

NASTRAN THERMAL ANALYZER
STATUS, EXPERIENCE, AND NEW DEVELOPMENTS

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SUMMARY

The unique finite-element-based NASTRAN Thermal Analyzer originally developed at Goddard Space Flight Center is a general-purpose heat-transfer analysis capability that has been incorporated into the NASTRAN system in its standard version of Level 15.5. The current status, experiences from field applications, and new developments are reported herein.

INTRODUCTION

The unique finite-element-based NASTRAN Thermal Analyzer (NTA) is a general-purpose heat-transfer analysis capability that has been integrated into the NASTRAN system since its Level 15.5 version. It is a computer program fully capable of treating problems including conduction with convective boundary conditions and radiative exchanges in both steady-state and transient cases. NTA (refs. 1 to 3) was originated and developed at the Goddard Space Flight Center (GSFC) as one of the software products of a research program titled STOP (the Structural Thermal Optical Program). STOP was designed to advance capabilities in the interdisciplinary areas of heat transfer and structural analysis. Its main objectives were to provide greater solution accuracy for combined thermal and structural analyses and to eliminate any interpolations in intermodel transfer of temperature data. It was accomplished by adopting the unified finite-element approach for both the thermal and structural analyses; it thus eliminated the need to form separate analytical models with the concomitant requirement for intermodel data transfer. Such a unified approach is especially effective in applications involving space telescopes and antennas where small thermally induced deflections can cause significant degradations in performance. When NASTRAN is relied

upon for structural analysis, including thermal loadings, the reliability of the structural solution depends largely on the accuracy of the temperature data input. Therefore, the use of the \bar{N} TA ensures a total structural-thermal model compatibility and avoids the tedious and time-consuming process of interpolation and extrapolation if temperature data were otherwise obtained by a heat-transfer computer program which is based on the lumped nodal method.

The development of the \bar{N} TA was reported to the Second NASTRAN Users Colloquium (ref. 4) three years ago when this software was implemented and its IBM version was first installed at GSFC (ref. Effort has since been spent in the verification of the delivered program, debugging and maintaining, application, and new developments. Since the \bar{N} TA was integrated into the NASTRAN system in its Level 15.5 version which was made available for general use through the NASA software dissemination apparatus, COSMIC, in June 1973, frequent inquiries have reached us from various sectors. Other government agencies, private industries, and universities have requested details concerning the use of this program, modelling techniques, thermal analysis in tandem with structural analysis, accuracy and efficiency considerations, etc. This paper is a partial response to requests such as these and is designed to report the current status of the \bar{N} TA, our experience with this computer program, and new capabilities that have been developed.

STATUS

In NASTRAN Level 15.5, the \bar{N} TA is a general-purpose heat-transfer computer program as opposed to the simple temperature analysis capability in Level 15.0 which was restricted to linear conduction problems only. This version of the \bar{N} TA contains corrections for coding errors which were detected by GSFC in post-delivery verification runs. All findings, including possible error fixes, were reported to the NSMO through SPR's (Software Problem Reports), and corrections were made by the NASTRAN maintenance contract service. In addition, the GSFC NASTRAN Level 15.5 IBM-360 version has been updated continually via an in-house effort. Many error corrections and modifications to accommodate new capabilities for both R&D work and flight program support were promptly made to satisfy our immediate needs. These evolutionary changes were reflected in the program identification shown by the last digit following the version labeling 15.5. The latest operational version at GSFC is Level 15.5.3.

Although maintaining the NASTRAN system for general users is the responsibility of the NSMO, we at GSFC have assisted \bar{N} TA users whenever they contacted us for advice. \bar{N} TA users have included

NASA field installations, other Government agencies, private industry, and universities. Last March, the NSMO established a new service contract, with Universal Analytics, Inc. as the subcontractor to Computer Science Corp., for regular maintenance of the NTA. GSFC was requested officially by NSMO to be a consultant and to respond to all inquiries received in relation to the NTA.

APPLICATION EXPERIENCES

Since the delivery of the IBM-360 NTA to GSFC in June of 1972, the system checkout phase has been proceeding. Various types of test problems were designed to verify the program capabilities and to unearth programming defects. At the end of that year, the Colorado Experiment of the OSO-I (OSO-8) was selected as the first flight experiment to employ the developed analytical tools of the STOP program (ref. 6). Emphasis was placed on securing temperature data computed using the NTA. While many features made the NTA especially suitable for the solution of a problem of this size and complexity, certain important quantities such as thermal contact resistances and the physical properties of surface coatings were analytically indeterminate, and a laboratory test was therefore essential to verify the model. This was achieved by applying the boundary conditions of the thermal vacuum test to the basic NASTRAN thermal model to obtain predictions for the test results. If marked temperature differences were noted between the predictions and the measured temperatures, the basic thermal model would be adjusted to reflect the couplings which could be calculated from the test results. Modifications were continued until the predictions matched the measured temperatures, and the modified model would then be considered fully verified. This verified model could then be used with confidence to develop temperature predictions when thermal loads simulating the orbital environment were applied.

The economic advantage of using this computer program can be best expressed by examining the computer time expenditures required to complete a run. Again, the OSO-I Colorado telescope is used as an example. This model consisted of a total of 488 grid points. Each steady-state run required 10 min. of CPU time and 12 min. of I/O time, while a five-orbit transient solution with 120 time steps required 24 min. of CPU time and 28 min. of I/O time. It must be emphasized that structurally compatible temperature data cards were direct outputs included in these indicated computer time expenditures. The cost effectiveness is evident.

The NTA has since been used to support many scientific instrument packages for various programs at GSFC, such as IUE (International Ultraviolet Explorer Satellite), SMM (Solar Maximum

Mission), Thematic Mapper, EUV (Extreme Ultraviolet Experiment), and TDRSS (Tracking and Data Relay Satellite System) antenna.

Other users who have been in contact with us and are actively employing the NTA to solve various heat-transfer problems are working on tasks involving nuclear reactors, weaponry, computer hardware, etc.

NEW DEVELOPMENTS

New additions have been developed or are being implemented to enhance the capabilities or convenience of the NTA and may be summarized as follows:

- A. The new capabilities already developed:
 - (1) A highly stable explicit integration algorithm suitable for the finite-element transient application (ref. 7)
 - (2) The temperature variance analysis (ref. 8)
 - (3) The plotting of the boundary elements of the HBDY type (ref. 8)
 - (4) A modification to the radiative matrix to accommodate the case of radiative exchanges with mixed diffuse-specular surface characteristics (ref. 9)
 - (5) A modification that condenses the processing procedure for large radiation matrices by a factor of 40.

- B. The new capabilities and convenience items currently being developed:
 - (1) The condensation of a radiatively nonlinear finite-element thermal model
 - (2) The entry of multiple boundary condition sets in one submission for execution (i.e., subcases)
 - (3) The ability to input temperature-dependent emissivities and absorptivities
 - (4) The one-dimensional thermo-fluid elements.

Although these new capabilities have been developed for the GSFC version only, they can be made available to general users

If the NSMO will take up the responsibility of incorporating them into future levels of the standard version of NASTRAN. We at GSFC are willing to provide assistance in using these new capabilities as we have been doing for the present version of NTA and its associated VIEW program (refs. 10 and 11) (a view factor generation computer program totally compatible with the NTA).

A necessary item for general users of the NTA is a complete, self-contained document using physically meaningful heat transfer terminology that would be familiar to general thermal analysts who may not have prior experience in any NASTRAN modelling. We have undertaken the task of preparing a manual in the tutorial style that would consist of the underlying finite-element theory in its heat transfer application, the general structure of the NTA, the most commonly used NASTRAN data cards for thermal analysis, heavily commented illustrative examples to demonstrate various types of modelling techniques for different physical problems, etc. The material is an expanded written version of the lecture given at GSFC last May and will be made available to any interested groups or individuals upon receipt of a written request to this author.

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