MODEL SYSTEMS CRITERIA

Clarence P. Young, Jr.
NASA Langley Research Center
Hampton, Virginia

Design criteria have been developed specifically for model systems to be tested at high Reynolds number in a cryogenic environment. More specifically, the criteria are aimed at identifying those special requirements and alternate criteria for utilizing the high Reynolds number facility (the National Transonic Facility) at Langley Research Center. The criteria are set forth in LHB 8850.1, Wind Tunnel Model Systems Criteria (Langley Research Center, Sept. 1981). This document is Langley policy, and its requirements are mandatory for all model systems to be tested at Langley. The principal revisions to this document are given in the illustrations.

Of particular interest to the users of the National Transonic Facility (NTF) is Chapter VII of this document, which sets forth the special requirements and alternate criteria for NTF models. Principal revisions to this chapter include a relaxation of the design safety factor to 1.5 on yield or 2 on ultimate (via waiver), and a material impact strength of 25 ft-lb. Relaxation of the safety factors will allow testing at high dynamic pressures using high-strength cryogenically acceptable alloys. The Charpy requirement is aimed at selecting materials for use at high stress levels, which requires very tough materials to avoid brittle fracture failure. The Charpy V-notch testing is a comparatively easy test certification. However, there are problems with the Charpy requirement in that it does not provide sufficient data for a fracture mechanics analysis. The parameter K_{Ic} (plane strain fracture toughness) is needed for quantitation studies, but it is difficult to obtain. It is recognized that a more definitive criterion is needed for different alloys. Also, the 25 ft-lb requirement should not be used to eliminate other materials such as aluminum or composites, some of which are quite suitable for cryogenic models if the appropriate fracture assessment is made for the specific application.

The use of lower safety factors requires that a fracture mechanics analysis be made for the reasons given in the illustrations. Such an analysis can be used to establish screening flaw sizes for nondestructive evaluation (NDE), which in most cases should satisfy the requirement. (However, if one or more flaws are found, this will require a life prediction based on crack propagation analyses.)

Testing at much higher dynamic pressures (compared to conventional high-speed models) requires that added attention be given to aeroelastic stability, both static (divergence) and dynamic (flutter). For this reason a safety factor of 2 is required against divergence and flutter. Insofar as the selection of analysis methods, that is left up to the user but should reflect state-of-the-art methodology and sufficient rigor to demonstrate a high degree of confidence.

In summary, criteria are defined which are intended to insure structural integrity of model systems and at the same time provide sufficient flexibility in their applications. It is recognized that certain criteria need to be more definitized, but at this stage criteria are by necessity more stringent in that high Reynolds number cryogenic testing is without precedent. However, as operational and design experience is gained, it is anticipated that a maturing of the criteria will occur, and more definitive standards will be developed.

DESIGN CRITERIA PHILOSOPHY

- BUILD UPON EXISTING CRITERIA FOR CONVENTIONAL WIND TUNNEL MODELS
- ESTABLISH SPECIAL REQUIREMENTS AND ALTERNATE CRITERIA FOR UTILIZING HIGH Re FACILITY (NTF) CAPABILITY
  - CRYO TEMP.
  - HIGH LOADS
- PROVIDE MAXIMUM FLEXIBILITY WHILE INSURING MODEL SYSTEM INTEGRITY

WIND-TUNNEL MODEL SYSTEMS CRITERIA DOCUMENT

- LHB 8850.1 DATED SEPTEMBER 30, 1981
  - SUPERCEDES USER-FURNISHED WIND-TUNNEL MODEL CRITERIA DOCUMENT LHB 8850.1 DATED OCTOBER 1976
  - INTERIM RELEASE - USER'S COMMENTS REQUESTED
  - GENERATED AS A PART OF NTF CRYO MODELS TECHNOLOGY DEVELOPMENT PROGRAM
- PRINCIPAL REVISIONS INCORPORATED IN NEW DOCUMENT
  - APPLIES TO ALL WIND TUNNEL MODELS AND MODEL SUPPORT SYSTEMS TESTED AT LaRC
  - SETS FORTH SPECIAL REQUIREMENTS FOR HIGH Re MODELS (CHAPTER VII)
  - REQUIRES QUALITY ASSURANCE PLAN
  - DEFINES WAIVER APPROVAL PROCEDURE
- IMPLEMENTATION RESPONSIBILITY - FACILITY SAFETY HEAD

PROBLEMS WITH CHARPY REQUIREMENT

- NOT ALWAYS A TRUE MEASURE OF TOUGHNESS NOR DOES IT PROVIDE INFORMATION NEEDED FOR FRACTURE MECHANICS ANALYSIS - K_{Ic} (PLANE STRAIN FRACTURE TOUGHNESS) IS A MORE SOPHISTICATED PARAMETER, CAN BE USED QUANTITATIVELY BUT DIFFICULT TO OBTAIN
- CHOSEN TO BE CONSERVATIVE BUT MAY BE DIFFICULT TO MEET - e.g., Ni 40, VASCO 200 MATERIAL EXPERIENCE TO DATE
- SHOULD NOT BE USED TO ELIMINATE OTHER MATERIALS WHICH ARE ACCEPTABLE FOR CRYOGENIC USE SUCH AS
  - ALUMINUM ALLOYS
  - COMPOSITES
- MORE DEFINITIVE CRITERIA ARE NEEDED FOR DIFFERENT ALLOY GROUPS

SPECIAL REQUIREMENTS AND ALTERNATE CRITERIA
(REF.: CHAPTER VII - LHB8850.1)

- UNIQUENESS
  - SETS FORTH ADDITIONAL REQUIREMENTS AND/OR EXCEPTIONS TO GENERAL CRITERIA FOR UNUSUALLY HIGH LOADS AND/OR EXTREME TEST TEMPERATURES
- ALLOWABLE STRESS - SAFETY FACTOR OF 3 ON YIELD OR 4 ON ULTIMATE (AS BUILT CONDITION, AT TEST CONDITION, INCLUDES THERMAL LOADS)
  - MAY BE RELAXED BY WAIVER TO 1.5 ON YIELD OR 2 ON ULTIMATE
- FATIGUE - SAFE LIFE DESIGN WITH SAFETY FACTOR OF 2 (UNCHANGED FROM PAST LaRC PRACTICE)

SPECIAL REQUIREMENTS AND ALTERNATE CRITERIA
(CONTINUED)

- FRACTURE TOUGHNESS
  - CHARPY V-NOTCH IMPACT STRENGTH - 25 FT.-LBS. AT TEST TEMP. - AS BUILT CONDITION
    - USE AS A SCREENING OR RANKING FACTOR IN MATERIAL SELECTION - AIM IS TO SELECT TOUGH, FRACTURE RESISTANT MATERIAL
    - CHARPY DATA GENERALLY AVAILABLE FOR HIGH STRENGTH ALLOYS - CAN WRITE IN SPEC.
    - COMPARATIVELY EASY TEST CERTIFICATION
    - DERIVED PRIMARILY FOR HIGH STRENGTH METALLIC ALLOYS NEEDED FOR HIGH LOADS APPLICATION
  - REQUIRES FRACTURE MECHANICS ANALYSIS (ASSESSMENT)
    - ESTABLISH SCREENING FLAW SIZE FOR DESTRUCTIVE EXAMINATION
    - LIFE PREDICTION FOR FLAW EXISTENCE (OR ASSUMED TO EXIST) AT CRITICAL LOCATION(S)
  - WHY NEEDED?
    - LOW TEMP. INCREASES PROBABILITY OF BRITTLE FRACTURE
    - HIGH LOADS APPLICATION IS LIKELY TO REQUIRE ALLOYS THAT ARE FLAW SENSITIVE
    - HIGH STRESS STATES TEND TO INCREASE CRACK INITIATION AND GROWTH RATE
    - HIGH COST OF MODEL FAILURE AND TUNNEL DAMAGE

SPECIAL REQUIREMENTS AND ALTERNATE CRITERIA (CONCLUDED)

- SYSTEM AEROELASTIC STABILITY
  - DIVERGENCE - SAFETY FACTOR OF 2 (UNCHANGED)
    - DEMONSTRATED BY IN-DEPTH ANALYSIS
    - SYSTEM STIFFNESS VERIFICATION (WHERE POSSIBLE)
  - FLUTTER - SAFETY FACTOR OF 2 (NEW)
    - DEMONSTRATED BY IN-DEPTH ANALYSIS
    - VIBRATION MODES VERIFICATION (WHERE POSSIBLE)

- ANALYSIS CONSIDERATIONS -

- SELECTION OF METHODS UP TO USER
- WHAT IS INTENT OF "STATE OF THE ART" AND "IN DEPTH"
  - GET YOUR ATTENTION - NO DESIGN PRECEDENTS
  - WORK TO HIGH LOADS, LOW MARGINS, NEED CONFIDENCE IN DESIGN → MORE RIGOROUS ANALYSIS
  - CONSIDER TOTAL SYSTEM EFFECTS, e.g., STRUCTURAL JOINT EFFECTS, BALANCE FLEXIBILITY, TOTAL AERO LOADS, DYNAMIC RESPONSE, THERMAL
- EXTENT OF ANALYSES? HOW MUCH IS ENOUGH?
  - MUST SATISFY REQUIREMENTS FOR MODEL INTEGRITY REPORT
  - DETERMINE REQUIREMENTS "A PRIORI" IF POSSIBLE
  - WILL VARY WITH MODEL COMPLEXITY, TEST REQUIREMENTS, ETC.
  - WORK CLOSELY WITH LaRC - FLEXIBILITY IS THERE TO GET WAIVERS

- SUMMARY -

- WIND TUNNEL MODEL SYSTEMS CRITERIA DOCUMENT (LHB 8850.1) DATED SEPTEMBER 30, 1981, PUBLISHED AND SHOULD BE USED FOR CRYOGENIC MODELS SYSTEMS DESIGN
- DOCUMENT IS AN INTERIM RELEASE - USER'S COMMENTS ARE SOLICITED
- DOCUMENT IS INTENDED TO INSURE INTEGRITY OF MODEL SYSTEMS AND ALLOW MAXIMUM FLEXIBILITY
- REQUIREMENTS FOR CRYOGENIC MODEL SYSTEMS ARE BY NECESSITY MORE STRINGENT
- LaRC RECOGNIZES THAT CERTAIN CRITERIA NEED TO BE MORE DEFINITIZED AND IS WORKING TOWARD THAT END VIA
    - APPLICATION TO CURRENT MODELS IN SYSTEM (WORKS THE PROBLEM)
    - PLANNED R & D ACTIVITIES