On the Fatigue Process of Metals.

Yozo MATSUOKA.

1. Introduction :

It was reported[1] already about the Fatigue Process in the case of Rotary bending. In that case, it was inconvenient to measure the variations of some properties as mensioned below. In this Experiment, by using Haihg's repeated tension and compression fatigue tester, it was intended to measure the variation of mechanical properties and specific gravity in fatigue process.

The effect of cold-working on fatigue strength was also researched. By these experiments, it was concluded how the minute crack grows and how the fatigue process may be explained.

By bending the wire- or plate-form metals severely, we can minimize the number of repetitions to fatigue failure less than 50. In such a case, the effects of cold-working and annealing were researched, and this contributed to construct the conclusion.

2. Variation of mechanical properties in fatigue process :

In a case of 0.3% carbon steel, and under 30 kg/mm^2 repeated stress, various numbers of repetitions were given to a series of test pieces. Next, statical tension tests were carried out to such a series, and thus the effects of fatigue to the mechanical properties were researched. In Fig. 1 and 2, the results were shown, and by these we can conclude as follows :

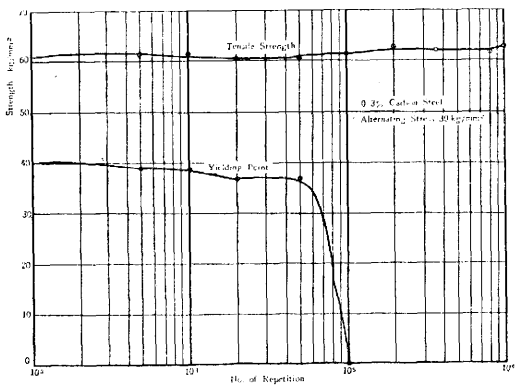

Fig. 1 Effect of Stress Repetition on Mechanical Properties.

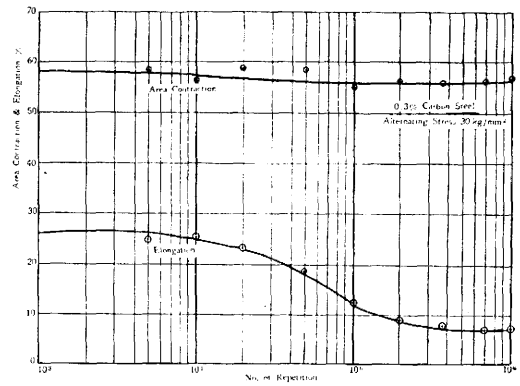

Fig. 2 Effect of Stress Repetition on Mechanical Properties.

(1) Remarkable variation were not seen to 10^4 repetitions.

(2) Tensile strength was increased in small extent for the repetitions above 10^4.

(3) Elongation was decreased remarkably with the number of repetitions.

(4) As the elongation after local contraction showed little variation in every cases, it was concluded that the elongations to the maximum load were affected enermously by the numbers of repetitions. If there were any crack in the metal, the elongation after local contraction must become smaller, In this point of view, the cracks in every these fatigue

procsses were not so great, and it is proper to consider these must be the effect of work-hardening.

(5) Area contraction showed small change. This coincide with the conclusion above obtained.

(6) Yielding points were diminished above 5×10^4 repetitions.

By these experiments, we can conclude as follows : In early period of fatigue process, any change of material must not be seen. After that, the material be work-hardened gradually. The growth of minute crack will be seen in the later period just before the fatigue failure. It must be started from the slip lines or grain boundaries severely stressed, after the work-hardening of these parts reached in some extent.

3. Variation of Specific Gravity in Fatigue process :

If the minute cracks were formed and grown in fatigue process, the specific gravity of metals must be decreased apparently.

Specific gravity may be changed even by the simple cold-working. So the changes of specific gravity in tensile and compressive cold-workng were examined. As is seen in Fig. 3, Specific gravity in tensile load were decreased clearly, but showed little change in compressive load.

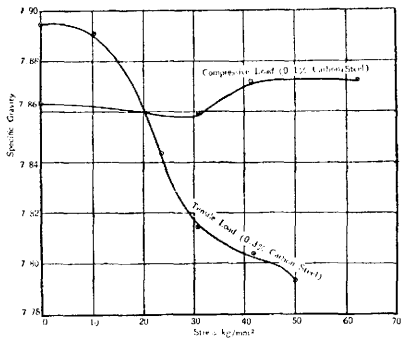

Fig. 3 Change of Specific Gravity by Cold Working.

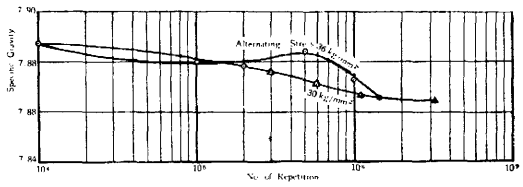

Fig. 4 Effect of Stress Repetition on Specific Gravity. (0.3% Carobon Steel)

In a case of 0.3 % carbon steel, under 36 kg/mm^2 and 30 kg/mm^2 repeated stresses, remarkable change were not seen as in Fig. 4. It was decreased in small extent with the number of repetitions. It must be the effect of work-hardening. It was impossible to find the behavior of minute crack from this experiments, as expected. But we can say a great crack must not be formed until the period just before the fatigue failure.

4. Effect of Cold-working on the fatigue strength :

The internal change produced in metals in fatigue process must be

(1) Work-hardening due to stress reversal.

(2) Formation and growth of minute crack.

By the work-hardening (1) only, fatigue failure must not be occured even if the strength were incresed. As the toughness is minimized, it becomes weaker indirectly, but fatigue failure must not be occured if the cracks were not formed. About the minute crack (2) it is believed, it exist initially as a defect of metals, or scratches caused by working. By our observation, there must be some cases not involved by the above mensioned causes. That is to say, there are some

cases, the minute cracks are formed and grown, and by this cracks, fatigue failure takes place. Anyway, the period, in which the minute crack grows to crack, must be in the later period of fatigue process, as mensioned above. And it is clear that the formation and growth of crack must have the relation with the work-hardening by stress reversal.

In Fig. 5, this relation were shown. In this experiment, the test pieces work-hardened in various degrees, were broken down by the Haigh's fatigue tester, and were compared with their numbers of repetitions to failure. From this, we can find that the numbers of repetitions were decreased with the degree of work-hardening, and also the fatigue strength were decreased. It shows that the formation and growth of minute crack becomes easier as the degree of work-hardening incleases. The work-hardening, in this meaning, is the cause of fatigue failure indirectly.

5. Supplementary experiments :

By bending the wire- or plate-formed metals severely, we can minimize the numbers of repetitions to fatigue failure to any small quantity as we wish. To research the fatigue process easily, two experiments were carried out by this principle, and were contributed to introduce the conclusion.

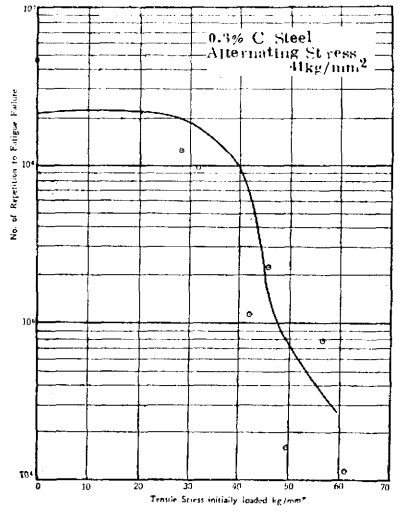

Fig. 5 Effect of Cold Working on Fatigue Strength.

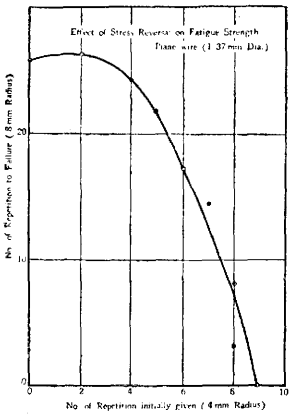

Fig. 6 Effect of Stress Reversal on Fatigue Strength.
Piano wire (1.37mm Dia.)

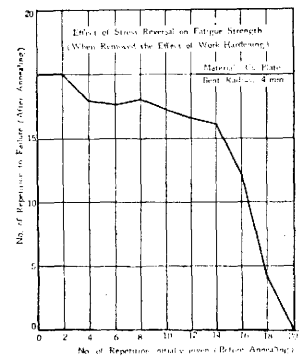

Fig. 7 Effect of Stress Reversal on Fatigue Strength.
(When Removed the Effect of Work-Hardening)

When piano wire were bent with 4 mm radius, it was broken down in 9 repetitions. To a series of piano wire thus bent in various repetitions, bending with 8 mm radius were given until failure occurs. In Fig. 6, we can see that the pieces which are given initially 2 or 3 repetitions were not changed the final repetitions, compared with virgin state pieces. That is, Minute crack does not grow in this period, and grows in the succeeding steps. The same results were got for Al, Cu and brass wire.

Bending with 4 mm radius were given to a series of Cu plate (annealed previously) in various repetitions. Next, annealing were given to the series so as to remove the effect of work-hardening. If any crack had been formed, it can not be removed nevertheless annealing. And succeeding step, they were broken to failure by bending 4 mm radius. The results thus got are

shown in Fig. 7. This indicate that the crack did not grow under the repetitions within 2, and grew gradually above that repetitions. To the repetitions over 14, numbers of repetitions to failure suddenly decreased. This indicates that there were a effect which had not been removed with annealing, i. e. the growth of minute crack.

By these, we can see that the initial repetitions are followed by the work-hardening only, but the succeeding steps, they are followed by the growth of minute crack, which leads to fatigue failure.

6. Conclusion :

The fatigue process may be explained as follows :

(1) When reversed a stress over elastic limit, metals be work-hardened and becomes brittle.

(2) The growth of minute crack, which is the cause of fatigue failure, takes place after the work-hardening reached to a certain extent. This minute crack grows very slowly, and it is just before fatigue failure that the minute crack grows to "crack".

(3) By the reversal of comparatively small stress (under fatigue limit), minute crack do not grow, though the work-hardening may be succeeded. It is because of its smaller extent of work-hardening. Metals suffered such a small stress, will be failed with smaller repetitions than the virgin metals, when stressed severely.

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(1) : R. Yamada & Y. Matsuoka ; Journ. of Japan Soc. of Mech. Engr. May 1934, P 273—281.

ジシアンジアミドの繊維への應用に關する研究

(第 1 報)

宮岡宇一郎　松井武夫

Investigation on the Applications of Dicyandiamide to the Textile Fibers. (The 1 st report)

Uichiro MIYAOKA,　Takeo MATSUI

Description of project :

A certain condensation product is obtained when dicyandiamide reacts on higher alcohol chloromethyl ether, i. e.,

$$R\text{-}O\text{-}CH_2\text{-}Cl + CN\text{-}NH\text{-}C\begin{matrix}NH\\NH_2\end{matrix} \rightarrow CN\text{-}NH\text{-}C\begin{matrix}NH\\NH\text{-}CH_2\text{-}O\text{-}R\end{matrix} + HCl$$

When textile fibers are dipped in solution or suspension of this substance, dried and baked a short time, the fibers are made highly water-proof. Cotton and rayon are mordanted to acid Colours.

Above are the results of preliminary investigations we made. Here we attempt to study this Phenomenon in detail.

Result obtained :

1. Aliphatic alcohol chloromethyl ether

Aliphatic alcohol chloromethyl ether (Octadecyl, Cetyl, Lauryl, Octyl, Butyl, Ethyl etc) are synthesized,