



Materials Science and Engineering
Congress and Exhibition on Advanced Materials and Processes

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1 - 4 September 2008 in Nürnberg, Germany

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Dear Professor Farhangdoost,

This is to confirm that you have been participating in the MSE 2008, Congress and Exhibition on Advanced Materials and Processes in Nürnberg, Germany.

We confirm the presentation of the poster entitled:

„Influence of Rotating Bending Fatigue Test on the Mechanical Parameters of Standard Specimens“

Authors:

K. Farhangdoost (Sp), E. Homaei, Ferdowsi University of Mashhad (Iran)

Thank you for your involvement!

We are looking forward to seeing you again at one of our next events.

With kind regards

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Mechanical Testing

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B. Rehmer (Sp), R. Pulz, S. Glaubitz, Federal Institute for Materials Research and Testing, Berlin (Germany)
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- D11-575 Wear Behaviour of some Materials for Self-Lubricating Bearing**
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S. Kobayashi (Sp), Y. Ioi, T. Takasugi, Tohoku University, Osaka (Japan)
- D11-775 Influence of Rotating Bending Fatigue Test on the Mechanical Parameters of Standard Specimens**
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Influence of rotating bending fatigue test on the mechanical parameters of standard specimens

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Abstract:

The aim of this paper is determining the rate of fatigue damage due to applying rotating bending fatigue test on standard specimens. The influence of rotating bending fatigue tests are investigated on the mechanical parameters- yield strength, ultimate strength, percentage of area reduction and the percentage of elongation- on standard specimens. Different fatigue loads are applied to the specimens on which fatigue test was run in such a way that no specimen reached to its fracture cycle. Then, tensile test was done on the specimens and the mechanical parameters were determined for each specimen. Then, the data was compared with the data obtained from the specimen on which no fatigue test was run and the tensile test was carried out on it directly. Results show that, in comparison to the other mechanical parameters, ultimate strength is more sensitive to the fatigue test that can be a reliable criterion for fatigue damage.

1. Introduction

Fatigue is important as a mode of failure, the phenomenon of fatigue has been studied extensively for more than one hundred years [1]. It is an important parameter to be considered in the behavior of mechanical components subjected to constant and variable amplitude loading [2]. Fatigue is primary cause for 80–90% of all engineering failure [3]. Formation of slip bands induces strain localization. The development of slip bands may result in substantial defect creation in localized regions [4]. The evaluation of residual life of materials loaded cyclically is of great practical importance. This requires non-destructive tools that enable one to assess changes in the material state since the beginning of service [5]. One historical

concept of fatigue damage has been thought to be the weakening or losing of the strength of a material due to irreversible slip in crystals or plastic strain cycling. In fact, it has been experimentally verified that the value of the residual fracture ductility of fatigued specimens is lower than that of the virgin state, and the decrease in fracture ductility becomes predominant as the number of cycles approaches fracture cycle [6]. Mechanical, metallurgical and environmental variables can influence the fatigue resistance of a structural component [2]. If the stresses due to fatigue loads are high enough, they will lead to failure of the component, even though the maximum stress is lower than the static strength of the material. Failure occurs when the crack has so weakened the local material that the

remaining cross section of the component cannot withstand the imposed mechanical load [7].

Rotating bending fatigue tests are the most usual way to investigate the fatigue behavior of a material or a component and, due to their speeds, they have also been widely used in research on short crack growth rates. Rotating bending fatigue tests represent perhaps the most simple way to investigate the fatigue behavior of materials or components. The successful application of rotating bending fatigue tests is due to different factors: the high load cycling rates; the simple testing procedure; and the low cost for use and maintenance. The speed of rotating bending fatigue tests is a consequence of the peculiar configuration of the test rig: a vertical load is transformed into a bending moment on a specimen rotating at high velocity [8].

In this paper changes on yield strength, ultimate strength, percentage of area reduction and the percentage of elongation on standard specimens due to rotating bending fatigue tests are studied and the sensitivity of these parameters to changes in number of cycles and fatigue load are investigated. Setup of the fatigue testing machine and environmental variables for all of the tests are same.

2. Experimental Method

2.1 Rotating bending fatigue test machine

Rotating bending fatigue test is a simple method of determining fatigue properties by applying known bending moments to rotating round specimens. The specimen has a continuous radius such that the maximum bending stresses are constant at all cross sections. The stress at a point on the surface of a rotating bending specimen varies sinusoid ally between numerically equal maximum tensile and compressive

stress values in every cycle. For an elastic material, we have:

$$\sigma = \frac{32M}{\pi d^3} \quad (1)$$

Where σ is the maximum surface stress; M is the bending moment at the cross section under consideration and d is the critical diameter of the specimen. Fatigue testing was carried out on a rotating bending fatigue testing machine (Roell Amseler, UBM 200) of capacity 6 NM (Newton-meter), at a frequency of 50 Hz and at room temperature. The sample was subjected to alternate cycles of tensile and compressive stresses as it is simultaneously bent and rotated.

2.2 Material

The specimens are made of Ck45, No thermal operations are done on these materials. This medium carbon high tensile steel is suitable for medium stressed parts in machinery and industrial tools. Chemical composition of this material is given in table 1.

Table 1. Chemical composition of Ck45 steel

Run	C	Si	S	P	Mn	FE
1	.4289	.124	.036	.028	.609	98.77
2	.4332	.133	.032	.02	.628	98.75
Avg	.4310	.128	.034	.024	.619	98.76

The test specimens are prepared on the basis of the instruction of fatigue testing instrument in accordance with the prescribed standard DIN 50113 (fig. 1). The bars were machined to form fatigue test specimens. After turning, the portion of the specimen having continuous radius was polished to get a mirror-finish. This was done to avoid the most likely influence of surface roughness on fatigue strength.

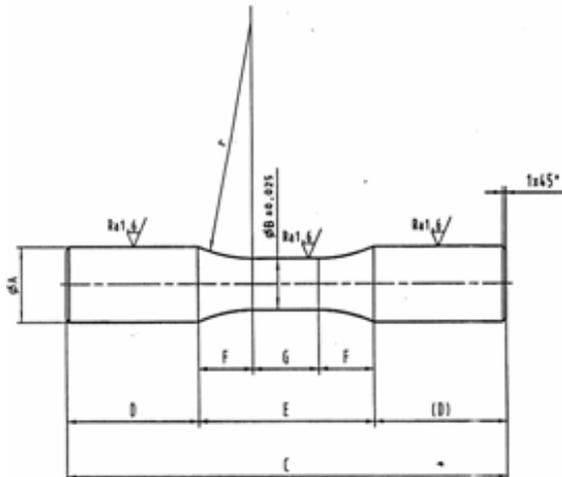


Fig. 1. Shape of standard specimen

2.3 Procedure of experiments

Different fatigue loads are applied to the specimens on which fatigue test is run in such a way that no specimen reaches to its fracture cycle, in other words, any specimen on which a certain load is applied is removed from fatigue test process before failure happens. For example, if we find from S-N diagram that the specimen is fractured because of bending load of 500 MPa after 100000 cycles, it is removed from testing process after 50000 cycles for determining the rate of fatigue damage. S-N diagram is shown in figure 2.

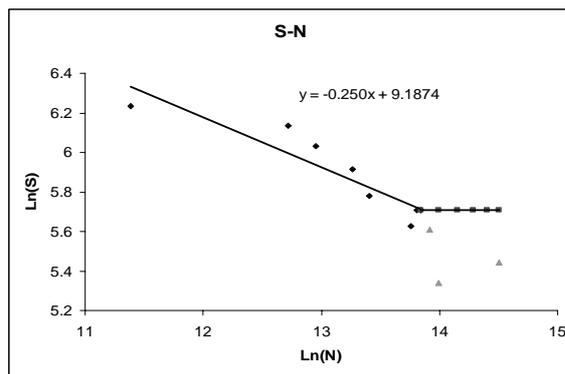


Fig. 2. S-N diagram for Ck45 from rotating bending fatigue test

Then, tensile test is done on the specimens and the mechanical parameters

are determined for each specimen. The data are shown in table 2.

Table 2. experimental data

σ (MPa)	N (cycle)	L (mm)	U (MPa)	Y (MPa)	A (%)
512	50	8.33	883.60	792.99	29.33
469.6195	50	8.5	881.53	818.19	31.53
429.0938	100	9.25	899.89	780.61	25.70
429.0938	200	8.94	959.33	914.29	31.67
422.6575	500	8.87	941.32	868.28	21.26
395.2253	200	9.89	898.74	831.95	25.99
373.8140	400	9.61	879.11	728.23	28.97
366.4119	600	9.79	906.97	840.69	11.12
330.3911	400	9.19	890.80	771.75	27.35
328.7336	600	9.32	907.28	866.51	28.73
320.6104	800	8.99	895.59	713.04	30.14
291.9203	500	9	914.04	833.61	32.70
290.4410	750	7.38	909.75	848.09	25.53
291.9203	900	7.11	935.08	846.44	24.32

σ is stress due to fatigue load, N is number of cycles that must be multiply with 1000, L is percent of elongation, U is ultimate strength, Y is yield strength and A is percent of area reduction.

Then, the data is compared with the data obtained from a virgin specimen (the specimen on which no fatigue test is done and the tensile test is carried out on it directly). The data for virgin specimen are shown in table 3.

Table 3. Experimental data for virgin specimen

L0(mm)	U0 (MPa)	Y0 (MPa)	A0
10.10	899.61	747.89	31.88

L0, U0, Y0 and A0 are the mechanical parameters for the virgin specimen.

3. Results and Discussion

Note the considerable amount of scatter in fatigue life. The existence of scatter in fatigue test results is common and deserving of considerable attention, since engineering design decisions must be based on recognition of the statistical character of

the fatigue process. The origins of test scatter are manifold. They include variations in testing environment, preparation of the specimen surface, alignment of the test machine, and a number of metallurgical variables. With regard to the testing apparatus, the least amount of scatter is produced by rotating bending machines, since misalignment is less critical than in axial loading machine [9].

By dividing percent of elongation outcomes from experimental data to the percent of elongation resulted from the virgin specimen data (L/L_0), we obtain non-dimensional values and fit the least mean square curve from each three points related to the same fatigue load and different number of cycles (fig. 3).

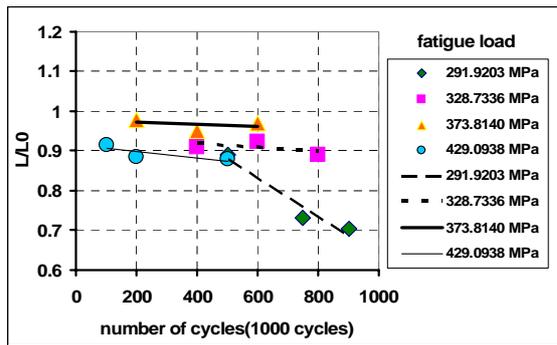


Fig. 3. Fatigue effect on percent of elongation

By dividing ultimate tensile strength outcomes from experimental data to the ultimate tensile strength resulted from the virgin specimen data (U/U_0), we obtain non-dimensional values and fit the least mean square curve from each three points related to the same fatigue load and different number of cycles (fig. 4).

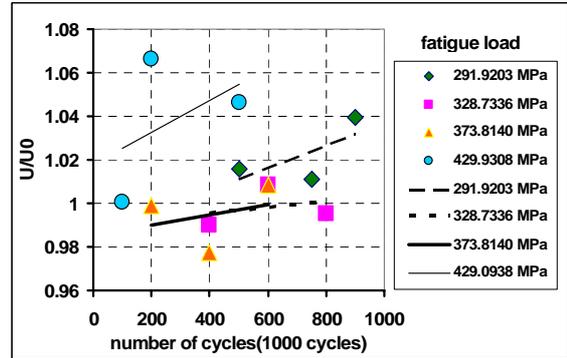


Fig. 4. Fatigue effect on ultimate tensile strength

By dividing yield strength outcomes from experimental data to the yield strength resulted from the virgin specimen data (Y/Y_0), we obtain non-dimensional values and fit the least mean square curve from each three points related to the same fatigue load and different number of cycles (fig. 5).

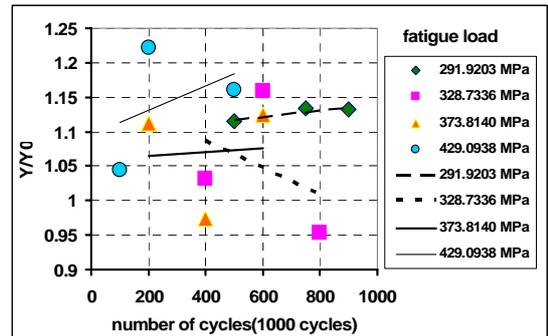


Fig. 5. Fatigue effect on yield strength

By dividing percent of area reduction outcomes from experimental data to the percent of area reduction resulted from the virgin specimen data (A/A_0), we obtain non-dimensional values and fit the least mean square curve from each three points related to the same fatigue load and different number of cycles (fig. 6).

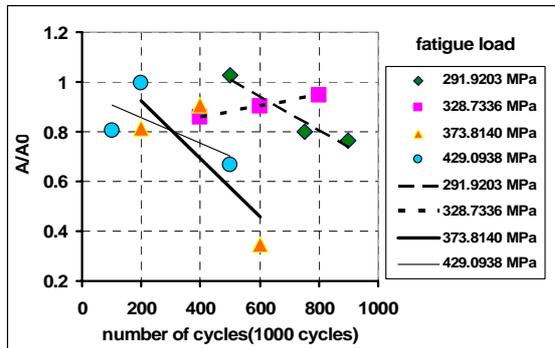


Fig. 6. Fatigue effect on percent of area reduction

Certain engineering alloys will cyclically strain harden and others will soften. Manson et al. observed that that propensity for cyclic hardening or softening depends on the ratio of monotonic ultimate strength to 0.2% offset yield strength. When $\sigma_{ult} / \sigma_{ys} > 1.4$, the material will harden, but when $\sigma_{ult} / \sigma_{ys} < 1.2$, softening will occur. For ratios between 1.2 and 1.4, forecasting becomes difficult, though a large change in properties is not expected. Therefore, initially hard and strong materials will generally cyclically strain soften, and initially soft materials will harden. Manson's rules make use of monotonic properties to determine whether cyclic hardening or softening will occur.

Generally, in this research, the ultimate tensile strength and the yield strength of the material increased and the material is hardened and in accordance, the percent of area reduction and elongation are decreased.

4. Conclusion

Results show that, in comparison to the other parameters, ultimate tensile strength is more sensitive to the fatigue test that can be a reliable criterion for fatigue damage. It is found that rotating bending fatigue test is induced that ultimate tensile strength and yield strength are increased and

area reduction and elongation are decreased. Generally, cyclic hardening occurs.

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