 0.00548
GRID     47             4.50000 0.27500 0.00645
GRID     48             5.00000 0.27500 0.00739
GRID     49             5.50000 0.27500 0.00827
GRID     50             6.00000 0.27500 0.00907
GRID     51             6.50000 0.27500 0.00978
GRID     52             7.00000 0.27500 0.01037
GRID     53             7.50000 0.27500 0.01085
```

```
GRID     54            8.00000 0.27500 0.01120
GRID     55            8.50000 0.27500 0.01141
GRID     56            9.00000 0.27500 0.01147
GRID     57            9.50000 0.27500 0.01140
GRID     58           10.00000 0.27500 0.01119
GRID     59           10.50000 0.27500 0.01084
GRID     60           11.00000 0.27500 0.01035
GRID     61           11.50000 0.27500 0.00975
GRID     62           12.00000 0.27500 0.00904
GRID     63           12.50000 0.27500 0.00824
GRID     64           13.00000 0.27500 0.00736
GRID     65           13.50000 0.27500 0.00642
GRID     66           14.00000 0.27500 0.00544
GRID     67           14.50000 0.27500 0.00446
GRID     68           15.00000 0.27500 0.00350
GRID     69           15.50000 0.27500 0.00258
GRID     70           16.00000 0.27500 0.00175
GRID     71           16.50000 0.27500 0.00104
GRID     72           17.00000 0.27500 0.00049
GRID     73           17.50000 0.27500 0.00013
GRID     74           18.00000 0.27500 0.00000
GRID     75            0.00000 0.50000 0.00000
GRID     76            0.50000 0.50000 0.00014
GRID     77            1.00000 0.50000 0.00050
GRID     78            1.50000 0.50000 0.00106
GRID     79            2.00000 0.50000 0.00177
GRID     80            2.50000 0.50000 0.00260
GRID     81            3.00000 0.50000 0.00352
GRID     82            3.50000 0.50000 0.00448
GRID     83            4.00000 0.50000 0.00546
GRID     84            4.50000 0.50000 0.00643
GRID     85            5.00000 0.50000 0.00737
GRID     86            5.50000 0.50000 0.00825
GRID     87            6.00000 0.50000 0.00905
GRID     88            6.50000 0.50000 0.00976
GRID     89            7.00000 0.50000 0.01036
GRID     90            7.50000 0.50000 0.01084
GRID     91            8.00000 0.50000 0.01119
GRID     92            8.50000 0.50000 0.01140
GRID     93            9.00000 0.50000 0.01147
GRID     94            9.50000 0.50000 0.01140
GRID     95           10.00000 0.50000 0.01119
GRID     96           10.50000 0.50000 0.01084
GRID     97           11.00000 0.50000 0.01036
GRID     98           11.50000 0.50000 0.00976
GRID     99           12.00000 0.50000 0.00905
GRID     100          12.50000 0.50000 0.00825
GRID     101          13.00000 0.50000 0.00737
GRID     102          13.50000 0.50000 0.00643
GRID     103          14.00000 0.50000 0.00546
GRID     104          14.50000 0.50000 0.00448
GRID     105          15.00000 0.50000 0.00352
GRID     106          15.50000 0.50000 0.00260
GRID     107          16.00000 0.50000 0.00177
GRID     108          16.50000 0.50000 0.00106
GRID     109          17.00000 0.50000 0.00050
GRID     110          17.50000 0.50000 0.00014
GRID     111          18.00000 0.50000 0.00000
GRID     112           0.00000 0.72500 0.00000
GRID     113           0.50000 0.72500 0.00013
GRID     114           1.00000 0.72500 0.00049
GRID     115           1.50000 0.72500 0.00104
GRID     116           2.00000 0.72500 0.00175
```

GRID	117	2.50000	0.72500	0.00258
GRID	118	3.00000	0.72500	0.00350
GRID	119	3.50000	0.72500	0.00446
GRID	120	4.00000	0.72500	0.00544
GRID	121	4.50000	0.72500	0.00642
GRID	122	5.00000	0.72500	0.00736
GRID	123	5.50000	0.72500	0.00824
GRID	124	6.00000	0.72500	0.00904
GRID	125	6.50000	0.72500	0.00975
GRID	126	7.00000	0.72500	0.01035
GRID	127	7.50000	0.72500	0.01084
GRID	128	8.00000	0.72500	0.01119
GRID	129	8.50000	0.72500	0.01140
GRID	130	9.00000	0.72500	0.01147
GRID	131	9.50000	0.72500	0.01141
GRID	132	10.00000	0.72500	0.01120
GRID	133	10.50000	0.72500	0.01085
GRID	134	11.00000	0.72500	0.01037
GRID	135	11.50000	0.72500	0.00978
GRID	136	12.00000	0.72500	0.00907
GRID	137	12.50000	0.72500	0.00827
GRID	138	13.00000	0.72500	0.00739
GRID	139	13.50000	0.72500	0.00645
GRID	140	14.00000	0.72500	0.00548
GRID	141	14.50000	0.72500	0.00450
GRID	142	15.00000	0.72500	0.00353
GRID	143	15.50000	0.72500	0.00262
GRID	144	16.00000	0.72500	0.00178
GRID	145	16.50000	0.72500	0.00106
GRID	146	17.00000	0.72500	0.00050
GRID	147	17.50000	0.72500	0.00014
GRID	148	18.00000	0.72500	0.00000
GRID	149	0.00000	1.00000	0.00000
GRID	150	0.50000	1.00000	0.00011
GRID	151	1.00000	1.00000	0.00046
GRID	152	1.50000	1.00000	0.00101
GRID	153	2.00000	1.00000	0.00172
GRID	154	2.50000	1.00000	0.00255
GRID	155	3.00000	1.00000	0.00347
GRID	156	3.50000	1.00000	0.00444
GRID	157	4.00000	1.00000	0.00542
GRID	158	4.50000	1.00000	0.00640
GRID	159	5.00000	1.00000	0.00734
GRID	160	5.50000	1.00000	0.00823
GRID	161	6.00000	1.00000	0.00904
GRID	162	6.50000	1.00000	0.00975
GRID	163	7.00000	1.00000	0.01036
GRID	164	7.50000	1.00000	0.01084
GRID	165	8.00000	1.00000	0.01120
GRID	166	8.50000	1.00000	0.01141
GRID	167	9.00000	1.00000	0.01149
GRID	168	9.50000	1.00000	0.01143
GRID	169	10.00000	1.00000	0.01122
GRID	170	10.50000	1.00000	0.01088
GRID	171	11.00000	1.00000	0.01040
GRID	172	11.50000	1.00000	0.00981
GRID	173	12.00000	1.00000	0.00910
GRID	174	12.50000	1.00000	0.00830
GRID	175	13.00000	1.00000	0.00742
GRID	176	13.50000	1.00000	0.00648
GRID	177	14.00000	1.00000	0.00550
GRID	178	14.50000	1.00000	0.00452
GRID	179	15.00000	1.00000	0.00355

```
GRID     180           15.50000 1.00000 0.00263
GRID     181           16.00000 1.00000 0.00179
GRID     182           16.50000 1.00000 0.00106
GRID     183           17.00000 1.00000 0.00049
GRID     184           17.50000 1.00000 0.00012
GRID     185           18.00000 1.00000 0.00000
```

glep_outer_elem.bdf

```
$ Pset: "glepelem" will be imported as: "pcomp.2"
CQUAD4   1       2       1       2       39      38
CQUAD4   2       2       2       3       40      39
CQUAD4   3       2       3       4       41      40
CQUAD4   4       2       4       5       42      41
CQUAD4   5       2       5       6       43      42
CQUAD4   6       2       6       7       44      43
CQUAD4   7       2       7       8       45      44
CQUAD4   8       2       8       9       46      45
CQUAD4   9       2       9       10      47      46
CQUAD4   10      2       10      11      48      47
CQUAD4   11      2       11      12      49      48
CQUAD4   12      2       12      13      50      49
CQUAD4   13      2       13      14      51      50
CQUAD4   14      2       14      15      52      51
CQUAD4   15      2       15      16      53      52
CQUAD4   16      2       16      17      54      53
CQUAD4   17      2       17      18      55      54
CQUAD4   18      2       18      19      56      55
CQUAD4   19      2       19      20      57      56
CQUAD4   20      2       20      21      58      57
CQUAD4   21      2       21      22      59      58
CQUAD4   22      2       22      23      60      59
CQUAD4   23      2       23      24      61      60
CQUAD4   24      2       24      25      62      61
CQUAD4   25      2       25      26      63      62
CQUAD4   26      2       26      27      64      63
CQUAD4   27      2       27      28      65      64
CQUAD4   28      2       28      29      66      65
CQUAD4   29      2       29      30      67      66
CQUAD4   30      2       30      31      68      67
CQUAD4   31      2       31      32      69      68
CQUAD4   32      2       32      33      70      69
CQUAD4   33      2       33      34      71      70
CQUAD4   34      2       34      35      72      71
CQUAD4   35      2       35      36      73      72
CQUAD4   36      2       36      37      74      73
CQUAD4   109     2       112     113     150     149
CQUAD4   110     2       113     114     151     150
CQUAD4   111     2       114     115     152     151
CQUAD4   112     2       115     116     153     152
CQUAD4   113     2       116     117     154     153
CQUAD4   114     2       117     118     155     154
CQUAD4   115     2       118     119     156     155
CQUAD4   116     2       119     120     157     156
CQUAD4   117     2       120     121     158     157
CQUAD4   118     2       121     122     159     158
CQUAD4   119     2       122     123     160     159
CQUAD4   120     2       123     124     161     160
CQUAD4   121     2       124     125     162     161
CQUAD4   122     2       125     126     163     162
CQUAD4   123     2       126     127     164     163
CQUAD4   124     2       127     128     165     164
CQUAD4   125     2       128     129     166     165
```

```
CQUAD4   126     2       129     130     167     166
CQUAD4   127     2       130     131     168     167
CQUAD4   128     2       131     132     169     168
CQUAD4   129     2       132     133     170     169
CQUAD4   130     2       133     134     171     170
CQUAD4   131     2       134     135     172     171
CQUAD4   132     2       135     136     173     172
CQUAD4   133     2       136     137     174     173
CQUAD4   134     2       137     138     175     174
CQUAD4   135     2       138     139     176     175
CQUAD4   136     2       139     140     177     176
CQUAD4   137     2       140     141     178     177
CQUAD4   138     2       141     142     179     178
CQUAD4   139     2       142     143     180     179
CQUAD4   140     2       143     144     181     180
CQUAD4   141     2       144     145     182     181
CQUAD4   142     2       145     146     183     182
CQUAD4   143     2       146     147     184     183
CQUAD4   144     2       147     148     185     184
```

smahc_inner_elem.bdf

```
$ Pset: "smachelem" will be imported as: "pcomp.1"
CQUAD4   37      1       38      39      76      75
CQUAD4   38      1       39      40      77      76
CQUAD4   39      1       40      41      78      77
CQUAD4   40      1       41      42      79      78
CQUAD4   41      1       42      43      80      79
CQUAD4   42      1       43      44      81      80
CQUAD4   43      1       44      45      82      81
CQUAD4   44      1       45      46      83      82
CQUAD4   45      1       46      47      84      83
CQUAD4   46      1       47      48      85      84
CQUAD4   47      1       48      49      86      85
CQUAD4   48      1       49      50      87      86
CQUAD4   49      1       50      51      88      87
CQUAD4   50      1       51      52      89      88
CQUAD4   51      1       52      53      90      89
CQUAD4   52      1       53      54      91      90
CQUAD4   53      1       54      55      92      91
CQUAD4   54      1       55      56      93      92
CQUAD4   55      1       56      57      94      93
CQUAD4   56      1       57      58      95      94
CQUAD4   57      1       58      59      96      95
CQUAD4   58      1       59      60      97      96
CQUAD4   59      1       60      61      98      97
CQUAD4   60      1       61      62      99      98
CQUAD4   61      1       62      63      100     99
CQUAD4   62      1       63      64      101     100
CQUAD4   63      1       64      65      102     101
CQUAD4   64      1       65      66      103     102
CQUAD4   65      1       66      67      104     103
CQUAD4   66      1       67      68      105     104
CQUAD4   67      1       68      69      106     105
CQUAD4   68      1       69      70      107     106
CQUAD4   69      1       70      71      108     107
CQUAD4   70      1       71      72      109     108
CQUAD4   71      1       72      73      110     109
CQUAD4   72      1       73      74      111     110
CQUAD4   73      1       75      76      113     112
CQUAD4   74      1       76      77      114     113
CQUAD4   75      1       77      78      115     114
CQUAD4   76      1       78      79      116     115
```

```
CQUAD4   77       1        79       80       117      116
CQUAD4   78       1        80       81       118      117
CQUAD4   79       1        81       82       119      118
CQUAD4   80       1        82       83       120      119
CQUAD4   81       1        83       84       121      120
CQUAD4   82       1        84       85       122      121
CQUAD4   83       1        85       86       123      122
CQUAD4   84       1        86       87       124      123
CQUAD4   85       1        87       88       125      124
CQUAD4   86       1        88       89       126      125
CQUAD4   87       1        89       90       127      126
CQUAD4   88       1        90       91       128      127
CQUAD4   89       1        91       92       129      128
CQUAD4   90       1        92       93       130      129
CQUAD4   91       1        93       94       131      130
CQUAD4   92       1        94       95       132      131
CQUAD4   93       1        95       96       133      132
CQUAD4   94       1        96       97       134      133
CQUAD4   95       1        97       98       135      134
CQUAD4   96       1        98       99       136      135
CQUAD4   97       1        99       100      137      136
CQUAD4   98       1        100      101      138      137
CQUAD4   99       1        101      102      139      138
CQUAD4   100      1        102      103      140      139
CQUAD4   101      1        103      104      141      140
CQUAD4   102      1        104      105      142      141
CQUAD4   103      1        105      106      143      142
CQUAD4   104      1        106      107      144      143
CQUAD4   105      1        107      108      145      144
CQUAD4   106      1        108      109      146      145
CQUAD4   107      1        109      110      147      146
CQUAD4   108      1        110      111      148      147
```

smahc_all_elem.bdf

```
$ Pset: "smahcelem" will be imported as: "pcomp.1"
CQUAD4   1        1        1        2        39       38
CQUAD4   2        1        2        3        40       39
CQUAD4   3        1        3        4        41       40
CQUAD4   4        1        4        5        42       41
CQUAD4   5        1        5        6        43       42
CQUAD4   6        1        6        7        44       43
CQUAD4   7        1        7        8        45       44
CQUAD4   8        1        8        9        46       45
CQUAD4   9        1        9        10       47       46
CQUAD4   10       1        10       11       48       47
CQUAD4   11       1        11       12       49       48
CQUAD4   12       1        12       13       50       49
CQUAD4   13       1        13       14       51       50
CQUAD4   14       1        14       15       52       51
CQUAD4   15       1        15       16       53       52
CQUAD4   16       1        16       17       54       53
CQUAD4   17       1        17       18       55       54
CQUAD4   18       1        18       19       56       55
CQUAD4   19       1        19       20       57       56
CQUAD4   20       1        20       21       58       57
CQUAD4   21       1        21       22       59       58
CQUAD4   22       1        22       23       60       59
CQUAD4   23       1        23       24       61       60
CQUAD4   24       1        24       25       62       61
CQUAD4   25       1        25       26       63       62
CQUAD4   26       1        26       27       64       63
CQUAD4   27       1        27       28       65       64
CQUAD4   28       1        28       29       66       65
```

CQUAD4	29	1	29	30	67	66
CQUAD4	30	1	30	31	68	67
CQUAD4	31	1	31	32	69	68
CQUAD4	32	1	32	33	70	69
CQUAD4	33	1	33	34	71	70
CQUAD4	34	1	34	35	72	71
CQUAD4	35	1	35	36	73	72
CQUAD4	36	1	36	37	74	73
CQUAD4	37	1	38	39	76	75
CQUAD4	38	1	39	40	77	76
CQUAD4	39	1	40	41	78	77
CQUAD4	40	1	41	42	79	78
CQUAD4	41	1	42	43	80	79
CQUAD4	42	1	43	44	81	80
CQUAD4	43	1	44	45	82	81
CQUAD4	44	1	45	46	83	82
CQUAD4	45	1	46	47	84	83
CQUAD4	46	1	47	48	85	84
CQUAD4	47	1	48	49	86	85
CQUAD4	48	1	49	50	87	86
CQUAD4	49	1	50	51	88	87
CQUAD4	50	1	51	52	89	88
CQUAD4	51	1	52	53	90	89
CQUAD4	52	1	53	54	91	90
CQUAD4	53	1	54	55	92	91
CQUAD4	54	1	55	56	93	92
CQUAD4	55	1	56	57	94	93
CQUAD4	56	1	57	58	95	94
CQUAD4	57	1	58	59	96	95
CQUAD4	58	1	59	60	97	96
CQUAD4	59	1	60	61	98	97
CQUAD4	60	1	61	62	99	98
CQUAD4	61	1	62	63	100	99
CQUAD4	62	1	63	64	101	100
CQUAD4	63	1	64	65	102	101
CQUAD4	64	1	65	66	103	102
CQUAD4	65	1	66	67	104	103
CQUAD4	66	1	67	68	105	104
CQUAD4	67	1	68	69	106	105
CQUAD4	68	1	69	70	107	106
CQUAD4	69	1	70	71	108	107
CQUAD4	70	1	71	72	109	108
CQUAD4	71	1	72	73	110	109
CQUAD4	72	1	73	74	111	110
CQUAD4	73	1	75	76	113	112
CQUAD4	74	1	76	77	114	113
CQUAD4	75	1	77	78	115	114
CQUAD4	76	1	78	79	116	115
CQUAD4	77	1	79	80	117	116
CQUAD4	78	1	80	81	118	117
CQUAD4	79	1	81	82	119	118
CQUAD4	80	1	82	83	120	119
CQUAD4	81	1	83	84	121	120
CQUAD4	82	1	84	85	122	121
CQUAD4	83	1	85	86	123	122
CQUAD4	84	1	86	87	124	123
CQUAD4	85	1	87	88	125	124
CQUAD4	86	1	88	89	126	125
CQUAD4	87	1	89	90	127	126
CQUAD4	88	1	90	91	128	127
CQUAD4	89	1	91	92	129	128
CQUAD4	90	1	92	93	130	129
CQUAD4	91	1	93	94	131	130

```
CQUAD4   92      1       94      95      132     131
CQUAD4   93      1       95      96      133     132
CQUAD4   94      1       96      97      134     133
CQUAD4   95      1       97      98      135     134
CQUAD4   96      1       98      99      136     135
CQUAD4   97      1       99      100     137     136
CQUAD4   98      1       100     101     138     137
CQUAD4   99      1       101     102     139     138
CQUAD4   100     1       102     103     140     139
CQUAD4   101     1       103     104     141     140
CQUAD4   102     1       104     105     142     141
CQUAD4   103     1       105     106     143     142
CQUAD4   104     1       106     107     144     143
CQUAD4   105     1       107     108     145     144
CQUAD4   106     1       108     109     146     145
CQUAD4   107     1       109     110     147     146
CQUAD4   108     1       110     111     148     147
CQUAD4   109     1       112     113     150     149
CQUAD4   110     1       113     114     151     150
CQUAD4   111     1       114     115     152     151
CQUAD4   112     1       115     116     153     152
CQUAD4   113     1       116     117     154     153
CQUAD4   114     1       117     118     155     154
CQUAD4   115     1       118     119     156     155
CQUAD4   116     1       119     120     157     156
CQUAD4   117     1       120     121     158     157
CQUAD4   118     1       121     122     159     158
CQUAD4   119     1       122     123     160     159
CQUAD4   120     1       123     124     161     160
CQUAD4   121     1       124     125     162     161
CQUAD4   122     1       125     126     163     162
CQUAD4   123     1       126     127     164     163
CQUAD4   124     1       127     128     165     164
CQUAD4   125     1       128     129     166     165
CQUAD4   126     1       129     130     167     166
CQUAD4   127     1       130     131     168     167
CQUAD4   128     1       131     132     169     168
CQUAD4   129     1       132     133     170     169
CQUAD4   130     1       133     134     171     170
CQUAD4   131     1       134     135     172     171
CQUAD4   132     1       135     136     173     172
CQUAD4   133     1       136     137     174     173
CQUAD4   134     1       137     138     175     174
CQUAD4   135     1       138     139     176     175
CQUAD4   136     1       139     140     177     176
CQUAD4   137     1       140     141     178     177
CQUAD4   138     1       141     142     179     178
CQUAD4   139     1       142     143     180     179
CQUAD4   140     1       143     144     181     180
CQUAD4   141     1       144     145     182     181
CQUAD4   142     1       145     146     183     182
CQUAD4   143     1       146     147     184     183
CQUAD4   144     1       147     148     185     184
```

9x1 SMAHC cantilever beam

nodes.bdf

```
$ Nodes of the Entire Model
GRID     1               0.      0.      0.
GRID     2               .5      0.      0.
GRID     3               1.      0.      0.
GRID     4               1.5     0.      0.
```

```
GRID    5               2.      0.      0.
GRID    6               2.5     0.      0.
GRID    7               3.      0.      0.
GRID    8               3.5     0.      0.
GRID    9               4.      0.      0.
GRID    10              4.5     0.      0.
GRID    11              5.      0.      0.
GRID    12              5.5     0.      0.
GRID    13              6.      0.      0.
GRID    14              6.5     0.      0.
GRID    15              7.      0.      0.
GRID    16              7.5     0.      0.
GRID    17              8.      0.      0.
GRID    18              8.5     0.      0.
GRID    19              9.      0.      0.
GRID    20              0.      .275    0.
GRID    21              .5      .275    0.
GRID    22              1.      .275    0.
GRID    23              1.5     .275    0.
GRID    24              2.      .275    0.
GRID    25              2.5     .275    0.
GRID    26              3.      .275    0.
GRID    27              3.5     .275    0.
GRID    28              4.      .275    0.
GRID    29              4.5     .275    0.
GRID    30              5.      .275    0.
GRID    31              5.5     .275    0.
GRID    32              6.      .275    0.
GRID    33              6.5     .275    0.
GRID    34              7.      .275    0.
GRID    35              7.5     .275    0.
GRID    36              8.      .275    0.
GRID    37              8.5     .275    0.
GRID    38              9.      .275    0.
GRID    39              0.      .5      0.
GRID    40              .5      .5      0.
GRID    41              1.      .5      0.
GRID    42              1.5     .5      0.
GRID    43              2.      .5      0.
GRID    44              2.5     .5      0.
GRID    45              3.      .5      0.
GRID    46              3.5     .5      0.
GRID    47              4.      .5      0.
GRID    48              4.5     .5      0.
GRID    49              5.      .5      0.
GRID    50              5.5     .5      0.
GRID    51              6.      .5      0.
GRID    52              6.5     .5      0.
GRID    53              7.      .5      0.
GRID    54              7.5     .5      0.
GRID    55              8.      .5      0.
GRID    56              8.5     .5      0.
GRID    57              9.      .5      0.
GRID    58              0.      .725    0.
GRID    59              .5      .725    0.
GRID    60              1.      .725    0.
GRID    61              1.5     .725    0.
GRID    62              2.      .725    0.
GRID    63              2.5     .725    0.
GRID    64              3.      .725    0.
GRID    65              3.5     .725    0.
GRID    66              4.      .725    0.
GRID    67              4.5     .725    0.
```

```
GRID    68              5.      .725    0.
GRID    69              5.5     .725    0.
GRID    70              6.      .725    0.
GRID    71              6.5     .725    0.
GRID    72              7.      .725    0.
GRID    73              7.5     .725    0.
GRID    74              8.      .725    0.
GRID    75              8.5     .725    0.
GRID    76              9.      .725    0.
GRID    77              0.      1.      0.
GRID    78              .5      1.      0.
GRID    79              1.      1.      0.
GRID    80              1.5     1.      0.
GRID    81              2.      1.      0.
GRID    82              2.5     1.      0.
GRID    83              3.      1.      0.
GRID    84              3.5     1.      0.
GRID    85              4.      1.      0.
GRID    86              4.5     1.      0.
GRID    87              5.      1.      0.
GRID    88              5.5     1.      0.
GRID    89              6.      1.      0.
GRID    90              6.5     1.      0.
GRID    91              7.      1.      0.
GRID    92              7.5     1.      0.
GRID    93              8.      1.      0.
GRID    94              8.5     1.      0.
GRID    95              9.      1.      0.
```

glep_outer_elem.bdf

```
$ Pset: "glepelem" will be imported as: "pcomp.1"
CQUAD4  1       1       1       2       21      20
CQUAD4  2       1       2       3       22      21
CQUAD4  3       1       3       4       23      22
CQUAD4  4       1       4       5       24      23
CQUAD4  5       1       5       6       25      24
CQUAD4  6       1       6       7       26      25
CQUAD4  7       1       7       8       27      26
CQUAD4  8       1       8       9       28      27
CQUAD4  9       1       9       10      29      28
CQUAD4  10      1       10      11      30      29
CQUAD4  11      1       11      12      31      30
CQUAD4  12      1       12      13      32      31
CQUAD4  13      1       13      14      33      32
CQUAD4  14      1       14      15      34      33
CQUAD4  15      1       15      16      35      34
CQUAD4  16      1       16      17      36      35
CQUAD4  17      1       17      18      37      36
CQUAD4  18      1       18      19      38      37
CQUAD4  55      1       58      59      78      77
CQUAD4  56      1       59      60      79      78
CQUAD4  57      1       60      61      80      79
CQUAD4  58      1       61      62      81      80
CQUAD4  59      1       62      63      82      81
CQUAD4  60      1       63      64      83      82
CQUAD4  61      1       64      65      84      83
CQUAD4  62      1       65      66      85      84
CQUAD4  63      1       66      67      86      85
CQUAD4  64      1       67      68      87      86
CQUAD4  65      1       68      69      88      87
CQUAD4  66      1       69      70      89      88
CQUAD4  67      1       70      71      90      89
```

```
CQUAD4   68      1       71      72      91      90
CQUAD4   69      1       72      73      92      91
CQUAD4   70      1       73      74      93      92
CQUAD4   71      1       74      75      94      93
CQUAD4   72      1       75      76      95      94
```

smahc_inner_elem.bdf

```
$ Pset: "smahcelem" will be imported as: "pcomp.2"
CQUAD4   19      2       20      21      40      39
CQUAD4   20      2       21      22      41      40
CQUAD4   21      2       22      23      42      41
CQUAD4   22      2       23      24      43      42
CQUAD4   23      2       24      25      44      43
CQUAD4   24      2       25      26      45      44
CQUAD4   25      2       26      27      46      45
CQUAD4   26      2       27      28      47      46
CQUAD4   27      2       28      29      48      47
CQUAD4   28      2       29      30      49      48
CQUAD4   29      2       30      31      50      49
CQUAD4   30      2       31      32      51      50
CQUAD4   31      2       32      33      52      51
CQUAD4   32      2       33      34      53      52
CQUAD4   33      2       34      35      54      53
CQUAD4   34      2       35      36      55      54
CQUAD4   35      2       36      37      56      55
CQUAD4   36      2       37      38      57      56
CQUAD4   37      2       39      40      59      58
CQUAD4   38      2       40      41      60      59
CQUAD4   39      2       41      42      61      60
CQUAD4   40      2       42      43      62      61
CQUAD4   41      2       43      44      63      62
CQUAD4   42      2       44      45      64      63
CQUAD4   43      2       45      46      65      64
CQUAD4   44      2       46      47      66      65
CQUAD4   45      2       47      48      67      66
CQUAD4   46      2       48      49      68      67
CQUAD4   47      2       49      50      69      68
CQUAD4   48      2       50      51      70      69
CQUAD4   49      2       51      52      71      70
CQUAD4   50      2       52      53      72      71
CQUAD4   51      2       53      54      73      72
CQUAD4   52      2       54      55      74      73
CQUAD4   53      2       55      56      75      74
CQUAD4   54      2       56      57      76      75
```

smahc_all_elem.bdf

```
$ Pset: "smahcelem" will be imported as: "pcomp.2"
CQUAD4   1       1       1       2       21      20
CQUAD4   2       1       2       3       22      21
CQUAD4   3       1       3       4       23      22
CQUAD4   4       1       4       5       24      23
CQUAD4   5       1       5       6       25      24
CQUAD4   6       1       6       7       26      25
CQUAD4   7       1       7       8       27      26
CQUAD4   8       1       8       9       28      27
CQUAD4   9       1       9       10      29      28
CQUAD4   10      1       10      11      30      29
CQUAD4   11      1       11      12      31      30
CQUAD4   12      1       12      13      32      31
CQUAD4   13      1       13      14      33      32
CQUAD4   14      1       14      15      34      33
CQUAD4   15      1       15      16      35      34
```

CQUAD4	16	1	16	17	36	35
CQUAD4	17	1	17	18	37	36
CQUAD4	18	1	18	19	38	37
CQUAD4	19	1	20	21	40	39
CQUAD4	20	1	21	22	41	40
CQUAD4	21	1	22	23	42	41
CQUAD4	22	1	23	24	43	42
CQUAD4	23	1	24	25	44	43
CQUAD4	24	1	25	26	45	44
CQUAD4	25	1	26	27	46	45
CQUAD4	26	1	27	28	47	46
CQUAD4	27	1	28	29	48	47
CQUAD4	28	1	29	30	49	48
CQUAD4	29	1	30	31	50	49
CQUAD4	30	1	31	32	51	50
CQUAD4	31	1	32	33	52	51
CQUAD4	32	1	33	34	53	52
CQUAD4	33	1	34	35	54	53
CQUAD4	34	1	35	36	55	54
CQUAD4	35	1	36	37	56	55
CQUAD4	36	1	37	38	57	56
CQUAD4	37	1	39	40	59	58
CQUAD4	38	1	40	41	60	59
CQUAD4	39	1	41	42	61	60
CQUAD4	40	1	42	43	62	61
CQUAD4	41	1	43	44	63	62
CQUAD4	42	1	44	45	64	63
CQUAD4	43	1	45	46	65	64
CQUAD4	44	1	46	47	66	65
CQUAD4	45	1	47	48	67	66
CQUAD4	46	1	48	49	68	67
CQUAD4	47	1	49	50	69	68
CQUAD4	48	1	50	51	70	69
CQUAD4	49	1	51	52	71	70
CQUAD4	50	1	52	53	72	71
CQUAD4	51	1	53	54	73	72
CQUAD4	52	1	54	55	74	73
CQUAD4	53	1	55	56	75	74
CQUAD4	54	1	56	57	76	75
CQUAD4	55	1	58	59	78	77
CQUAD4	56	1	59	60	79	78
CQUAD4	57	1	60	61	80	79
CQUAD4	58	1	61	62	81	80
CQUAD4	59	1	62	63	82	81
CQUAD4	60	1	63	64	83	82
CQUAD4	61	1	64	65	84	83
CQUAD4	62	1	65	66	85	84
CQUAD4	63	1	66	67	86	85
CQUAD4	64	1	67	68	87	86
CQUAD4	65	1	68	69	88	87
CQUAD4	66	1	69	70	89	88
CQUAD4	67	1	70	71	90	89
CQUAD4	68	1	71	72	91	90
CQUAD4	69	1	72	73	92	91
CQUAD4	70	1	73	74	93	92
CQUAD4	71	1	74	75	94	93
CQUAD4	72	1	75	76	95	94

Appendix D
ABAQUS Finite Element Mesh "Include" Files

18x1 inch SMAHC Beam Clamped at Both Ends

nodes.inp

```
*NODE, NSET=ALL_NODES
      1,          0.,          0.,           0.
      2,         0.5,          0.,           0.
      3,          1.,          0.,           0.
      4,         1.5,          0.,           0.
      5,          2.,          0.,           0.
      6,         2.5,          0.,           0.
      7,          3.,          0.,           0.
      8,         3.5,          0.,           0.
      9,          4.,          0.,           0.
     10,         4.5,          0.,           0.
     11,          5.,          0.,           0.
     12,         5.5,          0.,           0.
     13,          6.,          0.,           0.
     14,         6.5,          0.,           0.
     15,          7.,          0.,           0.
     16,         7.5,          0.,           0.
     17,          8.,          0.,           0.
     18,         8.5,          0.,           0.
     19,          9.,          0.,           0.
     20,         9.5,          0.,           0.
     21,         10.,          0.,           0.
     22,        10.5,          0.,           0.
     23,         11.,          0.,           0.
     24,        11.5,          0.,           0.
     25,         12.,          0.,           0.
     26,        12.5,          0.,           0.
     27,         13.,          0.,           0.
     28,        13.5,          0.,           0.
     29,         14.,          0.,           0.
     30,        14.5,          0.,           0.
     31,         15.,          0.,           0.
     32,        15.5,          0.,           0.
     33,         16.,          0.,           0.
     34,        16.5,          0.,           0.
     35,         17.,          0.,           0.
     36,        17.5,          0.,           0.
     37,         18.,          0.,           0.
     38,          0.,      0.275,           0.
     39,         0.5,      0.275,           0.
     40,          1.,      0.275,           0.
     41,         1.5,      0.275,           0.
     42,          2.,      0.275,           0.
     43,         2.5,      0.275,           0.
     44,          3.,      0.275,           0.
     45,         3.5,      0.275,           0.
     46,          4.,      0.275,           0.
     47,         4.5,      0.275,           0.
     48,          5.,      0.275,           0.
     49,         5.5,      0.275,           0.
     50,          6.,      0.275,           0.
     51,         6.5,      0.275,           0.
     52,          7.,      0.275,           0.
     53,         7.5,      0.275,           0.
```

```
 54,        8.,     0.275,        0.
 55,      8.5,     0.275,        0.
 56,        9.,     0.275,        0.
 57,      9.5,     0.275,        0.
 58,      10.,     0.275,        0.
 59,     10.5,     0.275,        0.
 60,      11.,     0.275,        0.
 61,     11.5,     0.275,        0.
 62,      12.,     0.275,        0.
 63,     12.5,     0.275,        0.
 64,      13.,     0.275,        0.
 65,     13.5,     0.275,        0.
 66,      14.,     0.275,        0.
 67,     14.5,     0.275,        0.
 68,      15.,     0.275,        0.
 69,     15.5,     0.275,        0.
 70,      16.,     0.275,        0.
 71,     16.5,     0.275,        0.
 72,      17.,     0.275,        0.
 73,     17.5,     0.275,        0.
 74,      18.,     0.275,        0.
 75,        0.,       0.5,        0.
 76,      0.5,       0.5,        0.
 77,        1.,       0.5,        0.
 78,      1.5,       0.5,        0.
 79,        2.,       0.5,        0.
 80,      2.5,       0.5,        0.
 81,        3.,       0.5,        0.
 82,      3.5,       0.5,        0.
 83,        4.,       0.5,        0.
 84,      4.5,       0.5,        0.
 85,        5.,       0.5,        0.
 86,      5.5,       0.5,        0.
 87,        6.,       0.5,        0.
 88,      6.5,       0.5,        0.
 89,        7.,       0.5,        0.
 90,      7.5,       0.5,        0.
 91,        8.,       0.5,        0.
 92,      8.5,       0.5,        0.
 93,        9.,       0.5,        0.
 94,      9.5,       0.5,        0.
 95,      10.,       0.5,        0.
 96,     10.5,       0.5,        0.
 97,      11.,       0.5,        0.
 98,     11.5,       0.5,        0.
 99,      12.,       0.5,        0.
100,     12.5,       0.5,        0.
101,      13.,       0.5,        0.
102,     13.5,       0.5,        0.
103,      14.,       0.5,        0.
104,     14.5,       0.5,        0.
105,      15.,       0.5,        0.
106,     15.5,       0.5,        0.
107,      16.,       0.5,        0.
108,     16.5,       0.5,        0.
109,      17.,       0.5,        0.
110,     17.5,       0.5,        0.
111,      18.,       0.5,        0.
112,        0.,     0.725,        0.
113,      0.5,     0.725,        0.
114,        1.,     0.725,        0.
115,      1.5,     0.725,        0.
116,        2.,     0.725,        0.
```

117,	2.5,	0.725,	0.
118,	3.,	0.725,	0.
119,	3.5,	0.725,	0.
120,	4.,	0.725,	0.
121,	4.5,	0.725,	0.
122,	5.,	0.725,	0.
123,	5.5,	0.725,	0.
124,	6.,	0.725,	0.
125,	6.5,	0.725,	0.
126,	7.,	0.725,	0.
127,	7.5,	0.725,	0.
128,	8.,	0.725,	0.
129,	8.5,	0.725,	0.
130,	9.,	0.725,	0.
131,	9.5,	0.725,	0.
132,	10.,	0.725,	0.
133,	10.5,	0.725,	0.
134,	11.,	0.725,	0.
135,	11.5,	0.725,	0.
136,	12.,	0.725,	0.
137,	12.5,	0.725,	0.
138,	13.,	0.725,	0.
139,	13.5,	0.725,	0.
140,	14.,	0.725,	0.
141,	14.5,	0.725,	0.
142,	15.,	0.725,	0.
143,	15.5,	0.725,	0.
144,	16.,	0.725,	0.
145,	16.5,	0.725,	0.
146,	17.,	0.725,	0.
147,	17.5,	0.725,	0.
148,	18.,	0.725,	0.
149,	0.,	1.,	0.
150,	0.5,	1.,	0.
151,	1.,	1.,	0.
152,	1.5,	1.,	0.
153,	2.,	1.,	0.
154,	2.5,	1.,	0.
155,	3.,	1.,	0.
156,	3.5,	1.,	0.
157,	4.,	1.,	0.
158,	4.5,	1.,	0.
159,	5.,	1.,	0.
160,	5.5,	1.,	0.
161,	6.,	1.,	0.
162,	6.5,	1.,	0.
163,	7.,	1.,	0.
164,	7.5,	1.,	0.
165,	8.,	1.,	0.
166,	8.5,	1.,	0.
167,	9.,	1.,	0.
168,	9.5,	1.,	0.
169,	10.,	1.,	0.
170,	10.5,	1.,	0.
171,	11.,	1.,	0.
172,	11.5,	1.,	0.
173,	12.,	1.,	0.
174,	12.5,	1.,	0.
175,	13.,	1.,	0.
176,	13.5,	1.,	0.
177,	14.,	1.,	0.
178,	14.5,	1.,	0.
179,	15.,	1.,	0.

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     180,        15.5,          1.,           0.
     181,         16.,          1.,           0.
     182,        16.5,          1.,           0.
     183,         17.,          1.,           0.
     184,        17.5,          1.,           0.
     185,         18.,          1.,           0.
```

glep_outer_elem.inp

```
*ELEMENT, TYPE=S4, ELSET=GLEPELEM
1, 1, 2, 39, 38
2, 2, 3, 40, 39
3, 3, 4, 41, 40
4, 4, 5, 42, 41
5, 5, 6, 43, 42
6, 6, 7, 44, 43
7, 7, 8, 45, 44
8, 8, 9, 46, 45
9, 9, 10, 47, 46
10, 10, 11, 48, 47
11, 11, 12, 49, 48
12, 12, 13, 50, 49
13, 13, 14, 51, 50
14, 14, 15, 52, 51
15, 15, 16, 53, 52
16, 16, 17, 54, 53
17, 17, 18, 55, 54
18, 18, 19, 56, 55
19, 19, 20, 57, 56
20, 20, 21, 58, 57
21, 21, 22, 59, 58
22, 22, 23, 60, 59
23, 23, 24, 61, 60
24, 24, 25, 62, 61
25, 25, 26, 63, 62
26, 26, 27, 64, 63
27, 27, 28, 65, 64
28, 28, 29, 66, 65
29, 29, 30, 67, 66
30, 30, 31, 68, 67
31, 31, 32, 69, 68
32, 32, 33, 70, 69
33, 33, 34, 71, 70
34, 34, 35, 72, 71
35, 35, 36, 73, 72
36, 36, 37, 74, 73
109, 112, 113, 150, 149
110, 113, 114, 151, 150
111, 114, 115, 152, 151
112, 115, 116, 153, 152
113, 116, 117, 154, 153
114, 117, 118, 155, 154
115, 118, 119, 156, 155
116, 119, 120, 157, 156
117, 120, 121, 158, 157
118, 121, 122, 159, 158
119, 122, 123, 160, 159
120, 123, 124, 161, 160
121, 124, 125, 162, 161
122, 125, 126, 163, 162
123, 126, 127, 164, 163
124, 127, 128, 165, 164
125, 128, 129, 166, 165
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126, 129, 130, 167, 166
127, 130, 131, 168, 167
128, 131, 132, 169, 168
129, 132, 133, 170, 169
130, 133, 134, 171, 170
131, 134, 135, 172, 171
132, 135, 136, 173, 172
133, 136, 137, 174, 173
134, 137, 138, 175, 174
135, 138, 139, 176, 175
136, 139, 140, 177, 176
137, 140, 141, 178, 177
138, 141, 142, 179, 178
139, 142, 143, 180, 179
140, 143, 144, 181, 180
141, 144, 145, 182, 181
142, 145, 146, 183, 182
143, 146, 147, 184, 183
144, 147, 148, 185, 184
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smahc_inner_elem.inp

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*ELEMENT, TYPE=S4, ELSET=SMAHCELEM
37, 38, 39, 76, 75
38, 39, 40, 77, 76
39, 40, 41, 78, 77
40, 41, 42, 79, 78
41, 42, 43, 80, 79
42, 43, 44, 81, 80
43, 44, 45, 82, 81
44, 45, 46, 83, 82
45, 46, 47, 84, 83
46, 47, 48, 85, 84
47, 48, 49, 86, 85
48, 49, 50, 87, 86
49, 50, 51, 88, 87
50, 51, 52, 89, 88
51, 52, 53, 90, 89
52, 53, 54, 91, 90
53, 54, 55, 92, 91
54, 55, 56, 93, 92
55, 56, 57, 94, 93
56, 57, 58, 95, 94
57, 58, 59, 96, 95
58, 59, 60, 97, 96
59, 60, 61, 98, 97
60, 61, 62, 99, 98
61, 62, 63, 100, 99
62, 63, 64, 101, 100
63, 64, 65, 102, 101
64, 65, 66, 103, 102
65, 66, 67, 104, 103
66, 67, 68, 105, 104
67, 68, 69, 106, 105
68, 69, 70, 107, 106
69, 70, 71, 108, 107
70, 71, 72, 109, 108
71, 72, 73, 110, 109
72, 73, 74, 111, 110
73, 75, 76, 113, 112
74, 76, 77, 114, 113
75, 77, 78, 115, 114
76, 78, 79, 116, 115
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77, 79, 80, 117, 116
78, 80, 81, 118, 117
79, 81, 82, 119, 118
80, 82, 83, 120, 119
81, 83, 84, 121, 120
82, 84, 85, 122, 121
83, 85, 86, 123, 122
84, 86, 87, 124, 123
85, 87, 88, 125, 124
86, 88, 89, 126, 125
87, 89, 90, 127, 126
88, 90, 91, 128, 127
89, 91, 92, 129, 128
90, 92, 93, 130, 129
91, 93, 94, 131, 130
92, 94, 95, 132, 131
93, 95, 96, 133, 132
94, 96, 97, 134, 133
95, 97, 98, 135, 134
96, 98, 99, 136, 135
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101, 103, 104, 141, 140
102, 104, 105, 142, 141
103, 105, 106, 143, 142
104, 106, 107, 144, 143
105, 107, 108, 145, 144
106, 108, 109, 146, 145
107, 109, 110, 147, 146
108, 110, 111, 148, 147
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smahc_all_elem.inp

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*ELEMENT, TYPE=S4, ELSET=SMAHCELEM
1, 1, 2, 39, 38
2, 2, 3, 40, 39
3, 3, 4, 41, 40
4, 4, 5, 42, 41
5, 5, 6, 43, 42
6, 6, 7, 44, 43
7, 7, 8, 45, 44
8, 8, 9, 46, 45
9, 9, 10, 47, 46
10, 10, 11, 48, 47
11, 11, 12, 49, 48
12, 12, 13, 50, 49
13, 13, 14, 51, 50
14, 14, 15, 52, 51
15, 15, 16, 53, 52
16, 16, 17, 54, 53
17, 17, 18, 55, 54
18, 18, 19, 56, 55
19, 19, 20, 57, 56
20, 20, 21, 58, 57
21, 21, 22, 59, 58
22, 22, 23, 60, 59
23, 23, 24, 61, 60
24, 24, 25, 62, 61
25, 25, 26, 63, 62
26, 26, 27, 64, 63
27, 27, 28, 65, 64
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28, 28, 29, 66, 65
29, 29, 30, 67, 66
30, 30, 31, 68, 67
31, 31, 32, 69, 68
32, 32, 33, 70, 69
33, 33, 34, 71, 70
34, 34, 35, 72, 71
35, 35, 36, 73, 72
36, 36, 37, 74, 73
37, 38, 39, 76, 75
38, 39, 40, 77, 76
39, 40, 41, 78, 77
40, 41, 42, 79, 78
41, 42, 43, 80, 79
42, 43, 44, 81, 80
43, 44, 45, 82, 81
44, 45, 46, 83, 82
45, 46, 47, 84, 83
46, 47, 48, 85, 84
47, 48, 49, 86, 85
48, 49, 50, 87, 86
49, 50, 51, 88, 87
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51, 52, 53, 90, 89
52, 53, 54, 91, 90
53, 54, 55, 92, 91
54, 55, 56, 93, 92
55, 56, 57, 94, 93
56, 57, 58, 95, 94
57, 58, 59, 96, 95
58, 59, 60, 97, 96
59, 60, 61, 98, 97
60, 61, 62, 99, 98
61, 62, 63, 100, 99
62, 63, 64, 101, 100
63, 64, 65, 102, 101
64, 65, 66, 103, 102
65, 66, 67, 104, 103
66, 67, 68, 105, 104
67, 68, 69, 106, 105
68, 69, 70, 107, 106
69, 70, 71, 108, 107
70, 71, 72, 109, 108
71, 72, 73, 110, 109
72, 73, 74, 111, 110
73, 75, 76, 113, 112
74, 76, 77, 114, 113
75, 77, 78, 115, 114
76, 78, 79, 116, 115
77, 79, 80, 117, 116
78, 80, 81, 118, 117
79, 81, 82, 119, 118
80, 82, 83, 120, 119
81, 83, 84, 121, 120
82, 84, 85, 122, 121
83, 85, 86, 123, 122
84, 86, 87, 124, 123
85, 87, 88, 125, 124
86, 88, 89, 126, 125
87, 89, 90, 127, 126
88, 90, 91, 128, 127
89, 91, 92, 129, 128
90, 92, 93, 130, 129
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91, 93, 94, 131, 130
92, 94, 95, 132, 131
93, 95, 96, 133, 132
94, 96, 97, 134, 133
95, 97, 98, 135, 134
96, 98, 99, 136, 135
97, 99, 100, 137, 136
98, 100, 101, 138, 137
99, 101, 102, 139, 138
100, 102, 103, 140, 139
101, 103, 104, 141, 140
102, 104, 105, 142, 141
103, 105, 106, 143, 142
104, 106, 107, 144, 143
105, 107, 108, 145, 144
106, 108, 109, 146, 145
107, 109, 110, 147, 146
108, 110, 111, 148, 147
109, 112, 113, 150, 149
110, 113, 114, 151, 150
111, 114, 115, 152, 151
112, 115, 116, 153, 152
113, 116, 117, 154, 153
114, 117, 118, 155, 154
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117, 120, 121, 158, 157
118, 121, 122, 159, 158
119, 122, 123, 160, 159
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121, 124, 125, 162, 161
122, 125, 126, 163, 162
123, 126, 127, 164, 163
124, 127, 128, 165, 164
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132, 135, 136, 173, 172
133, 136, 137, 174, 173
134, 137, 138, 175, 174
135, 138, 139, 176, 175
136, 139, 140, 177, 176
137, 140, 141, 178, 177
138, 141, 142, 179, 178
139, 142, 143, 180, 179
140, 143, 144, 181, 180
141, 144, 145, 182, 181
142, 145, 146, 183, 182
143, 146, 147, 184, 183
144, 147, 148, 185, 184
```

9x1 inch SMAHC Cantilever Beam

nodes.inp

```
*NODE, NSET=ALL_NODES
       1,            0.,             0.
       2,           0.5,             0.
       3,            1.,             0.
```

```
 4,           1.5,            0.
 5,            2.,            0.
 6,           2.5,            0.
 7,            3.,            0.
 8,           3.5,            0.
 9,            4.,            0.
10,           4.5,            0.
11,            5.,            0.
12,           5.5,            0.
13,            6.,            0.
14,           6.5,            0.
15,            7.,            0.
16,           7.5,            0.
17,            8.,            0.
18,           8.5,            0.
19,            9.,            0.
20,            0.,         0.275
21,           0.5,         0.275
22,            1.,         0.275
23,           1.5,         0.275
24,            2.,         0.275
25,           2.5,         0.275
26,            3.,         0.275
27,           3.5,         0.275
28,            4.,         0.275
29,           4.5,         0.275
30,            5.,         0.275
31,           5.5,         0.275
32,            6.,         0.275
33,           6.5,         0.275
34,            7.,         0.275
35,           7.5,         0.275
36,            8.,         0.275
37,           8.5,         0.275
38,            9.,         0.275
39,            0.,           0.5
40,           0.5,           0.5
41,            1.,           0.5
42,           1.5,           0.5
43,            2.,           0.5
44,           2.5,           0.5
45,            3.,           0.5
46,           3.5,           0.5
47,            4.,           0.5
48,           4.5,           0.5
49,            5.,           0.5
50,           5.5,           0.5
51,            6.,           0.5
52,           6.5,           0.5
53,            7.,           0.5
54,           7.5,           0.5
55,            8.,           0.5
56,           8.5,           0.5
57,            9.,           0.5
58,            0.,         0.725
59,           0.5,         0.725
60,            1.,         0.725
61,           1.5,         0.725
62,            2.,         0.725
63,           2.5,         0.725
64,            3.,         0.725
65,           3.5,         0.725
66,            4.,         0.725
```

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     67,           4.5,         0.725
     68,            5.,         0.725
     69,           5.5,         0.725
     70,            6.,         0.725
     71,           6.5,         0.725
     72,            7.,         0.725
     73,           7.5,         0.725
     74,            8.,         0.725
     75,           8.5,         0.725
     76,            9.,         0.725
     77,            0.,            1.
     78,           0.5,            1.
     79,            1.,            1.
     80,           1.5,            1.
     81,            2.,            1.
     82,           2.5,            1.
     83,            3.,            1.
     84,           3.5,            1.
     85,            4.,            1.
     86,           4.5,            1.
     87,            5.,            1.
     88,           5.5,            1.
     89,            6.,            1.
     90,           6.5,            1.
     91,            7.,            1.
     92,           7.5,            1.
     93,            8.,            1.
     94,           8.5,            1.
     95,            9.,            1.
```

glep_outer_elem.inp

```
*ELEMENT, TYPE=S4, ELSET=GLEPELEM
      1,       1,       2,      21,      20
      2,       2,       3,      22,      21
      3,       3,       4,      23,      22
      4,       4,       5,      24,      23
      5,       5,       6,      25,      24
      6,       6,       7,      26,      25
      7,       7,       8,      27,      26
      8,       8,       9,      28,      27
      9,       9,      10,      29,      28
     10,      10,      11,      30,      29
     11,      11,      12,      31,      30
     12,      12,      13,      32,      31
     13,      13,      14,      33,      32
     14,      14,      15,      34,      33
     15,      15,      16,      35,      34
     16,      16,      17,      36,      35
     17,      17,      18,      37,      36
     18,      18,      19,      38,      37
     55,      58,      59,      78,      77
     56,      59,      60,      79,      78
     57,      60,      61,      80,      79
     58,      61,      62,      81,      80
     59,      62,      63,      82,      81
     60,      63,      64,      83,      82
     61,      64,      65,      84,      83
     62,      65,      66,      85,      84
     63,      66,      67,      86,      85
     64,      67,      68,      87,      86
     65,      68,      69,      88,      87
     66,      69,      70,      89,      88
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      67,      70,      71,      90,      89
      68,      71,      72,      91,      90
      69,      72,      73,      92,      91
      70,      73,      74,      93,      92
      71,      74,      75,      94,      93
      72,      75,      76,      95,      94
```

smahc_inner_elem.inp

```
*ELEMENT, TYPE=S4, ELSET=SMAHCELEM
      19,      20,      21,      40,      39
      20,      21,      22,      41,      40
      21,      22,      23,      42,      41
      22,      23,      24,      43,      42
      23,      24,      25,      44,      43
      24,      25,      26,      45,      44
      25,      26,      27,      46,      45
      26,      27,      28,      47,      46
      27,      28,      29,      48,      47
      28,      29,      30,      49,      48
      29,      30,      31,      50,      49
      30,      31,      32,      51,      50
      31,      32,      33,      52,      51
      32,      33,      34,      53,      52
      33,      34,      35,      54,      53
      34,      35,      36,      55,      54
      35,      36,      37,      56,      55
      36,      37,      38,      57,      56
      37,      39,      40,      59,      58
      38,      40,      41,      60,      59
      39,      41,      42,      61,      60
      40,      42,      43,      62,      61
      41,      43,      44,      63,      62
      42,      44,      45,      64,      63
      43,      45,      46,      65,      64
      44,      46,      47,      66,      65
      45,      47,      48,      67,      66
      46,      48,      49,      68,      67
      47,      49,      50,      69,      68
      48,      50,      51,      70,      69
      49,      51,      52,      71,      70
      50,      52,      53,      72,      71
      51,      53,      54,      73,      72
      52,      54,      55,      74,      73
      53,      55,      56,      75,      74
      54,      56,      57,      76,      75
```

smahc_all_elem.inp

```
*ELEMENT, TYPE=S4, ELSET=SMAHCELEM
       1,       1,       2,      21,      20
       2,       2,       3,      22,      21
       3,       3,       4,      23,      22
       4,       4,       5,      24,      23
       5,       5,       6,      25,      24
       6,       6,       7,      26,      25
       7,       7,       8,      27,      26
       8,       8,       9,      28,      27
       9,       9,      10,      29,      28
      10,      10,      11,      30,      29
      11,      11,      12,      31,      30
      12,      12,      13,      32,      31
      13,      13,      14,      33,      32
      14,      14,      15,      34,      33
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```
15,      15,      16,      35,      34
16,      16,      17,      36,      35
17,      17,      18,      37,      36
18,      18,      19,      38,      37
19,      20,      21,      40,      39
20,      21,      22,      41,      40
21,      22,      23,      42,      41
22,      23,      24,      43,      42
23,      24,      25,      44,      43
24,      25,      26,      45,      44
25,      26,      27,      46,      45
26,      27,      28,      47,      46
27,      28,      29,      48,      47
28,      29,      30,      49,      48
29,      30,      31,      50,      49
30,      31,      32,      51,      50
31,      32,      33,      52,      51
32,      33,      34,      53,      52
33,      34,      35,      54,      53
34,      35,      36,      55,      54
35,      36,      37,      56,      55
36,      37,      38,      57,      56
37,      39,      40,      59,      58
38,      40,      41,      60,      59
39,      41,      42,      61,      60
40,      42,      43,      62,      61
41,      43,      44,      63,      62
42,      44,      45,      64,      63
43,      45,      46,      65,      64
44,      46,      47,      66,      65
45,      47,      48,      67,      66
46,      48,      49,      68,      67
47,      49,      50,      69,      68
48,      50,      51,      70,      69
49,      51,      52,      71,      70
50,      52,      53,      72,      71
51,      53,      54,      73,      72
52,      54,      55,      74,      73
53,      55,      56,      75,      74
54,      56,      57,      76,      75
55,      58,      59,      78,      77
56,      59,      60,      79,      78
57,      60,      61,      80,      79
58,      61,      62,      81,      80
59,      62,      63,      82,      81
60,      63,      64,      83,      82
61,      64,      65,      84,      83
62,      65,      66,      85,      84
63,      66,      67,      86,      85
64,      67,      68,      87,      86
65,      68,      69,      88,      87
66,      69,      70,      89,      88
67,      70,      71,      90,      89
68,      71,      72,      91,      90
69,      72,      73,      92,      91
70,      73,      74,      93,      92
71,      74,      75,      94,      93
72,      75,      76,      95,      94
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Appendix E
MSC.Nastran Material Property "Include" Files

glepnast_secsec75.dat

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$ Glass-Epoxy Properties, units of in-lbf-sec-degrees F
MAT8, 1, 7.1500+6, 2.9000+6, 2.9000-1, 1.4000+6, 1.4000+6, 1.4000+6, 1.9000-4,
, 2.9280-6, 6.1390-6, 75.
MATT8, 1,  1,  2,  3,  4,  4,  4,
,  5,  6
$ E1
TABLEM1,  1,
, 60., 7.1500+6, 70., 7.1500+6, 80., 7.1500+6, 90., 7.1400+6,
,100., 7.1300+6,110., 7.1200+6,120., 7.1100+6,130., 7.0950+6,
,140., 7.0800+6,150., 7.0700+6,160., 7.0700+6,170., 7.0650+6,
,180., 7.0600+6,190., 7.0550+6,200., 7.0500+6,210., 7.0500+6,
,220., 7.0500+6,230., 7.0450+6,240., 7.0400+6,250., 7.0400+6,
,260., 7.0500+6,270., 7.0550+6,280., 7.0600+6,290., 7.0700+6,
,300., 7.0800+6,310., 7.0800+6, ENDT
$ E2
TABLEM1,  2,
, 60., 2.9000+6, 70., 2.9000+6, 80., 2.9000+6, 90., 2.8600+6,
,100., 2.8200+6,110., 2.7850+6,120., 2.7500+6,130., 2.7150+6,
,140., 2.6800+6,150., 2.6400+6,160., 2.5800+6,170., 2.5250+6,
,180., 2.4700+6,190., 2.4100+6,200., 2.3500+6,210., 2.2850+6,
,220., 2.2200+6,230., 2.1550+6,240., 2.0900+6,250., 2.0300+6,
,260., 1.9500+6,270., 1.8750+6,280., 1.8000+6,290., 1.7250+6,
,300., 1.6500+6,310., 1.6500+6, ENDT
$ v12
TABLEM1,  3,
, 60., 2.9000-1, 70., 2.9000-1, 80., 2.9000-1, 90., 2.9000-1,
,100., 2.9000-1,110., 2.9000-1,120., 2.9000-1,130., 2.9000-1,
,140., 2.9000-1,150., 2.9000-1,160., 2.9000-1,170., 2.9000-1,
,180., 2.9000-1,190., 2.9000-1,200., 2.9000-1,210., 2.9000-1,
,220., 2.9000-1,230., 2.9000-1,240., 2.9000-1,250., 2.9000-1,
,260., 2.9000-1,270., 2.9000-1,280., 2.9000-1,290., 2.9000-1,
,300., 2.9000-1,310., 2.9000-1, ENDT
$ G12
TABLEM1,  4,
, 60., 1.4000+6, 70., 1.4000+6, 80., 1.4000+6, 90., 1.3700+6,
,100., 1.3400+6,110., 1.3150+6,120., 1.2900+6,130., 1.2650+6,
,140., 1.2400+6,150., 1.2200+6,160., 1.2000+6,170., 1.1750+6,
,180., 1.1500+6,190., 1.1250+6,200., 1.1000+6,210., 1.0400+6,
,220., 9.8000+5,230., 9.2500+5,240., 8.7000+5,250., 8.1000+5,
,260., 7.5000+5,270., 6.8500+5,280., 6.2000+5,290., 5.6000+5,
,300., 5.0000+5,310., 5.0000+5, ENDT
$ a1, secant (ref 75 F)
TABLEM1,  5,
, 60., 2.9280-6, 70., 2.9850-6, 80., 3.1550-6, 90., 3.3130-6,
,100., 3.4710-6,110., 3.5740-6,120., 3.6770-6,130., 3.7190-6,
,140., 3.7610-6,150., 3.7710-6,160., 3.7660-6,170., 3.7505-6,
,180., 3.7350-6,190., 3.7155-6,200., 3.6960-6,210., 3.6835-6,
,220., 3.6710-6,230., 3.6700-6,240., 3.6690-6,250., 3.6770-6,
,260., 3.6910-6,270., 3.7085-6,280., 3.7260-6,290., 3.7465-6,
,300., 3.7670-6,310., 3.7670-6, ENDT
$ a2, secant (ref 75 F)
TABLEM1,  6,
, 60., 6.1390-6, 70., 6.4170-6, 80., 7.2530-6, 90., 8.2215-6,
,100., 9.1900-6,110., 9.9350-6,120., 1.0680-5,130., 1.1125-5,
,140., 1.1570-5,150., 1.1840-5,160., 1.2020-5,170., 1.2110-5,
,180., 1.2200-5,190., 1.2220-5,200., 1.2240-5,210., 1.2235-5,
,220., 1.2230-5,230., 1.2240-5,240., 1.2250-5,250., 1.2280-5,
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,260., 1.2330-5,270., 1.2400-5,280., 1.2470-5,290., 1.2555-5,
,300., 1.2640-5,310., 1.2640-5, ENDT
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glepnast_tantan75.dat

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$ Glass-Epoxy Properties, units of in-lbf-sec-degrees F
MAT8, 1, 7.1500+6, 2.9000+6, 2.9000-1, 1.4000+6, 1.4000+6, 1.4000+6, 1.9000-4,
, 2.9000-6, 6.0000-6, 75.
MATT8, 1,  1,  2,  3,  4,  4,  4,
,  5,  6
$ E1
TABLEM1,  1,
, 60., 7.1500+6, 70., 7.1500+6, 80., 7.1500+6, 90., 7.1400+6,
,100., 7.1300+6,110., 7.1200+6,120., 7.1100+6,130., 7.0950+6,
,140., 7.0800+6,150., 7.0700+6,160., 7.0700+6,170., 7.0650+6,
,180., 7.0600+6,190., 7.0550+6,200., 7.0500+6,210., 7.0500+6,
,220., 7.0500+6,230., 7.0450+6,240., 7.0400+6,250., 7.0400+6,
,260., 7.0500+6,270., 7.0550+6,280., 7.0600+6,290., 7.0700+6,
,300., 7.0800+6,310., 7.0800+6, ENDT
$ E2
TABLEM1,  2,
, 60., 2.9000+6, 70., 2.9000+6, 80., 2.9000+6, 90., 2.8600+6,
,100., 2.8200+6,110., 2.7850+6,120., 2.7500+6,130., 2.7150+6,
,140., 2.6800+6,150., 2.6400+6,160., 2.5800+6,170., 2.5250+6,
,180., 2.4700+6,190., 2.4100+6,200., 2.3500+6,210., 2.2850+6,
,220., 2.2200+6,230., 2.1550+6,240., 2.0900+6,250., 2.0300+6,
,260., 1.9500+6,270., 1.8750+6,280., 1.8000+6,290., 1.7250+6,
,300., 1.6500+6,310., 1.6500+6, ENDT
$ v12
TABLEM1,  3,
, 60., 2.9000-1, 70., 2.9000-1, 80., 2.9000-1, 90., 2.9000-1,
,100., 2.9000-1,110., 2.9000-1,120., 2.9000-1,130., 2.9000-1,
,140., 2.9000-1,150., 2.9000-1,160., 2.9000-1,170., 2.9000-1,
,180., 2.9000-1,190., 2.9000-1,200., 2.9000-1,210., 2.9000-1,
,220., 2.9000-1,230., 2.9000-1,240., 2.9000-1,250., 2.9000-1,
,260., 2.9000-1,270., 2.9000-1,280., 2.9000-1,290., 2.9000-1,
,300., 2.9000-1,310., 2.9000-1, ENDT
$ G12
TABLEM1,  4,
, 60., 1.4000+6, 70., 1.4000+6, 80., 1.4000+6, 90., 1.3700+6,
,100., 1.3400+6,110., 1.3150+6,120., 1.2900+6,130., 1.2650+6,
,140., 1.2400+6,150., 1.2200+6,160., 1.2000+6,170., 1.1750+6,
,180., 1.1500+6,190., 1.1250+6,200., 1.1000+6,210., 1.0400+6,
,220., 9.8000+5,230., 9.2500+5,240., 8.7000+5,250., 8.1000+5,
,260., 7.5000+5,270., 6.8500+5,280., 6.2000+5,290., 5.6000+5,
,300., 5.0000+5,310., 5.0000+5, ENDT
$ a1, tangent
TABLEM1,  5,
, 60., 2.9000-6, 70., 2.9000-6, 80., 3.2400-6, 90., 3.5500-6,
,100., 3.8600-6,110., 3.9350-6,120., 4.0100-6,130., 3.9500-6,
,140., 3.8900-6,150., 3.7800-6,160., 3.6800-6,170., 3.6000-6,
,180., 3.5200-6,190., 3.4950-6,200., 3.4700-6,210., 3.5100-6,
,220., 3.5500-6,230., 3.6550-6,240., 3.7600-6,250., 3.8700-6,
,260., 3.9900-6,270., 4.0550-6,280., 4.1200-6,290., 4.1800-6,
,300., 4.2400-6,310., 4.2400-6, ENDT
$ a2, tangent
TABLEM1,  6,
, 60., 6.0000-6, 70., 6.0000-6, 80., 7.6700-6, 90., 9.6750-6,
,100., 1.1680-5,110., 1.2545-5,120., 1.3410-5,130., 1.3555-5,
,140., 1.3700-5,150., 1.3490-5,160., 1.3280-5,170., 1.2970-5,
,180., 1.2660-5,190., 1.2440-5,200., 1.2220-5,210., 1.2200-5,
,220., 1.2180-5,230., 1.2385-5,240., 1.2590-5,250., 1.2960-5,
,260., 1.3340-5,270., 1.3745-5,280., 1.4150-5,290., 1.4375-5,
,300., 1.4600-5,310., 1.4600-5, ENDT
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glepnast_stnstn75.dat

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$ Glass-Epoxy Properties, units of in-lbf-sec-degrees F
MAT8, 1, 7.1500+6, 2.9000+6, 2.9000-1, 1.4000+6, 1.4000+6, 1.4000+6, 1.9000-4,
, 2.9000-6, 6.0000-6, 75.
MATT8, 1,  1,  2,  3,  4,  4,  4,
, -5, -6
$ E1
TABLEM1,  1,
, 60., 7.1500+6, 70., 7.1500+6, 80., 7.1500+6, 90., 7.1400+6,
,100., 7.1300+6,110., 7.1200+6,120., 7.1100+6,130., 7.0950+6,
,140., 7.0800+6,150., 7.0700+6,160., 7.0700+6,170., 7.0650+6,
,180., 7.0600+6,190., 7.0550+6,200., 7.0500+6,210., 7.0500+6,
,220., 7.0500+6,230., 7.0450+6,240., 7.0400+6,250., 7.0400+6,
,260., 7.0500+6,270., 7.0550+6,280., 7.0600+6,290., 7.0700+6,
,300., 7.0800+6,310., 7.0800+6, ENDT
$ E2
TABLEM1,  2,
, 60., 2.9000+6, 70., 2.9000+6, 80., 2.9000+6, 90., 2.8600+6,
,100., 2.8200+6,110., 2.7850+6,120., 2.7500+6,130., 2.7150+6,
,140., 2.6800+6,150., 2.6400+6,160., 2.5800+6,170., 2.5250+6,
,180., 2.4700+6,190., 2.4100+6,200., 2.3500+6,210., 2.2850+6,
,220., 2.2200+6,230., 2.1550+6,240., 2.0900+6,250., 2.0300+6,
,260., 1.9500+6,270., 1.8750+6,280., 1.8000+6,290., 1.7250+6,
,300., 1.6500+6,310., 1.6500+6, ENDT
$ v12
TABLEM1,  3,
, 60., 2.9000-1, 70., 2.9000-1, 80., 2.9000-1, 90., 2.9000-1,
,100., 2.9000-1,110., 2.9000-1,120., 2.9000-1,130., 2.9000-1,
,140., 2.9000-1,150., 2.9000-1,160., 2.9000-1,170., 2.9000-1,
,180., 2.9000-1,190., 2.9000-1,200., 2.9000-1,210., 2.9000-1,
,220., 2.9000-1,230., 2.9000-1,240., 2.9000-1,250., 2.9000-1,
,260., 2.9000-1,270., 2.9000-1,280., 2.9000-1,290., 2.9000-1,
,300., 2.9000-1,310., 2.9000-1, ENDT
$ G12
TABLEM1,  4,
, 60., 1.4000+6, 70., 1.4000+6, 80., 1.4000+6, 90., 1.3700+6,
,100., 1.3400+6,110., 1.3150+6,120., 1.2900+6,130., 1.2650+6,
,140., 1.2400+6,150., 1.2200+6,160., 1.2000+6,170., 1.1750+6,
,180., 1.1500+6,190., 1.1250+6,200., 1.1000+6,210., 1.0400+6,
,220., 9.8000+5,230., 9.2500+5,240., 8.7000+5,250., 8.1000+5,
,260., 7.5000+5,270., 6.8500+5,280., 6.2000+5,290., 5.6000+5,
,300., 5.0000+5,310., 5.0000+5, ENDT
$ strain1 (ref 75 F)
TABLEM1, -5,
, 60.,-4.2225-5, 70.,-1.4925-5, 75., 0.000000, 80., 1.5775-5,
, 90., 4.9725-5,100., 8.6775-5,110., 1.2575-4,120., 1.6547-4,
,130., 2.0527-4,140., 2.4447-4,150., 2.8282-4,160., 3.2012-4,
,170., 3.5652-4,180., 3.9212-4,190., 4.2720-4,200., 4.6202-4,
,210., 4.9692-4,220., 5.3222-4,230., 5.6825-4,240., 6.0532-4,
,250., 6.4347-4,260., 6.8277-4,270., 7.2300-4,280., 7.6387-4,
,290., 8.0537-4,300., 8.4747-4,310., 8.8987-4, ENDT
$ strain2 (ref 75 F)
TABLEM1, -6,
, 60.,-8.3738-5, 70.,-3.2088-5, 75., 0.000000, 80., 3.6263-5,
, 90., 1.2299-4,100., 2.2976-4,110., 3.5089-4,120., 4.8066-4,
,130., 6.1549-4,140., 7.5176-4,150., 8.8771-4,160., 1.0216-3,
,170., 1.1528-3,180., 1.2810-3,190., 1.4065-3,200., 1.5298-3,
,210., 1.6519-3,220., 1.7738-3,230., 1.8966-3,240., 2.0215-3,
,250., 2.1492-3,260., 2.2807-3,270., 2.4161-3,280., 2.5556-3,
,290., 2.6982-3,300., 2.8431-3,310., 2.9891-3, ENDT
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nitinast_secsec75.dat

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$ Nitinol Properties, units of in-lbf-sec-degrees F
MAT8, 2, 3.9400+6, 3.9400+6, 3.0000-1, 1.5154+6, 1.5154+6, 1.5154+6, 5.3490-4,
, 3.6700-6, 3.6700-6, 75.
MATT8, 2,  7,  8,  9, 10, 10, 10,
, 11, 12
$ E1
TABLEM1,  7,
, 60., 3.9400+6, 70., 3.9400+6, 80., 3.5967+6, 90., 3.2533+6,
,100., 2.9100+6,110., 3.7280+6,120., 4.5460+6,130., 5.3640+6,
,140., 6.1820+6,150., 7.0000+6,160., 7.9560+6,170., 8.9120+6,
,180., 9.3120+6,190., 9.1560+6,200., 9.0000+6,210., 9.2700+6,
,220., 9.5400+6,230., 9.8100+6,240., 1.0080+7,250., 1.0350+7,
,260., 1.0274+7,270., 1.0198+7,280., 1.0122+7,290., 1.0046+7,
,300., 9.9700+6,310., 9.9700+6, ENDT
$ E2
TABLEM1,  8,
, 60., 3.9400+6, 70., 3.9400+6, 80., 3.5967+6, 90., 3.2533+6,
,100., 2.9100+6,110., 3.7280+6,120., 4.5460+6,130., 5.3640+6,
,140., 6.1820+6,150., 7.0000+6,160., 7.9560+6,170., 8.9120+6,
,180., 9.3120+6,190., 9.1560+6,200., 9.0000+6,210., 9.2700+6,
,220., 9.5400+6,230., 9.8100+6,240., 1.0080+7,250., 1.0350+7,
,260., 1.0274+7,270., 1.0198+7,280., 1.0122+7,290., 1.0046+7,
,300., 9.9700+6,310., 9.9700+6, ENDT
$ v12
TABLEM1,  9,
, 60., 3.0000-1, 70., 3.0000-1, 80., 3.0000-1, 90., 3.0000-1,
,100., 3.0000-1,110., 3.0000-1,120., 3.0000-1,130., 3.0000-1,
,140., 3.0000-1,150., 3.0000-1,160., 3.0000-1,170., 3.0000-1,
,180., 3.0000-1,190., 3.0000-1,200., 3.0000-1,210., 3.0000-1,
,220., 3.0000-1,230., 3.0000-1,240., 3.0000-1,250., 3.0000-1,
,260., 3.0000-1,270., 3.0000-1,280., 3.0000-1,290., 3.0000-1,
,300., 3.0000-1,310., 3.0000-1, ENDT
$ G12
TABLEM1, 10,
, 60., 1.5154+6, 70., 1.5154+6, 80., 1.3833+6, 90., 1.2513+6,
,100., 1.1192+6,110., 1.4338+6,120., 1.7485+6,130., 2.0631+6,
,140., 2.3777+6,150., 2.6923+6,160., 3.0600+6,170., 3.4277+6,
,180., 3.5815+6,190., 3.5215+6,200., 3.4615+6,210., 3.5654+6,
,220., 3.6692+6,230., 3.7731+6,240., 3.8769+6,250., 3.9808+6,
,260., 3.9515+6,270., 3.9223+6,280., 3.8931+6,290., 3.8638+6,
,300., 3.8346+6,310., 3.8346+6, ENDT
$ a1, secant (ref 75 F)
TABLEM1, 11,
, 60., 3.6700-6, 70., 3.6700-6, 80.,-1.7163-5, 90.,-2.1504-5,
,100.,-2.8000-5,110.,-3.1697-5,120.,-5.5823-5,130.,-7.4697-5,
,140.,-7.8652-5,150.,-7.4427-5,160.,-6.6451-5,170.,-5.8474-5,
,180.,-5.5178-5,190.,-5.4990-5,200.,-5.3992-5,210.,-5.0707-5,
,220.,-4.6989-5,230.,-4.3763-5,240.,-4.0751-5,250.,-3.7864-5,

,260.,-3.6536-5,270.,-3.5138-5,280.,-3.3913-5,290.,-3.2723-5,
,300.,-3.1728-5,310.,-3.1728-5, ENDT
$ a2, secant (ref 75 F)
TABLEM1, 12,
, 60., 3.6700-6, 70., 3.6700-6, 80., 3.6700-6, 90., 3.6700-6,
,100., 3.6700-6,110., 3.6700-6,120., 3.7087-6,130., 3.7968-6,
,140., 3.9113-6,150., 4.0418-6,160., 4.1826-6,170., 4.3305-6,
,180., 4.4833-6,190., 4.6248-6,200., 4.7436-6,210., 4.8448-6,
,220., 4.9321-6,230., 5.0081-6,240., 5.0749-6,250., 5.1340-6,
,260., 5.1868-6,270., 5.2341-6,280., 5.2768-6,290., 5.3156-6,
,300., 5.3509-6,310., 5.3509-6, ENDT
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nitinast_stntan75.dat

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$ Nitinol Properties, units of in-lbf-sec-degrees F
MAT8, 2, 3.9400+6, 3.9400+6, 3.0000-1, 1.5154+6, 1.5154+6, 1.5154+6, 5.3490-4,
, 0.0000+0, 3.6700-6, 75.
MATT8, 2,  7,  8,  9, 10, 10, 10,
,-11, 12
$ E1
TABLEM1,  7,
, 60., 3.9400+6, 70., 3.9400+6, 80., 3.5967+6, 90., 3.2533+6,
,100., 2.9100+6,110., 3.7280+6,120., 4.5460+6,130., 5.3640+6,
,140., 6.1820+6,150., 7.0000+6,160., 7.9560+6,170., 8.9120+6,
,180., 9.3120+6,190., 9.1560+6,200., 9.0000+6,210., 9.2700+6,
,220., 9.5400+6,230., 9.8100+6,240., 1.0080+7,250., 1.0350+7,
,260., 1.0274+7,270., 1.0198+7,280., 1.0122+7,290., 1.0046+7,
,300., 9.9700+6,310., 9.9700+6, ENDT
$ E2
TABLEM1,  8,
, 60., 3.9400+6, 70., 3.9400+6, 80., 3.5967+6, 90., 3.2533+6,
,100., 2.9100+6,110., 3.7280+6,120., 4.5460+6,130., 5.3640+6,
,140., 6.1820+6,150., 7.0000+6,160., 7.9560+6,170., 8.9120+6,
,180., 9.3120+6,190., 9.1560+6,200., 9.0000+6,210., 9.2700+6,
,220., 9.5400+6,230., 9.8100+6,240., 1.0080+7,250., 1.0350+7,
,260., 1.0274+7,270., 1.0198+7,280., 1.0122+7,290., 1.0046+7,
,300., 9.9700+6,310., 9.9700+6, ENDT
$ v12
TABLEM1,  9,
, 60., 3.0000-1, 70., 3.0000-1, 80., 3.0000-1, 90., 3.0000-1,
,100., 3.0000-1,110., 3.0000-1,120., 3.0000-1,130., 3.0000-1,
,140., 3.0000-1,150., 3.0000-1,160., 3.0000-1,170., 3.0000-1,
,180., 3.0000-1,190., 3.0000-1,200., 3.0000-1,210., 3.0000-1,
,220., 3.0000-1,230., 3.0000-1,240., 3.0000-1,250., 3.0000-1,
,260., 3.0000-1,270., 3.0000-1,280., 3.0000-1,290., 3.0000-1,
,300., 3.0000-1,310., 3.0000-1, ENDT
$ G12
TABLEM1, 10,
, 60., 1.5154+6, 70., 1.5154+6, 80., 1.3833+6, 90., 1.2513+6,
,100., 1.1192+6,110., 1.4338+6,120., 1.7485+6,130., 2.0631+6,
,140., 2.3777+6,150., 2.6923+6,160., 3.0600+6,170., 3.4277+6,
,180., 3.5815+6,190., 3.5215+6,200., 3.4615+6,210., 3.5654+6,
,220., 3.6692+6,230., 3.7731+6,240., 3.8769+6,250., 3.9808+6,
,260., 3.9515+6,270., 3.9223+6,280., 3.8931+6,290., 3.8638+6,
,300., 3.8346+6,310., 3.8346+6, ENDT
$ strain1 (ref 75 F)
TABLEM1,-11,
, 60.,-5.5050-5, 70.,-1.8350-5, 75., 0.000000, 80.,-8.5813-5,
, 90.,-3.2256-4,100.,-7.0001-4,110.,-1.1094-3,120.,-2.5120-3,
,130.,-4.1083-3,140.,-5.1124-3,150.,-5.5820-3,160.,-5.6483-3,
,170.,-5.5550-3,180.,-5.7937-3,190.,-6.3239-3,200.,-6.7490-3,
,210.,-6.8454-3,220.,-6.8134-3,230.,-6.7832-3,240.,-6.7240-3,
,250.,-6.6261-3,260.,-6.7592-3,270.,-6.8520-3,280.,-6.9522-3,
,290.,-7.0355-3,300.,-7.1387-3,310.,-7.1387-3, ENDT
$ a2, tangent
TABLEM1, 12,
, 60., 3.6700-6, 70., 3.6700-6, 80., 3.6700-6, 90., 3.6700-6,
,100., 3.6700-6,110., 3.6700-6,120., 4.0186-6,130., 4.3671-6,
,140., 4.7157-6,150., 5.0643-6,160., 5.4129-6,170., 5.7614-6,
,180., 6.1100-6,190., 6.1100-6,200., 6.1100-6,210., 6.1100-6,
,220., 6.1100-6,230., 6.1100-6,240., 6.1100-6,250., 6.1100-6,
,260., 6.1100-6,270., 6.1100-6,280., 6.1100-6,290., 6.1100-6,
,300., 6.1100-6,310., 6.1100-6, ENDT
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$ Nitinol Properties, units of in-lbf-sec-degrees F
MAT8, 2, 3.9400+6, 3.9400+6, 3.0000-1, 1.5154+6, 1.5154+6, 1.5154+6, 5.3490-4,
, 0.0000+0, 3.6700-6, 75.
MATT8, 2,  7,  8,  9, 10, 10, 10,
,-11,-12
$ E1
TABLEM1,  7,
, 60., 3.9400+6, 70., 3.9400+6, 80., 3.5967+6, 90., 3.2533+6,
,100., 2.9100+6,110., 3.7280+6,120., 4.5460+6,130., 5.3640+6,
,140., 6.1820+6,150., 7.0000+6,160., 7.9560+6,170., 8.9120+6,
,180., 9.3120+6,190., 9.1560+6,200., 9.0000+6,210., 9.2700+6,
,220., 9.5400+6,230., 9.8100+6,240., 1.0080+7,250., 1.0350+7,
,260., 1.0274+7,270., 1.0198+7,280., 1.0122+7,290., 1.0046+7,
,300., 9.9700+6,310., 9.9700+6, ENDT
$ E2
TABLEM1,  8,
, 60., 3.9400+6, 70., 3.9400+6, 80., 3.5967+6, 90., 3.2533+6,
,100., 2.9100+6,110., 3.7280+6,120., 4.5460+6,130., 5.3640+6,
,140., 6.1820+6,150., 7.0000+6,160., 7.9560+6,170., 8.9120+6,
,180., 9.3120+6,190., 9.1560+6,200., 9.0000+6,210., 9.2700+6,
,220., 9.5400+6,230., 9.8100+6,240., 1.0080+7,250., 1.0350+7,
,260., 1.0274+7,270., 1.0198+7,280., 1.0122+7,290., 1.0046+7,
,300., 9.9700+6,310., 9.9700+6, ENDT
$ v12
TABLEM1,  9,
, 60., 3.0000-1, 70., 3.0000-1, 80., 3.0000-1, 90., 3.0000-1,
,100., 3.0000-1,110., 3.0000-1,120., 3.0000-1,130., 3.0000-1,
,140., 3.0000-1,150., 3.0000-1,160., 3.0000-1,170., 3.0000-1,
,180., 3.0000-1,190., 3.0000-1,200., 3.0000-1,210., 3.0000-1,
,220., 3.0000-1,230., 3.0000-1,240., 3.0000-1,250., 3.0000-1,
,260., 3.0000-1,270., 3.0000-1,280., 3.0000-1,290., 3.0000-1,
,300., 3.0000-1,310., 3.0000-1, ENDT
$ G12
TABLEM1, 10,
, 60., 1.5154+6, 70., 1.5154+6, 80., 1.3833+6, 90., 1.2513+6,
,100., 1.1192+6,110., 1.4338+6,120., 1.7485+6,130., 2.0631+6,
,140., 2.3777+6,150., 2.6923+6,160., 3.0600+6,170., 3.4277+6,
,180., 3.5815+6,190., 3.5215+6,200., 3.4615+6,210., 3.5654+6,
,220., 3.6692+6,230., 3.7731+6,240., 3.8769+6,250., 3.9808+6,
,260., 3.9515+6,270., 3.9223+6,280., 3.8931+6,290., 3.8638+6,
,300., 3.8346+6,310., 3.8346+6, ENDT
$ strain1 (ref 75 F)
TABLEM1,-11,
, 60.,-5.5050-5, 70.,-1.8350-5, 75., 0.000000, 80.,-8.5813-5,
, 90.,-3.2256-4,100.,-7.0001-4,110.,-1.1094-3,120.,-2.5120-3,
,130.,-4.1083-3,140.,-5.1124-3,150.,-5.5820-3,160.,-5.6483-3,
,170.,-5.5550-3,180.,-5.7937-3,190.,-6.3239-3,200.,-6.7490-3,
,210.,-6.8454-3,220.,-6.8134-3,230.,-6.7832-3,240.,-6.7240-3,
,250.,-6.6261-3,260.,-6.7592-3,270.,-6.8520-3,280.,-6.9522-3,
,290.,-7.0355-3,300.,-7.1387-3,310.,-7.1387-3, ENDT
$ strain2 (ref 75 F)
TABLEM1,-12,
, 60.,-5.5050-5, 70.,-1.8350-5, 75., 0.000000, 80., 1.8350-5,
, 90., 5.5050-5,100., 9.1750-5,110., 1.2845-4,120., 1.6689-4,
,130., 2.0882-4,140., 2.5424-4,150., 3.0314-4,160., 3.5552-4,
,170., 4.1139-4,180., 4.7075-4,190., 5.3185-4,200., 5.9295-4,
,210., 6.5405-4,220., 7.1515-4,230., 7.7625-4,240., 8.3735-4,
,250., 8.9845-4,260., 9.5955-4,270., 1.0207-3,280., 1.0818-3,
,290., 1.1428-3,300., 1.2039-3,310., 1.2650-3, ENDT
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smahcmix0nast_secsec75.dat

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$ SMAHC Mixture (0 degree layers) Properties, units of in-lbf-sec-degrees F
MAT8, 2, 5.3722+6, 3.3966+6, 2.9554-1, 1.4616+6, 1.4616+6, 1.4616+6, 3.8102-4,
, 3.2294-6, 4.7716-6, 75.
MATT8, 2,  7,  8,  9, 10, 10, 10,
, 11, 12
$ E1
TABLEM1,  7,
, 60., 5.3722+6, 70., 5.3722+6, 80., 5.1820+6, 90., 4.9874+6,
,100., 4.7928+6,110., 5.2414+6,120., 5.6899+6,130., 6.1363+6,
,140., 6.5826+6,150., 7.0312+6,160., 7.5607+6,170., 8.0880+6,
,180., 8.3073+6,190., 8.2186+6,200., 8.1300+6,210., 8.2795+6,
,220., 8.4291+6,230., 8.5764+6,240., 8.7237+6,250., 8.8732+6,
,260., 8.8356+6,270., 8.7957+6,280., 8.7559+6,290., 8.7182+6,
,300., 8.6806+6,310., 8.6806+6, ENDT
$ E2
TABLEM1,  8,
, 60., 3.3966+6, 70., 3.3966+6, 80., 3.2485+6, 90., 3.0653+6,
,100., 2.8691+6,110., 3.2387+6,120., 3.5203+6,130., 3.7372+6,
,140., 3.9053+6,150., 4.0303+6,160., 4.1230+6,170., 4.1869+6,
,180., 4.1648+6,190., 4.0714+6,200., 3.9779+6,210., 3.9216+6,
,220., 3.8606+6,230., 3.7952+6,240., 3.7256+6,250., 3.6591+6,
,260., 3.5373+6,270., 3.4216+6,280., 3.3049+6,290., 3.1870+6,
,300., 3.0680+6,310., 3.0680+6, ENDT
$ v12
TABLEM1,  9,
, 60., 2.9554-1, 70., 2.9554-1, 80., 2.9554-1, 90., 2.9554-1,
,100., 2.9554-1,110., 2.9554-1,120., 2.9554-1,130., 2.9554-1,
,140., 2.9554-1,150., 2.9554-1,160., 2.9554-1,170., 2.9554-1,
,180., 2.9554-1,190., 2.9554-1,200., 2.9554-1,210., 2.9554-1,
,220., 2.9554-1,230., 2.9554-1,240., 2.9554-1,250., 2.9554-1,
,260., 2.9554-1,270., 2.9554-1,280., 2.9554-1,290., 2.9554-1,
,300., 2.9554-1,310., 2.9554-1, ENDT
$ G12
TABLEM1, 10,
, 60., 1.4616+6, 70., 1.4616+6, 80., 1.3907+6, 90., 1.3016+6,
,100., 1.2080+6,110., 1.3783+6,120., 1.5092+6,130., 1.6099+6,
,140., 1.6871+6,150., 1.7500+6,160., 1.8090+6,170., 1.8475+6,
,180., 1.8430+6,190., 1.8055+6,200., 1.7681+6,210., 1.7114+6,
,220., 1.6496+6,230., 1.5895+6,240., 1.5251+6,250., 1.4494+6,
,260., 1.3605+6,270., 1.2618+6,280., 1.1603+6,290., 1.0638+6,
,300., 9.6456+5,310., 9.6456+5, ENDT
$ a1, secant (ref 75 F)
TABLEM1, 11,
, 60., 3.2294-6, 70., 3.2632-6, 80.,-4.6553-6, 90.,-5.6528-6,
,100.,-7.1121-6,110.,-1.0320-5,120.,-2.2652-5,130.,-3.4245-5,
,140.,-3.9105-5,150.,-3.9346-5,160.,-3.7157-5,170.,-3.4223-5,
,180.,-3.2840-5,190.,-3.2507-5,200.,-3.1673-5,210.,-3.0044-5,
,220.,-2.8085-5,230.,-2.6379-5,240.,-2.4758-5,250.,-2.3159-5,
,260.,-2.2216-5,270.,-2.1237-5,280.,-2.0373-5,290.,-1.9528-5,
,300.,-1.8812-5,310.,-1.8812-5, ENDT
$ a2, secant (ref 75 F)
TABLEM1, 12,
, 60., 4.7716-6, 70., 4.8956-6, 80., 5.2686-6, 90., 5.7007-6,
,100., 6.1328-6,110., 6.4652-6,120., 6.8190-6,130., 7.0663-6,
,140., 7.3283-6,150., 7.5210-6,160., 7.6793-6,170., 7.8013-6,
,180., 7.9262-6,190., 8.0134-6,200., 8.0881-6,210., 8.1420-6,
,220., 8.1881-6,230., 8.2346-6,240., 8.2761-6,250., 8.3222-6,
,260., 8.3737-6,270., 8.4312-6,280., 8.4861-6,290., 8.5455-6,
,300., 8.6030-6,310., 8.6030-6, ENDT
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smahcmix0nast_stntan75.dat

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$ SMAHC Mixture (0 degree layers) Properties, units of in-lbf-sec-degrees F
MAT8, 2, 5.3722+6, 3.3966+6, 2.9554-1, 1.4616+6, 1.4616+6, 1.4616+6, 3.8102-4,
, 1.7220-6, 4.7095-6, 75.
MATT8, 2,  7,  8,  9, 10, 10, 10,
,-11, 12
$ E1
TABLEM1,  7,
, 60., 5.3722+6, 70., 5.3722+6, 80., 5.1820+6, 90., 4.9874+6,
,100., 4.7928+6,110., 5.2414+6,120., 5.6899+6,130., 6.1363+6,
,140., 6.5826+6,150., 7.0312+6,160., 7.5607+6,170., 8.0880+6,
,180., 8.3073+6,190., 8.2186+6,200., 8.1300+6,210., 8.2795+6,
,220., 8.4291+6,230., 8.5764+6,240., 8.7237+6,250., 8.8732+6,
,260., 8.8356+6,270., 8.7957+6,280., 8.7559+6,290., 8.7182+6,
,300., 8.6806+6,310., 8.6806+6, ENDT
$ E2
TABLEM1,  8,
, 60., 3.3966+6, 70., 3.3966+6, 80., 3.2485+6, 90., 3.0653+6,
,100., 2.8691+6,110., 3.2387+6,120., 3.5203+6,130., 3.7372+6,
,140., 3.9053+6,150., 4.0303+6,160., 4.1230+6,170., 4.1869+6,
,180., 4.1648+6,190., 4.0714+6,200., 3.9779+6,210., 3.9216+6,
,220., 3.8606+6,230., 3.7952+6,240., 3.7256+6,250., 3.6591+6,
,260., 3.5373+6,270., 3.4216+6,280., 3.3049+6,290., 3.1870+6,
,300., 3.0680+6,310., 3.0680+6, ENDT
$ v12
TABLEM1,  9,
, 60., 2.9554-1, 70., 2.9554-1, 80., 2.9554-1, 90., 2.9554-1,
,100., 2.9554-1,110., 2.9554-1,120., 2.9554-1,130., 2.9554-1,
,140., 2.9554-1,150., 2.9554-1,160., 2.9554-1,170., 2.9554-1,
,180., 2.9554-1,190., 2.9554-1,200., 2.9554-1,210., 2.9554-1,
,220., 2.9554-1,230., 2.9554-1,240., 2.9554-1,250., 2.9554-1,
,260., 2.9554-1,270., 2.9554-1,280., 2.9554-1,290., 2.9554-1,
,300., 2.9554-1,310., 2.9554-1, ENDT
$ G12
TABLEM1, 10,
, 60., 1.4616+6, 70., 1.4616+6, 80., 1.3907+6, 90., 1.3016+6,
,100., 1.2080+6,110., 1.3783+6,120., 1.5092+6,130., 1.6099+6,
,140., 1.6871+6,150., 1.7500+6,160., 1.8090+6,170., 1.8475+6,
,180., 1.8430+6,190., 1.8055+6,200., 1.7681+6,210., 1.7114+6,
,220., 1.6496+6,230., 1.5895+6,240., 1.5251+6,250., 1.4494+6,
,260., 1.3605+6,270., 1.2618+6,280., 1.1603+6,290., 1.0638+6,
,300., 9.6456+5,310., 9.6456+5, ENDT
$ strain1, (ref 75 F)
TABLEM1,-11,
, 60.,-4.7434-5, 70.,-1.6316-5, 75., 0.000000, 80.,-2.3276-5,
, 90.,-8.4773-5,100.,-1.7780-4,110.,-3.6081-4,120.,-1.0193-3,
,130.,-1.8831-3,140.,-2.5418-3,150.,-2.9510-3,160.,-3.1583-3,
,170.,-3.2511-3,180.,-3.4482-3,190.,-3.7383-3,200.,-3.9591-3,
,210.,-4.0561-3,220.,-4.0723-3,230.,-4.0890-3,240.,-4.0851-3,
,250.,-4.0528-3,260.,-4.1100-3,270.,-4.1412-3,280.,-4.1764-3,
,290.,-4.1987-3,300.,-4.2326-3,310.,-4.2172-3, ENDT
$ a2, tangent
TABLEM1, 12,
, 60., 4.7095-6, 70., 4.7095-6, 80., 5.4546-6, 90., 6.3492-6,
,100., 7.2437-6,110., 7.6296-6,120., 8.2086-6,130., 8.4663-6,
,140., 8.7241-6,150., 8.8235-6,160., 8.9228-6,170., 8.9776-6,
,180., 9.0323-6,190., 8.9342-6,200., 8.8360-6,210., 8.8271-6,
,220., 8.8182-6,230., 8.9096-6,240., 9.0011-6,250., 9.1662-6,
,260., 9.3357-6,270., 9.5164-6,280., 9.6971-6,290., 9.7975-6,
,300., 9.8978-6,310., 9.8978-6, ENDT
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smahcmix0nast_stnstn75.dat

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$ SMAHC Mixture (0 degree layers) Properties, units of in-lbf-sec-degrees F
MAT8, 2, 5.3722+6, 3.3966+6, 2.9554-1, 1.4616+6, 1.4616+6, 1.4616+6, 3.8102-4,
, 1.7220-6, 4.7095-6, 75.
MATT8, 2,  7,  8,  9, 10, 10, 10,
,-11,-12
$ E1
TABLEM1,  7,
, 60., 5.3722+6, 70., 5.3722+6, 80., 5.1820+6, 90., 4.9874+6,
,100., 4.7928+6,110., 5.2414+6,120., 5.6899+6,130., 6.1363+6,
,140., 6.5826+6,150., 7.0312+6,160., 7.5607+6,170., 8.0880+6,
,180., 8.3073+6,190., 8.2186+6,200., 8.1300+6,210., 8.2795+6,
,220., 8.4291+6,230., 8.5764+6,240., 8.7237+6,250., 8.8732+6,
,260., 8.8356+6,270., 8.7957+6,280., 8.7559+6,290., 8.7182+6,
,300., 8.6806+6,310., 8.6806+6, ENDT
$ E2
TABLEM1,  8,
, 60., 3.3966+6, 70., 3.3966+6, 80., 3.2485+6, 90., 3.0653+6,
,100., 2.8691+6,110., 3.2387+6,120., 3.5203+6,130., 3.7372+6,
,140., 3.9053+6,150., 4.0303+6,160., 4.1230+6,170., 4.1869+6,
,180., 4.1648+6,190., 4.0714+6,200., 3.9779+6,210., 3.9216+6,
,220., 3.8606+6,230., 3.7952+6,240., 3.7256+6,250., 3.6591+6,
,260., 3.5373+6,270., 3.4216+6,280., 3.3049+6,290., 3.1870+6,
,300., 3.0680+6,310., 3.0680+6, ENDT
$ v12
TABLEM1,  9,
, 60., 2.9554-1, 70., 2.9554-1, 80., 2.9554-1, 90., 2.9554-1,
,100., 2.9554-1,110., 2.9554-1,120., 2.9554-1,130., 2.9554-1,
,140., 2.9554-1,150., 2.9554-1,160., 2.9554-1,170., 2.9554-1,
,180., 2.9554-1,190., 2.9554-1,200., 2.9554-1,210., 2.9554-1,
,220., 2.9554-1,230., 2.9554-1,240., 2.9554-1,250., 2.9554-1,
,260., 2.9554-1,270., 2.9554-1,280., 2.9554-1,290., 2.9554-1,
,300., 2.9554-1,310., 2.9554-1, ENDT
$ G12
TABLEM1, 10,
, 60., 1.4616+6, 70., 1.4616+6, 80., 1.3907+6, 90., 1.3016+6,
,100., 1.2080+6,110., 1.3783+6,120., 1.5092+6,130., 1.6099+6,
,140., 1.6871+6,150., 1.7500+6,160., 1.8090+6,170., 1.8475+6,
,180., 1.8430+6,190., 1.8055+6,200., 1.7681+6,210., 1.7114+6,
,220., 1.6496+6,230., 1.5895+6,240., 1.5251+6,250., 1.4494+6,
,260., 1.3605+6,270., 1.2618+6,280., 1.1603+6,290., 1.0638+6,
,300., 9.6456+5,310., 9.6456+5, ENDT
$ strain1 (ref 75 F)
TABLEM1,-11,
, 60.,-4.7434-5, 70.,-1.6316-5, 75., 0.000000, 80.,-2.3276-5,
, 90.,-8.4773-5,100.,-1.7780-4,110.,-3.6081-4,120.,-1.0193-3,
,130.,-1.8831-3,140.,-2.5418-3,150.,-2.9510-3,160.,-3.1583-3,
,170.,-3.2511-3,180.,-3.4482-3,190.,-3.7383-3,200.,-3.9591-3,
,210.,-4.0561-3,220.,-4.0723-3,230.,-4.0890-3,240.,-4.0851-3,
,250.,-4.0528-3,260.,-4.1100-3,270.,-4.1412-3,280.,-4.1764-3,
,290.,-4.1987-3,300.,-4.2326-3,310.,-4.2172-3, ENDT
$ strain2 (ref 75 F)
TABLEM1,-12,
, 60.,-6.7849-5, 70.,-2.4479-5, 75., 0.000000, 80., 2.6342-5,
, 90., 8.5361-5,100., 1.5332-4,110., 2.2769-4,120., 3.0688-4,
,130., 3.9026-4,140., 4.7621-4,150., 5.6395-4,160., 6.5268-4,
,170., 7.4218-4,180., 8.3223-4,190., 9.2206-4,200., 1.0109-3,
,210., 1.0992-3,220., 1.1875-3,230., 1.2761-3,240., 1.3656-3,
,250., 1.4565-3,260., 1.5490-3,270., 1.6433-3,280., 1.7393-3,
,290., 1.8368-3,300., 1.9353-3,310., 2.0342-3, ENDT
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Appendix F
ABAQUS Material Property "Include" Files

glepabaq_secsec75.dat

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*MATERIAL, NAME=GLEP
*DENSITY
 1.9000E-04,
*ELASTIC, TYPE=LAMINA
 7.1500E+06,  2.9000E+06, .290,  1.4000E+06,  1.4000E+06,  1.4000E+06,  60.
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 7.1500E+06,  2.9000E+06, .290,  1.4000E+06,  1.4000E+06,  1.4000E+06,  80.
 7.1400E+06,  2.8600E+06, .290,  1.3700E+06,  1.3700E+06,  1.3700E+06,  90.
 7.1300E+06,  2.8200E+06, .290,  1.3400E+06,  1.3400E+06,  1.3400E+06, 100.
 7.1200E+06,  2.7850E+06, .290,  1.3150E+06,  1.3150E+06,  1.3150E+06, 110.
 7.1100E+06,  2.7500E+06, .290,  1.2900E+06,  1.2900E+06,  1.2900E+06, 120.
 7.0950E+06,  2.7150E+06, .290,  1.2650E+06,  1.2650E+06,  1.2650E+06, 130.
 7.0800E+06,  2.6800E+06, .290,  1.2400E+06,  1.2400E+06,  1.2400E+06, 140.
 7.0700E+06,  2.6400E+06, .290,  1.2200E+06,  1.2200E+06,  1.2200E+06, 150.
 7.0700E+06,  2.5800E+06, .290,  1.2000E+06,  1.2000E+06,  1.2000E+06, 160.
 7.0650E+06,  2.5250E+06, .290,  1.1750E+06,  1.1750E+06,  1.1750E+06, 170.
 7.0600E+06,  2.4700E+06, .290,  1.1500E+06,  1.1500E+06,  1.1500E+06, 180.
 7.0550E+06,  2.4100E+06, .290,  1.1250E+06,  1.1250E+06,  1.1250E+06, 190.
 7.0500E+06,  2.3500E+06, .290,  1.1000E+06,  1.1000E+06,  1.1000E+06, 200.
 7.0500E+06,  2.2850E+06, .290,  1.0400E+06,  1.0400E+06,  1.0400E+06, 210.
 7.0500E+06,  2.2200E+06, .290,  9.8000E+05,  9.8000E+05,  9.8000E+05, 220.
 7.0450E+06,  2.1550E+06, .290,  9.2500E+05,  9.2500E+05,  9.2500E+05, 230.
 7.0400E+06,  2.0900E+06, .290,  8.7000E+05,  8.7000E+05,  8.7000E+05, 240.
 7.0400E+06,  2.0300E+06, .290,  8.1000E+05,  8.1000E+05,  8.1000E+05, 250.
 7.0500E+06,  1.9500E+06, .290,  7.5000E+05,  7.5000E+05,  7.5000E+05, 260.
 7.0550E+06,  1.8750E+06, .290,  6.8500E+05,  6.8500E+05,  6.8500E+05, 270.
 7.0600E+06,  1.8000E+06, .290,  6.2000E+05,  6.2000E+05,  6.2000E+05, 280.
 7.0700E+06,  1.7250E+06, .290,  5.6000E+05,  5.6000E+05,  5.6000E+05, 290.
 7.0800E+06,  1.6500E+06, .290,  5.0000E+05,  5.0000E+05,  5.0000E+05, 300.
 7.0800E+06,  1.6500E+06, .290,  5.0000E+05,  5.0000E+05,  5.0000E+05, 310.
*EXPANSION, TYPE=ORTHO, ZERO= 75.0
 2.9280E-06,  6.1390E-06, ,  60.
 2.9850E-06,  6.4170E-06, ,  70.
 3.1550E-06,  7.2530E-06, ,  80.
 3.3130E-06,  8.2215E-06, ,  90.
 3.4710E-06,  9.1900E-06, , 100.
 3.5740E-06,  9.9350E-06, , 110.
 3.6770E-06,  1.0680E-05, , 120.
 3.7190E-06,  1.1125E-05, , 130.
 3.7610E-06,  1.1570E-05, , 140.
 3.7710E-06,  1.1840E-05, , 150.
 3.7660E-06,  1.2020E-05, , 160.
 3.7505E-06,  1.2110E-05, , 170.
 3.7350E-06,  1.2200E-05, , 180.
 3.7155E-06,  1.2220E-05, , 190.
 3.6960E-06,  1.2240E-05, , 200.
 3.6835E-06,  1.2235E-05, , 210.
 3.6710E-06,  1.2230E-05, , 220.
 3.6700E-06,  1.2240E-05, , 230.
 3.6690E-06,  1.2250E-05, , 240.
 3.6770E-06,  1.2280E-05, , 250.
 3.6910E-06,  1.2330E-05, , 260.
 3.7085E-06,  1.2400E-05, , 270.
 3.7260E-06,  1.2470E-05, , 280.
 3.7465E-06,  1.2555E-05, , 290.
 3.7670E-06,  1.2640E-05, , 300.
 3.7670E-06,  1.2640E-05, , 310.
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nitiabaq_secsec75.dat

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*MATERIAL, NAME=NITI
*DENSITY
 5.3490E-04,
*ELASTIC, TYPE=LAMINA
 3.9400E+06,  3.9400E+06, .300,  1.5154E+06,  1.5154E+06,  1.5154E+06,  60.
 3.9400E+06,  3.9400E+06, .300,  1.5154E+06,  1.5154E+06,  1.5154E+06,  70.
 3.5967E+06,  3.5967E+06, .300,  1.3833E+06,  1.3833E+06,  1.3833E+06,  80.
 3.2533E+06,  3.2533E+06, .300,  1.2513E+06,  1.2513E+06,  1.2513E+06,  90.
 2.9100E+06,  2.9100E+06, .300,  1.1192E+06,  1.1192E+06,  1.1192E+06, 100.
 3.7280E+06,  3.7280E+06, .300,  1.4338E+06,  1.4338E+06,  1.4338E+06, 110.
 4.5460E+06,  4.5460E+06, .300,  1.7485E+06,  1.7485E+06,  1.7485E+06, 120.
 5.3640E+06,  5.3640E+06, .300,  2.0631E+06,  2.0631E+06,  2.0631E+06, 130.
 6.1820E+06,  6.1820E+06, .300,  2.3777E+06,  2.3777E+06,  2.3777E+06, 140.
 7.0000E+06,  7.0000E+06, .300,  2.6923E+06,  2.6923E+06,  2.6923E+06, 150.
 7.9560E+06,  7.9560E+06, .300,  3.0600E+06,  3.0600E+06,  3.0600E+06, 160.
 8.9120E+06,  8.9120E+06, .300,  3.4277E+06,  3.4277E+06,  3.4277E+06, 170.
 9.3120E+06,  9.3120E+06, .300,  3.5815E+06,  3.5815E+06,  3.5815E+06, 180.
 9.1560E+06,  9.1560E+06, .300,  3.5215E+06,  3.5215E+06,  3.5215E+06, 190.
 9.0000E+06,  9.0000E+06, .300,  3.4615E+06,  3.4615E+06,  3.4615E+06, 200.
 9.2700E+06,  9.2700E+06, .300,  3.5654E+06,  3.5654E+06,  3.5654E+06, 210.
 9.5400E+06,  9.5400E+06, .300,  3.6692E+06,  3.6692E+06,  3.6692E+06, 220.
 9.8100E+06,  9.8100E+06, .300,  3.7731E+06,  3.7731E+06,  3.7731E+06, 230.
 1.0080E+07,  1.0080E+07, .300,  3.8769E+06,  3.8769E+06,  3.8769E+06, 240.
 1.0350E+07,  1.0350E+07, .300,  3.9808E+06,  3.9808E+06,  3.9808E+06, 250.
 1.0274E+07,  1.0274E+07, .300,  3.9515E+06,  3.9515E+06,  3.9515E+06, 260.
 1.0198E+07,  1.0198E+07, .300,  3.9223E+06,  3.9223E+06,  3.9223E+06, 270.
 1.0122E+07,  1.0122E+07, .300,  3.8931E+06,  3.8931E+06,  3.8931E+06, 280.
 1.0046E+07,  1.0046E+07, .300,  3.8638E+06,  3.8638E+06,  3.8638E+06, 290.
 9.9700E+06,  9.9700E+06, .300,  3.8346E+06,  3.8346E+06,  3.8346E+06, 300.
 9.9700E+06,  9.9700E+06, .300,  3.8346E+06,  3.8346E+06,  3.8346E+06, 310.
*EXPANSION, TYPE=ORTHO, ZERO= 75.0
 3.6700E-06,  3.6700E-06, ,  60.
 3.6700E-06,  3.6700E-06, ,  70.
-1.7163E-05,  3.6700E-06, ,  80.
-2.1504E-05,  3.6700E-06, ,  90.
-2.8000E-05,  3.6700E-06, , 100.
-3.1697E-05,  3.6700E-06, , 110.
-5.5823E-05,  3.7087E-06, , 120.
-7.4697E-05,  3.7968E-06, , 130.
-7.8652E-05,  3.9113E-06, , 140.
-7.4427E-05,  4.0418E-06, , 150.
-6.6451E-05,  4.1826E-06, , 160.
-5.8474E-05,  4.3305E-06, , 170.
-5.5178E-05,  4.4833E-06, , 180.
-5.4990E-05,  4.6248E-06, , 190.
-5.3992E-05,  4.7436E-06, , 200.
-5.0707E-05,  4.8448E-06, , 210.
-4.6989E-05,  4.9321E-06, , 220.
-4.3763E-05,  5.0081E-06, , 230.
-4.0751E-05,  5.0749E-06, , 240.
-3.7864E-05,  5.1340E-06, , 250.
-3.6536E-05,  5.1868E-06, , 260.
-3.5138E-05,  5.2341E-06, , 270.
-3.3913E-05,  5.2768E-06, , 280.
-3.2723E-05,  5.3156E-06, , 290.
-3.1728E-05,  5.3509E-06, , 300.
-3.1728E-05,  5.3509E-06, , 310.
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smahcmix0abaq_secsec75.dat

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*MATERIAL, NAME=SMAHCMIX0
*DENSITY
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*ELASTIC, TYPE=LAMINA
 5.3722E+06,  3.3966E+06, .296,  1.4616E+06,  1.4616E+06,  1.4616E+06,  60.
 5.3722E+06,  3.3966E+06, .296,  1.4616E+06,  1.4616E+06,  1.4616E+06,  70.
 5.1820E+06,  3.2485E+06, .296,  1.3907E+06,  1.3907E+06,  1.3907E+06,  80.
 4.9874E+06,  3.0653E+06, .296,  1.3016E+06,  1.3016E+06,  1.3016E+06,  90.
 4.7928E+06,  2.8691E+06, .296,  1.2080E+06,  1.2080E+06,  1.2080E+06, 100.
 5.2414E+06,  3.2387E+06, .296,  1.3783E+06,  1.3783E+06,  1.3783E+06, 110.
 5.6899E+06,  3.5203E+06, .296,  1.5092E+06,  1.5092E+06,  1.5092E+06, 120.
 6.1363E+06,  3.7372E+06, .296,  1.6099E+06,  1.6099E+06,  1.6099E+06, 130.
 6.5826E+06,  3.9053E+06, .296,  1.6871E+06,  1.6871E+06,  1.6871E+06, 140.
 7.0312E+06,  4.0303E+06, .296,  1.7500E+06,  1.7500E+06,  1.7500E+06, 150.
 7.5607E+06,  4.1230E+06, .296,  1.8090E+06,  1.8090E+06,  1.8090E+06, 160.
 8.0880E+06,  4.1869E+06, .296,  1.8475E+06,  1.8475E+06,  1.8475E+06, 170.
 8.3073E+06,  4.1648E+06, .296,  1.8430E+06,  1.8430E+06,  1.8430E+06, 180.
 8.2186E+06,  4.0714E+06, .296,  1.8055E+06,  1.8055E+06,  1.8055E+06, 190.
 8.1300E+06,  3.9779E+06, .296,  1.7681E+06,  1.7681E+06,  1.7681E+06, 200.
 8.2795E+06,  3.9216E+06, .296,  1.7114E+06,  1.7114E+06,  1.7114E+06, 210.
 8.4291E+06,  3.8606E+06, .296,  1.6496E+06,  1.6496E+06,  1.6496E+06, 220.
 8.5764E+06,  3.7952E+06, .296,  1.5895E+06,  1.5895E+06,  1.5895E+06, 230.
 8.7237E+06,  3.7256E+06, .296,  1.5251E+06,  1.5251E+06,  1.5251E+06, 240.
 8.8732E+06,  3.6591E+06, .296,  1.4494E+06,  1.4494E+06,  1.4494E+06, 250.
 8.8356E+06,  3.5373E+06, .296,  1.3605E+06,  1.3605E+06,  1.3605E+06, 260.
 8.7957E+06,  3.4216E+06, .296,  1.2618E+06,  1.2618E+06,  1.2618E+06, 270.
 8.7559E+06,  3.3049E+06, .296,  1.1603E+06,  1.1603E+06,  1.1603E+06, 280.
 8.7182E+06,  3.1870E+06, .296,  1.0638E+06,  1.0638E+06,  1.0638E+06, 290.
 8.6806E+06,  3.0680E+06, .296,  9.6456E+05,  9.6456E+05,  9.6456E+05, 300.
 8.6806E+06,  3.0680E+06, .296,  9.6456E+05,  9.6456E+05,  9.6456E+05, 310.
*EXPANSION, TYPE=ORTHO, ZERO= 75.0
 3.2294E-06,  4.7716E-06, ,  60.
 3.2632E-06,  4.8956E-06, ,  70.
-4.6553E-06,  5.2686E-06, ,  80.
-5.6528E-06,  5.7007E-06, ,  90.
-7.1121E-06,  6.1328E-06, , 100.
-1.0320E-05,  6.4652E-06, , 110.
-2.2652E-05,  6.8190E-06, , 120.
-3.4245E-05,  7.0663E-06, , 130.
-3.9105E-05,  7.3283E-06, , 140.
-3.9346E-05,  7.5210E-06, , 150.
-3.7157E-05,  7.6793E-06, , 160.
-3.4223E-05,  7.8013E-06, , 170.
-3.2840E-05,  7.9262E-06, , 180.
-3.2507E-05,  8.0134E-06, , 190.
-3.1673E-05,  8.0881E-06, , 200.
-3.0044E-05,  8.1420E-06, , 210.
-2.8085E-05,  8.1881E-06, , 220.
-2.6379E-05,  8.2346E-06, , 230.
-2.4758E-05,  8.2761E-06, , 240.
-2.3159E-05,  8.3222E-06, , 250.
-2.2216E-05,  8.3737E-06, , 260.
-2.1237E-05,  8.4312E-06, , 270.
-2.0373E-05,  8.4861E-06, , 280.
-1.9528E-05,  8.5455E-06, , 290.
-1.8812E-05,  8.6030E-06, , 300.
-1.8812E-05,  8.6030E-06, , 310.
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14. ABSTRACT
A thermoelastic constitutive model for shape memory alloys (SMAs) and SMA hybrid composites (SMAHCs) was recently implemented in the commercial codes MSC.Nastran and ABAQUS. The model is implemented and supported within the core of the commercial codes, so no user subroutines or external calculations are necessary. The model and resulting structural analysis has been previously demonstrated and experimentally verified for thermoelastic, vibration and acoustic, and structural shape control applications. The commercial implementations are described in related documents cited in the references, where various results are also shown that validate the commercial implementations relative to a research code. This paper is a companion to those documents in that it provides additional detail on the actual input files and solution procedures and serves as a repository for ASCII text versions of the input files necessary for duplication of the available results.

15. SUBJECT TERMS
ABAQUS; MSC.Nastran; SMA hybrid composites; Deflection control; Finite element analysis; Post-buckling control; Shape control; Shape memory alloys; Vibration control

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