AD NUMBER

AD029130

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 26 APR 1954. Other requests shall be referred to National Aeronautics and Space Administration, Washington, DC.

AUTHORITY

NASA TR Server website

RESEARCH MEMORANDUM

INVESTIGATION OF EFFECT OF NOTCHES ON ELEVATED-TEMPERATURE FATIGUE STRENGTH OF N-155 ALLOY

By C. A. Hoffman

Lewis Flight Propulsion Laboratory
Cleveland, Ohio

NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
April 26, 1954

3195

CL-1

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

INVESTIGATION OF EFFECT OF NOTCHES ON ELEVATED-TEMPERATURE FATIGUE STRENGTH OF N-155 ALLOY

By C. A. Hoffman

SUMMARY

An investigation of the effect of notches on the fatigue strength of N-155 alloy at elevated temperatures was conducted by the NACA in cooperation with the Gas Turbine Panel of the joint A.S.T.M.-A.S.M.E. Committee on Effects of Temperature on the Properties of Metals.

Studies were made at 1350° and 1500° F in completely reversed bending. The results on relatively few specimens indicated that: (a) Notches reduced fatigue strength at 1350° F by approximately 34 to 40 percent and at 1500° F by approximately 30 to 37 percent over the range of 3 to 150 hours, and (b) the notch sensitivity in fatigue under conditions of completely reversed bending at 1350° and 1500° F was considerably less than that predicted for static bending under elastic conditions.

INTRODUCTION

There are comparatively few data available on the effect of notches on the fatigue characteristics of heat-resistant alloys at high temperature. The NACA Lewis laboratory, in cooperation with the Gas Turbine Panel of the joint A.S.T.M.-A.S.M.E. Committee on Effects of Temperature on the Properties of Metals, conducted fatigue tests of notched specimens under conditions of reversed bending.

Tests were conducted on N-155 alloy. Completely reversed bending at 1350° and 1500° F was investigated.

APPARATUS AND PROCEDURE

The material used in this investigation was N-155 alloy, which had the following percentage composition:

C	Mn	Si	Cr	Ni	Co	Mo	W	Cb	N	Fe
0.13	1.64	0.42	21.22	19.00	19.70	2.90	2.61	0.84	0.13	balance

The following heat treatment was used: solution treatment at 2200° F for 1 hour, followed by a water quench, then by aging 16 hours at 1400° F, followed by air cooling.

The specimen design used is illustrated in figure 1. The theoretical stress-concentration factor in bending was 3.56 according to the method of Timoshenko (ref. 1) and 2.5 (i.e., technical stress-concentration factor) according to the method of Neuber (ref. 2). Presumably, these factors are specifically applicable to a condition of elastic deformation under static-load conditions. 3195

A Westinghouse completely reversed-bending fatigue machine was used. The specimen was held vertically and weighted at its lower end so that its natural frequency of vibration would correspond to the excitation frequency (120 cps) of the fatigue machine. The specimen was then vibrated at resonance. The stress in the specimen was produced by the inertia loads caused by the resonant vibration of the specimen-weight-clamp system.

A thermocouple was attached to the specimen by means of a metal strap spot-welded to the specimen above the test section, and the hot junction of the thermocouple was located directly over the notch. Heat was supplied by a resistance-wound electric furnace placed about the specimen.

RESULTS AND DISCUSSION

The results obtained are presented in table I and are plotted in figure 2. For purposes of comparison, curves of unnotched N-155 alloy of the same heat (A1726) and with the same heat treatment (ref. 3), are included in this figure.

Figure 2 reveals that the fatigue strength has been considerably reduced by the notches; that is, by approximately 34 to 40 percent at 1350° F and by 30 to 37 percent at 1500° F over the range of approximately 3 to 150 hours. The effective stress-concentration factor K_f (ratio of unnotched to notched strength at any given number of cycles) varied from 1.5 to 1.7 for the range of time involved at 1350° F. The effective stress-concentration factor at 1500° F varied from 1.4 to 1.6 over the range of time involved. It is readily apparent that the effective stress-concentration factors at both 1350° and 1500° F are less than the theoretical values of 3.56 and 2.5 for static loading, which were based upon the methods of references 1 and 2, respectively.

On the basis of the results for the comparatively few specimens involved, it is noted that the effective stress-concentration factor shows a slight increasing trend with time at 1350° F but a slight decreasing trend with time at 1500° F. In reference 4, it is indicated that the effective stress-concentration factor increased with time (i.e., to 10^7 cycles) at both 1350° and 1500° F for N-155 alloy of the same heat (A1726) and heat treatment as the material reported herein. The specimens reported in reference 4 were used in a rotating-beam test at speeds up to 400 rpm. On the basis of number of cycles to failure, the notch fatigue strengths reported herein are essentially in agreement with those reported in reference 4 and presented in figure 3. The notch fatigue data for the present investigation, particularly at 1350° F, are somewhat higher, however. This result may be due in part to the higher frequency and resultant lesser time at temperature for a given number of cycles to failure in the present investigation.

3195

It is noticed from figure 2 that the unnotched specimens seem to reach a fatigue limit of about ±40,000 pounds per square inch at 1350° F, whereas the notched specimens at this temperature show a continued decrease of strength with time. This difference, of course, could be due to experimental scatter, but if it is an actual difference, it is interesting that the shape of the curve is affected by the presence of the notch.

SUMMARY OF RESULTS

CL-1 back

The results of an investigation of the effect of notches on the elevated-temperature fatigue strength of N-155 alloy are as follows:

1. Notches reduced fatigue strength at 1350° F by approximately 34 to 40 percent and at 1500° F by approximately 30 to 37 percent over the range of 3 to 150 hours.

2. The notch sensitivity in fatigue, under conditions of completely reversed bending at 1350° and 1500° F, was considerably less than that predicted for static bending under elastic conditions.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, December 14, 1953

REFERENCES

1. Timoshenko, S.: Strength of Materials. Part II. Second ed., D. Van Nostrand Co., Inc., 1941.

2. Neuber, H.: Theory of Notch Stresses: Principles for Exact Stress Calculation. Trans. No. 74, Navy Dept., David Taylor Model Basin, Nov. 1945.

3. NACA Subcommittee on Heat-Resisting Materials: Cooperative Investigation of Relationship Between Static and Fatigue Properties of Heat-Resistant Alloys at Elevated Temperatures. NACA RM 51A04, 1951.

4. Demer, L. J., and Lazan, B. J.: Damping, Elasticity and Fatigue Properties of Unnotched and Notched N-155 at Room and Elevated Temperatures. WADC Tech. Rep. No. 53-70, Air Res. and Dev. Command, U.S. Air Force, Wright-Patterson Air Force Base, Dayton (Ohio), Feb. 1953. (Materials Lab. Contract No. AF 33(038)-18903, RDO No. 614-16.)

TABLE I. - SUMMARY OF FATIGUE DATA

Number of specimens	Temperature, °F	Maximum outer fiber stress, psi	Time, hr
1	1350	27,800	3.2
1	1350	25,000	61.7
1	1350	23,000	152.5
1	1500	22,100	5.7
1	1500	19,950	37.2
1	1500	20,080	134.0
1	1500	20,130	4.9

3195

3195

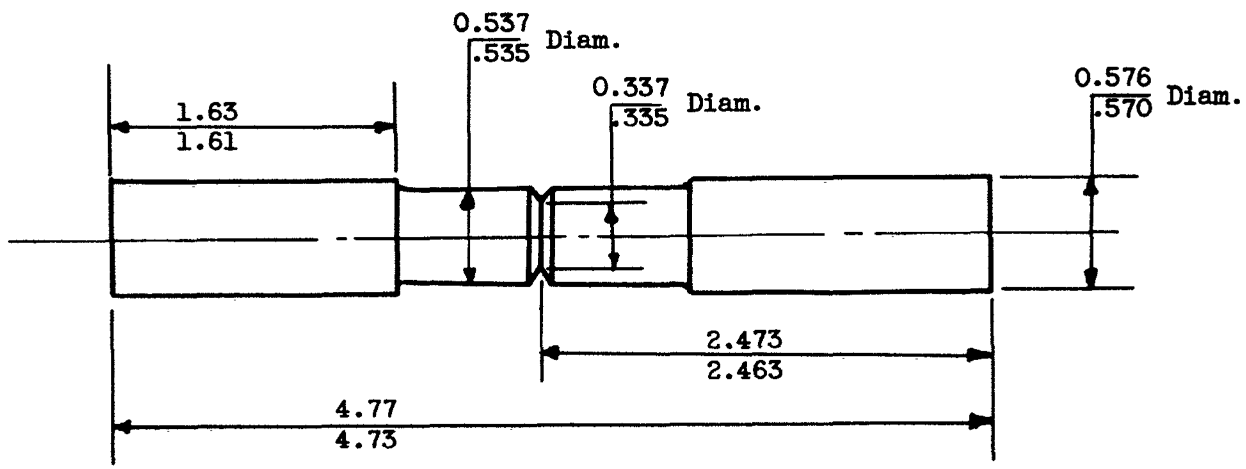

Figure 1. - Notched specimen. Notch data: angle, 60°; radius at root, 0.015 inch; theoretical stress-concentration factor, 3.56 (ref. 1), 2.5 (ref. 2); depth, 0.100 inch.

3195

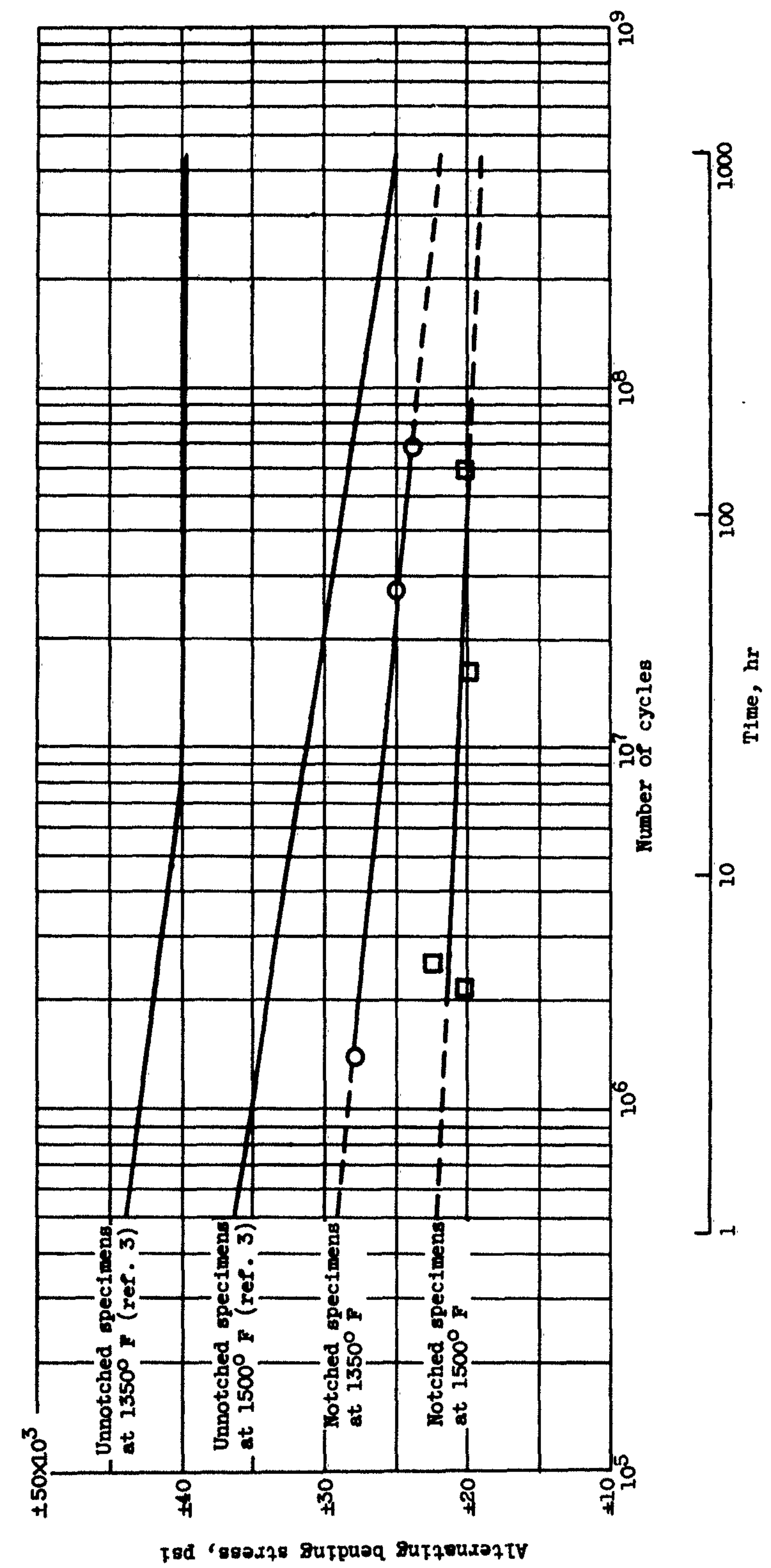

Figure 2. - Reversed bending fatigue curves at 7200 cycles per minute (Westinghouse machine).

3195

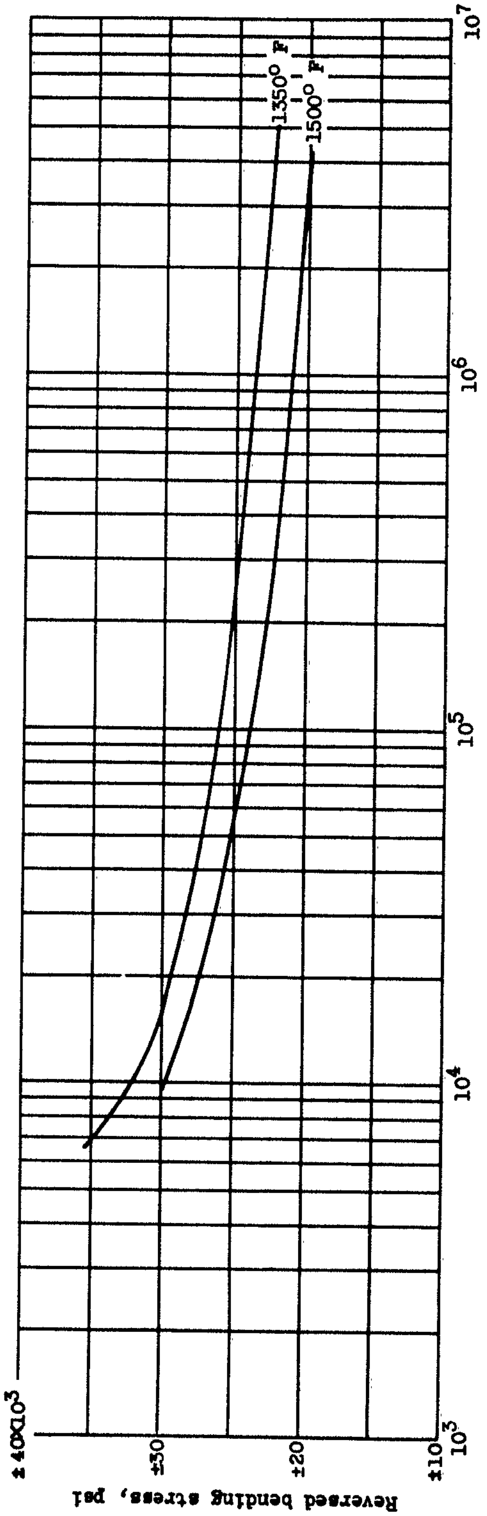

Figure 3. - Notch fatigue strength (data from rotating beam tests at speeds up to 400 rpm, ref. 4).

NACA RM E53L31a
National Advisory Committee for Aeronautics.
INVESTIGATION OF EFFECT OF NOTCHES ON ELEVATED-TEMPERATURE FATIGUE STRENGTH OF N-155 ALLOY. C. A. Hoffman. April 1954. 8p. diagrs., tab. (NACA RM E53L31a)

An investigation of the effect of notches on the fatigue strength of N-155 alloy at elevated temperatures was conducted by the NACA in cooperation with the Gas Turbine Panel of the joint A.S.T.M.-A.S.M.E. Committee on Effects of Temperature on the Properties of Metals. Studies were made at 1350° and 1500° F in completely reversed bending. The results on relatively few specimens indicated that: (a) Notches reduced fatigue strength at 1350° F by approximately 34 to 40 percent and at 1500° F by approximately 30 to 37 percent over the range of 3 to 150 hours, and (b) the notch sensitivity in fatigue under conditions of completely reversed bending at 1350° and 1500° F was considerably less than that predicted for static bending under elastic conditions.

Copies obtainable from NACA, Washington

1. Materials (5)
2. Alloys, Heat-Resisting (5.1.4)
3. Materials, Properties (5.2)
4. Materials, Properties - Fatigue (5.2.5)

I. Hoffman, Charles A.
II. NACA RM E53L31a

NACA

NACA RM E53L31a
National Advisory Committee for Aeronautics.
INVESTIGATION OF EFFECT OF NOTCHES ON ELEVATED-TEMPERATURE FATIGUE STRENGTH OF N-155 ALLOY. C. A. Hoffman. April 1954. 8p. diagrs., tab. (NACA RM E53L31a)

An investigation of the effect of notches on the fatigue strength of N-155 alloy at elevated temperatures was conducted by the NACA in cooperation with the Gas Turbine Panel of the joint A.S.T.M.-A.S.M.E. Committee on Effects of Temperature on the Properties of Metals. Studies were made at 1350° and 1500° F in completely reversed bending. The results on relatively few specimens indicated that: (a) Notches reduced fatigue strength at 1350° F by approximately 34 to 40 percent and at 1500° F by approximately 30 to 37 percent over the range of 3 to 150 hours, and (b) the notch sensitivity in fatigue under conditions of completely reversed bending at 1350° and 1500° F was considerably less than that predicted for static bending under elastic conditions.

Copies obtainable from NACA, Washington

1. Materials (5)
2. Alloys, Heat-Resisting (5.1.4)
3. Materials, Properties (5.2)
4. Materials, Properties - Fatigue (5.2.5)

I. Hoffman, Charles A.
II. NACA RM E53L31a

NACA

NACA RM E53L31a
National Advisory Committee for Aeronautics.
INVESTIGATION OF EFFECT OF NOTCHES ON ELEVATED-TEMPERATURE FATIGUE STRENGTH OF N-155 ALLOY. C. A. Hoffman. April 1954. 8p. diagrs., tab. (NACA RM E53L31a)

An investigation of the effect of notches on the fatigue strength of N-155 alloy at elevated temperatures was conducted by the NACA in cooperation with the Gas Turbine Panel of the joint A.S.T.M.-A.S.M.E. Committee on Effects of Temperature on the Properties of Metals. Studies were made at 1350° and 1500° F in completely reversed bending. The results on relatively few specimens indicated that: (a) Notches reduced fatigue strength at 1350° F by approximately 34 to 40 percent and at 1500° F by approximately 30 to 37 percent over the range of 3 to 150 hours, and (b) the notch sensitivity in fatigue under conditions of completely reversed bending at 1350° and 1500° F was considerably less than that predicted for static bending under elastic conditions.

Copies obtainable from NACA, Washington

1. Materials (5)
2. Alloys, Heat-Resisting (5.1.4)
3. Materials, Properties (5.2)
4. Materials, Properties - Fatigue (5.2.5)

I. Hoffman, Charles A.
II. NACA RM E53L31a

NACA

NACA RM E53L31a
National Advisory Committee for Aeronautics.
INVESTIGATION OF EFFECT OF NOTCHES ON ELEVATED-TEMPERATURE FATIGUE STRENGTH OF N-155 ALLOY. C. A. Hoffman. April 1954. 8p. diagrs., tab. (NACA RM E53L31a)

An investigation of the effect of notches on the fatigue strength of N-155 alloy at elevated temperatures was conducted by the NACA in cooperation with the Gas Turbine Panel of the joint A.S.T.M.-A.S.M.E. Committee on Effects of Temperature on the Properties of Metals. Studies were made at 1350° and 1500° F in completely reversed bending. The results on relatively few specimens indicated that: (a) Notches reduced fatigue strength at 1350° F by approximately 34 to 40 percent and at 1500° F by approximately 30 to 37 percent over the range of 3 to 150 hours, and (b) the notch sensitivity in fatigue under conditions of completely reversed bending at 1350° and 1500° F was considerably less than that predicted for static bending under elastic conditions.

Copies obtainable from NACA, Washington

1. Materials (5)
2. Alloys, Heat-Resisting (5.1.4)
3. Materials, Properties (5.2)
4. Materials, Properties - Fatigue (5.2.5)

I. Hoffman, Charles A.
II. NACA RM E53L31a

NACA