TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 792

EFFECT OF ALTERNATELY HIGH AND LOW REPEATED STRESSES UPON THE FATIGUE STRENGTH OF 25ST ALUMINUM ALLOY

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Aluminum Company of America

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E R R A T A

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Page 1, paragraph 1:

Fourth line should read: "at 3500 cycles per minute" instead of "at 3500 cycles per second."

Page 3, paragraph 2 under "DISCUSSION OF RESULTS":

The end of the last sentence should read: "are shown in figure 3" instead of "are shown by crosses in figure 1."

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SUMMARY

Fatigue tests were made on one lot of $\frac{3}{4}$-inch diameter rolled-and-drawn 25ST aluminum-alloy rod normal in composition and tensile properties. The specimens were tested at 3500 cycles per ~~second~~ min in a rotating-beam fatigue testing machine. Tests were made for three ratios (20:1, 50:1, and 200:1) of the number of cycles applied at low stress to the number applied at high stress.

In general, failure occurred when the number of cycles at either the low or the high stress approached the ordinary fatigue curve for the material, regardless of the sequence in which the stresses were applied.

INTRODUCTION

In many machines or structures, parts which are subjected to fatigue stresses may also sometimes be subjected to an overstress, perhaps accidentally. In aircraft propellers, such overstressing may occur as a result of vibration at certain critical frequencies existing below the normal operating speed, and they may occur during take-off.

The available information concerning the effects of this overstressing on the fatigue strength of such structural parts is rather meager, and generally concerns ferrous materials. In a recent paper (reference 1) on this subject, it was concluded that overstress may either increase or decrease the endurance limit, although the endurance limit is usually increased only by small numbers of cycles of overstress that are near the endurance limit.

In order to obtain some data concerning the effect of overstressing on the fatigue strength of aluminum aircraft propellers, certain fatigue tests of 25ST were made using alternately high and low repeated stresses. The specimens were to be subjected first to a fixed number of cycles of a high stress and then to a low stress for a larger number of cycles, this routine being repeated until failure occurred.

The object of these tests was to determine the effect of certain amounts of alternately high and low repeated stresses upon the fatigue life of 25ST; the conditions of alternately high and low stresses simulate, to a limited extent, the conditions that occur in aircraft propellers in service.

MATERIAL

All fatigue tests were made using one lot of $\frac{3}{4}$-inch diameter rolled-and-drawn 25ST rod, designated lot P-747, which was normal in composition and in tensile properties.

The chemical analysis of the rod was as follows: 4.39 percent copper, 0.49 percent iron, 0.78 percent silicon, and 0.71 percent manganese.

The tensile properties were: tensile strength, 58,900 pounds per square inch; yield strength, 33,300 pounds per square inch; and elongation in 2 inches, 25.0 percent.

METHOD OF TEST

All tests were made in the R. R. Moore rotating-beam fatigue-testing machines using standard specimens having 0.300-inch minimum diameter in the reduced section. The tests were run at a speed of 3500 cycles per minute.

The tests may be divided into three groups, according to ratio of number of cycles applied at the low stress to the number applied at the high stress, these ratios being 20:1, 50:1, and 200:1. The ratios were maintained throughout the various tests by changing the loads periodically as stated in table I. In the selection of the total number of cycles for each pair of periods of high and low applied stress, consideration was given to the expected life, this number being smaller for the tests that would be completed in a short length of time. A complete change of stress was made at least once daily except Sundays and holidays in some of the tests. With the exception of the tests using the 200:1 ratio, which were run only during regular working hours, all of the tests were run continuously to failure. In each test the nominal number of cycles in each stress period, and the respective stresses, are stated in table I. In every test, the higher of the two stresses was the first one applied.

DISCUSSION OF RESULTS

The results are summarized in table I and have been plotted in figure 1. For each test, two points have been plotted, one indicating the total cycles at the higher stress and the other the total number of cycles of stress (high and low) that the specimen withstood. Each such pair of points is connected by a broken line, with different types of broken lines indicating different ratios of stress periods. The detailed procedure in one of the tests is shown graphically in figure 2.

The solid curve shown in figure 1 was determined from regular fatigue tests of the same lot of rod (P-747). The test data from which this curve was obtained are shown ~~by crosses in figure 1.~~ in FIG. 3

In the tests originally planned in this investigation, the number of cycles of applied low stress was 20 times the number at the high stress. Four such tests were made, and in each the low stress was 12,000 pounds per square inch, which is below the regular endurance limit. In each one, the total number of cycles at the higher stress when failure occurred is in fair agreement with the regular curve, the number of cycles at the lower stress apparently having had no definitely noticeable effect upon the fatigue life at the higher stress. In three of these four tests, failure occurred during a high stress period. In the other test, failure had probably started before the last reduction in stress was made.

Larger ratios of stress periods were used in other tests in order to obtain some data concerning the effect of overstressing upon fatigue life. This overstressing consisted in a proportionately small number of cycles at a stress considerably above the lower stress used, both stresses being above the endurance limit. One test was made using a 50:1 ratio and two, using a 200:1 ratio. From the results obtained, it appears that the overstressing used in the tests had very little, if any, harmful effect upon the fatigue life.

As noted previously, the tests using the 200:1 ratio of stress periods were not run continuously. Although it is possible that the rest periods may have had an influence upon the fatigue life, the few data obtained indicate that such an effect, if any, is probably small. There has been reported, in unpublished data, some definite indication that alternate stressing above the endurance limit, followed by resting, causes a strengthening effect in a certain steel.

CONCLUSIONS

The fatigue tests of 25ST made in this investigation concerning the effects of alternately high and low repeated stresses may be summarized as follows:

1. For tests in which the greater number of cycles was at a stress below the endurance limit, the number of cycles applied at this stress apparently had no effect upon the fatigue life at the higher stress.

2. For tests in which the greater number of cycles was at a stress above the endurance limit, the relatively small number of cycles at a higher stress had little, if any, effect upon the fatigue life at the lower stress.

3. In general, failure occurred when the number of cycles at either the low stress or the high stress approached the ordinary fatigue curve for the material, regardless of the sequence in which the stresses were applied.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Penna., December 14, 1939.

REFERENCE

1. Kommers, J. B.: The Effect of Overstressing and Understressing in Fatigue. Trans. A.S.T.M., vol. 38, pt. II, 1938, pp. 249-262.

TABLE I. SUMMARY OF ALTERNATELY HIGH AND LOW REPEATED STRESS FATIGUE TESTS

Specimen number	Maximum applied stress (lb/sq in.)	Cycles per period			Number of cycles at failure	Stress at which failure occurred (lb/sq in.)
		Nominal number	Ratio: low stress / high stress			
P747-5-1	High Stress 25,000	100,000	20:1		1,096,000	
	Low Stress 12,000	2,000,000			20,049,700	
				Total	21,145,700	25,000
P747-5-3	High Stress 22,500	240,000	20:1		1,531,200	
	Low Stress 12,000	4,800,000			29,013,800	
				Total	30,545,000	22,500
P747-5-4	High Stress 20,000	[a]100,000			3,217,500	
	Low Stress 12,000	[a]2,000,000	20:1		62,677,900	
				Total	65,895,400	20,000
P747-5-2	High Stress 17,500	240,000			17,717,700	
	Low Stress 12,000	4,800,000	20:1		349,783,800	
				Total	367,501,500	12,000
P747-2-20	High Stress 25,000	100,000			224,000	
	Low Stress 17,500	5,000,000	50:1		10,158,500	25,000
				Total	10,382,500	
P747-3-1[b]	High Stress 25,000	4,000			16,000	
	Low Stress 20,000	800,000	200:1		2,904,300	20,000
				Total	2,920,300	
P747-3-2[b]	High Stress 25,000	4,000			96,400	
	Low Stress 17,500	800,000	200:1		17,258,400	
				Total	17,354,800	17,500

[a]During latter half of test, the high and low stress periods were increased to 240,000 and 4,800,000 cycles, respectively.

[b]Tests stopped each night instead of being run continuously.

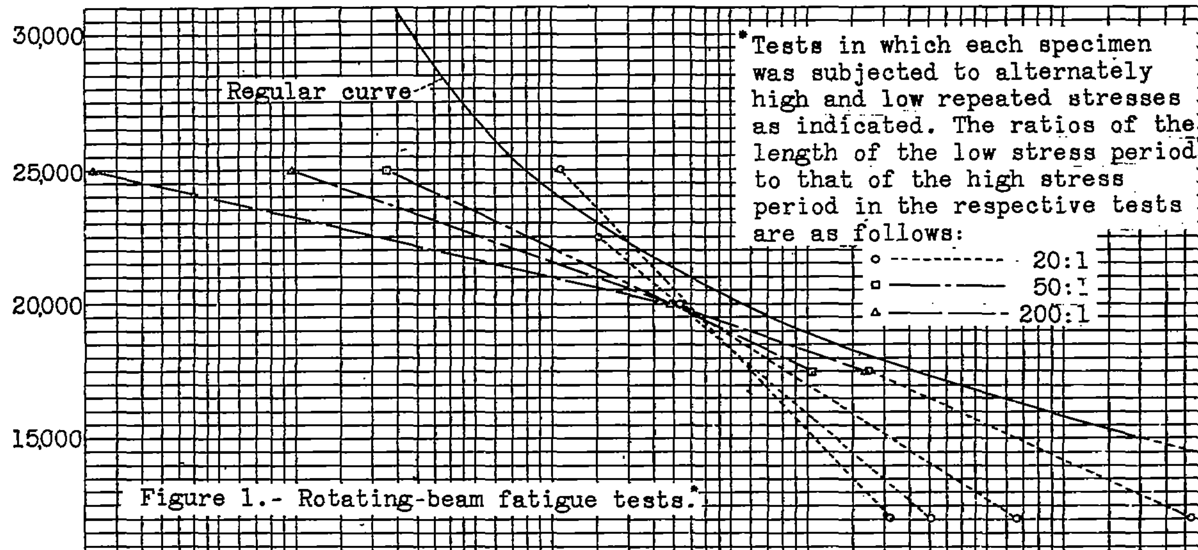

Figure 1.- Rotating-beam fatigue tests.*

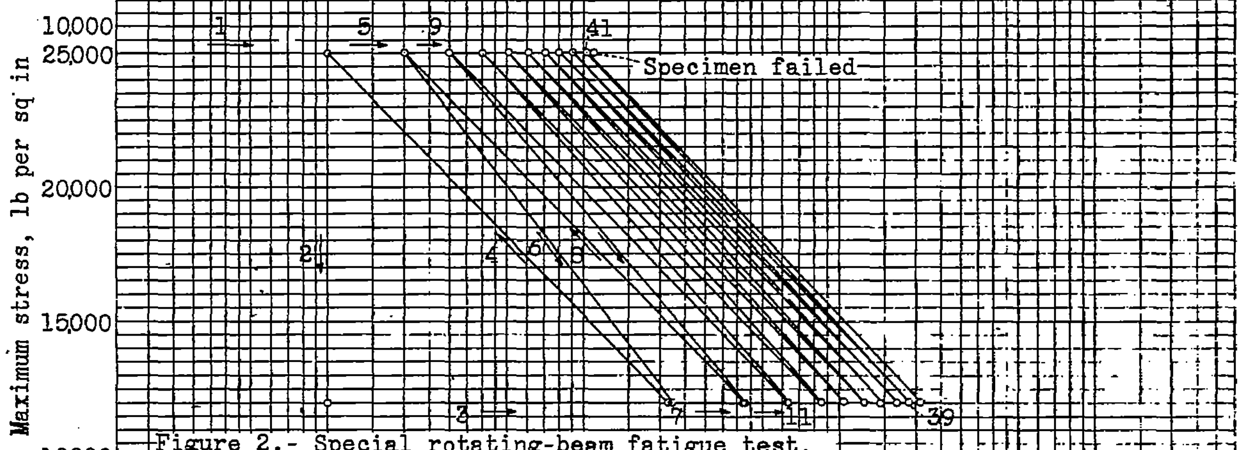

Figure 2.- Special rotating-beam fatigue test.

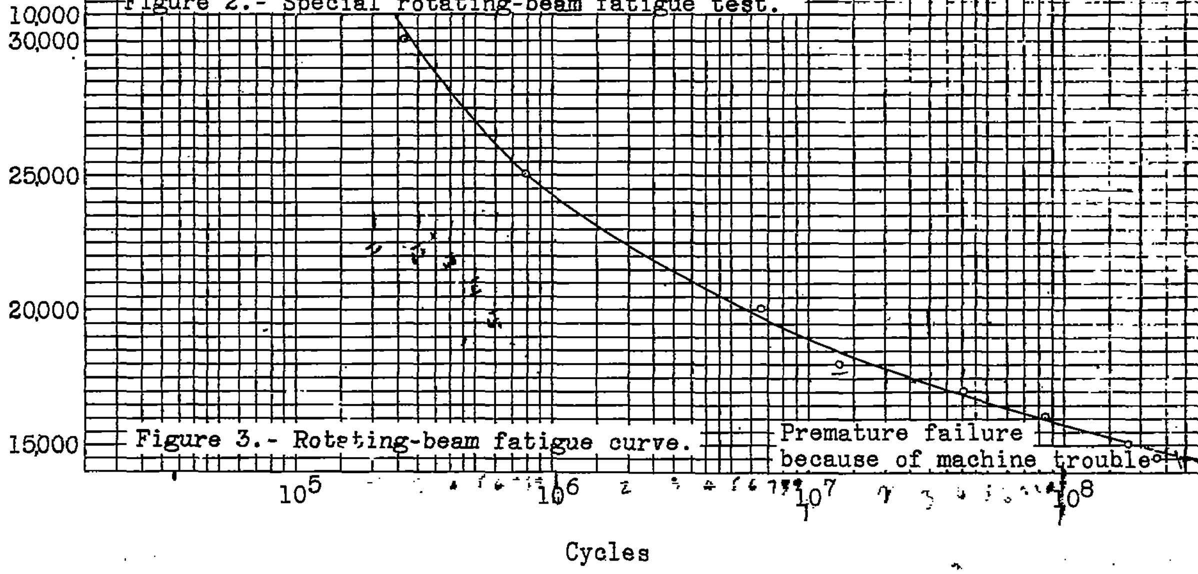

Figure 3.- Rotating-beam fatigue curve.

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