ASPECTS OF FRACTURE MECHANICS IN CRYOGENIC MODEL DESIGN

PART II - NTF MATERIALS

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Over the past several years, fatigue crack growth and fracture toughness tests have been conducted at Langley for some candidate materials for use in the National Transonic Facility (NTF). These materials may be used in making strain gage balances, stings, and wind tunnel models. The purpose of this study was to present results of fatigue crack growth and fracture toughness tests conducted on three candidate materials. Fatigue crack growth and fracture toughness tests were conducted on NITRONIC 40 at room temperature and -275°F. Fracture toughness tests were also conducted on Vascomax 200 and 250 maraging steel from room temperature to -320°F (fig. 1).

NITRONIC 40 was used to make the Pathfinder I model. The model was machined from a large plate (5.5 by 44 by 60 in.)(fig. 2). After some Charpy V-notch impact energy tests (in the short transverse direction) showed somewhat low impact energies (20 to 25 ft-lb) at -275°F, a concern was expressed about the fracture toughness of the material. A fracture mechanics test program was then initiated to conduct fatigue crack growth and fracture toughness tests. Center crack tension and notch bend specimens were machined from the end of the large plate. The specimens tested the material in nearly the same direction as that of the highest stress in the wing structure. The material was tested in two conditions: as received and stress relieved (fig. 3).

The fatigue crack growth rate tests were conducted at room temperature and -275°F on three-point notch bend specimens. The crack growth rates were plotted against the stress intensity factor range ΔK, a crack tip characterizing parameter. These results showed that the crack growth rates at a given ΔK were much less at -275°F than at room temperature (about a factor of 3) (fig. 4).

The fracture toughness tests on the "as received" and "stress relieved" materials at -275°F were conducted on the center crack tension specimens. These results showed that the fracture toughness was high (estimated to be 120 ksi-in.$^{1/2}$) and that the net section stress S_n at failure was between the yield stress σ_{ys} and the ultimate tensile strength σ_u of the material, which indicated that the material was very ductile at cryogenic temperatures. The solid curve in figure 5 shows the results of a fracture analysis using the Two-Parameter Fracture Criterion (TPFC). The two fracture parameters (K_F and m) were obtained from these tests. These results show that the "elastic" fracture toughness K_{Ie} changes with crack length-to-width ratio (2a/W), but the calculated net section stresses were always greater than the yield stress. Fracture toughness tests conducted on the notch bend specimens showed similar high toughness. The fracture toughness of NITRONIC 40 exceeds the Pathfinder criteria requirement of 85 ksi-in.$^{1/2}$ at cryogenic temperatures (-275°F).

Toughness tests were also conducted on Vascomax CVM-200 and CVM-250 maraging steel from room temperature to -320°F using round and rectangular compact specimens (fig. 6). The CVM-200 and CVM-250 had a toughness of 130 and 75 ksi-in$^{1/2}$, respectively, at room temperature. At -275°F, the toughness of the CVM-200 and CVM-250 was about 80 and 60 ksi-in.$^{1/2}$, respectively. Thus, the fracture toughness of CVM-250 maraging steel does not meet the 85 ksi-in.$^{1/2}$ criteria at any temperature, and the CVM-250 maraging steel is marginal at -275°F (fig. 7).

- FATIGUE CRACK GROWTH AND FRACTURE TOUGHNESS OF NITRONIC 40 TESTED AT -275°F.
- FRACTURE TOUGHNESS OF VASCOMAX 200 AND 250 MARAGING STEEL TESTED FROM ROOM TEMPERATURE TO -320°F.

Figure 1.- Objectives.

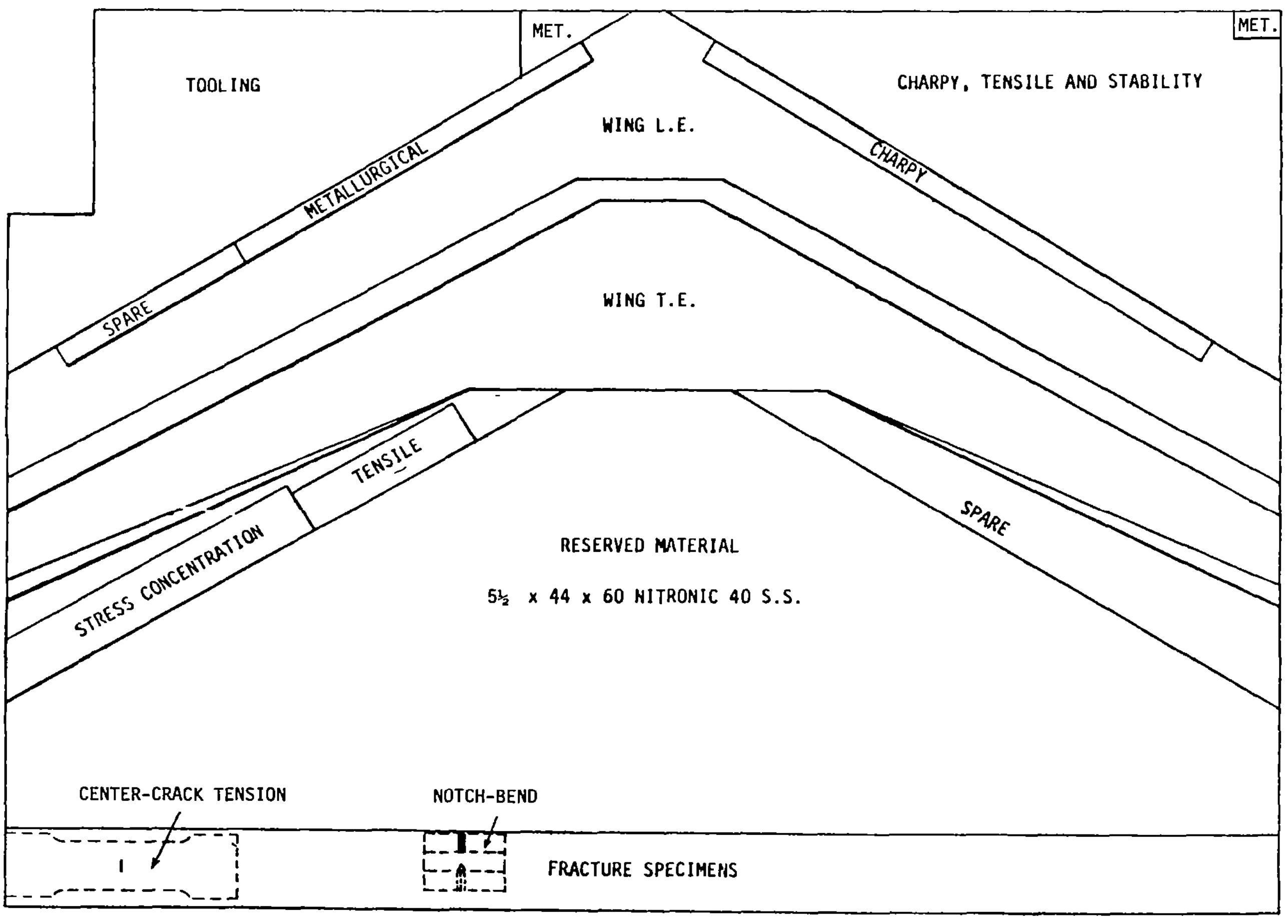

Figure 2.- NITRONIC 40 plate.

SPECIMENS	PURPOSE	CONDITION	NO. TESTED	HOLDOUTS
CENTER CRACK	TOUGHNESS	AS RECEIVED	3	(3 BLANKS)
		STRESS RELIEVED	3	4
NOTCH-BEND	FATIGUE - CRACK GROWTH AND TOUGHNESS	AS RECEIVED	9	(1 BLANK)
		STRESS RELIEVED	9	0

Figure 3.- NITRONIC 40 test specimens.

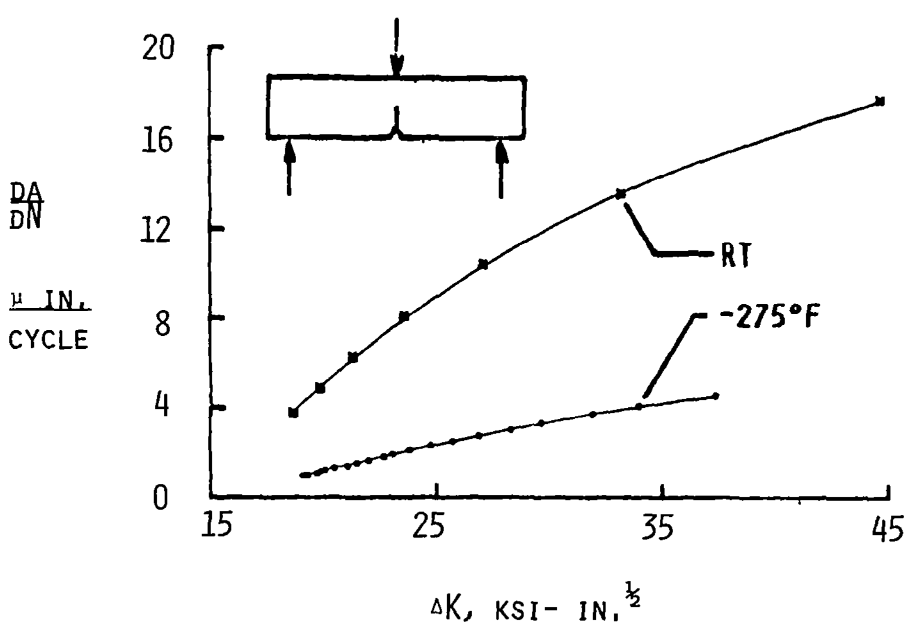

Figure 4.- Fatigue crack growth in NITRONIC 40 at two temperatures.

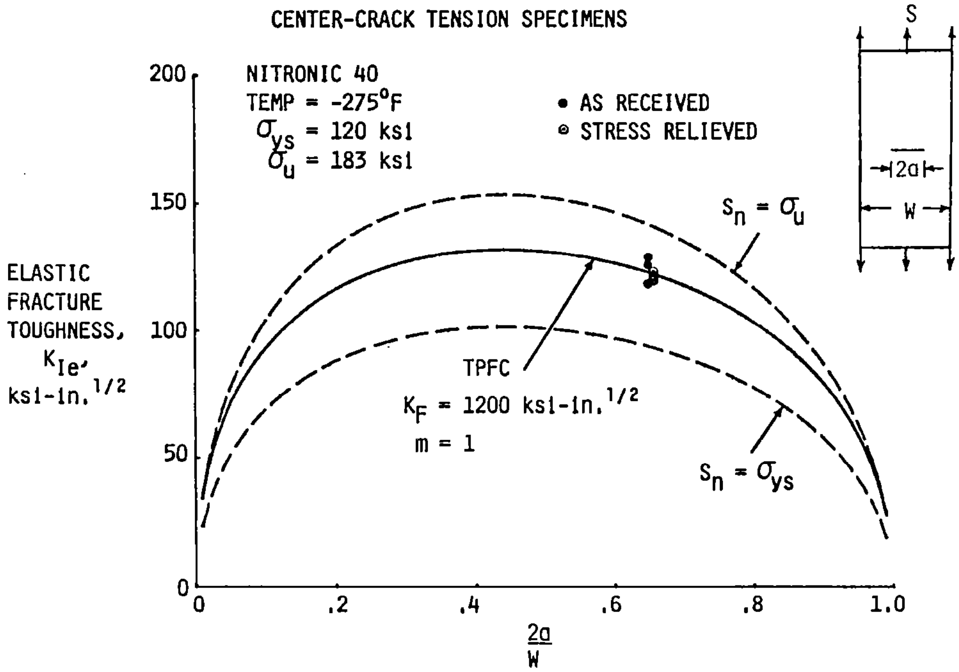

Figure 5.- Fracture toughness of NTF Pathfinder model material.

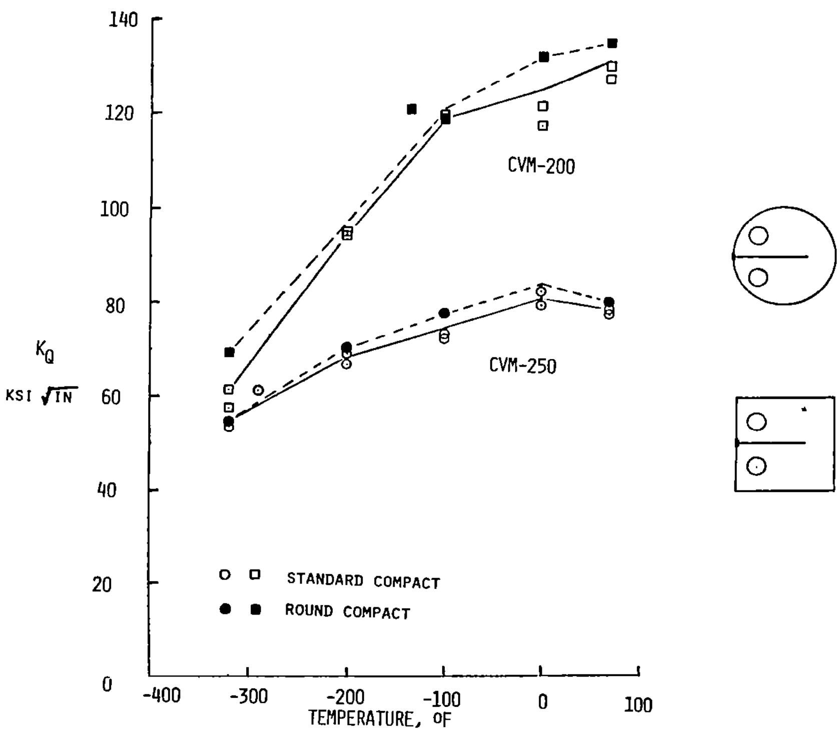

Figure 6.- Fracture toughness of two maraging steels.

- FRACTURE TOUGHNESS OF NITRONIC-40 MEETS PATHFINDER CRITERIA (85 KSI-IN.$^{1/2}$) AT CRYOGENIC TEMPERATURE (-275°F)

- CRACK INITIATION AND GROWTH IN NITRONIC 40 ARE MORE CRITICAL TO MODEL DESIGN THAN FRACTURE TOUGHNESS

- FRACTURE TOUGHNESS OF CVM-250 MARAGING STEEL DOES NOT MEET 85 KSI-IN.$^{1/2}$ CRITERIA AT ROOM TEMPERATURE AND CVM-200 MARAGING STEEL IS MARGINAL, BUT PROBABLY ACCEPTABLE, AT -275°F

Figure 7.- Conclusions.