Fatigue Property of Incoloy 800 Alloy

by Tadashi AIHARA & Tomoyuki ISHII***

Summery

The fatigue test has been made for Incoloy 800 alloy by tension-compression type testing machine under controlled stress amplitude. This alloy is able to be hardened by the precipitation of gamma prime particles, and the fatigue strength is improved by the age hardening heat treatment. By the observation of stress and strain during alternating stressing the remarkable characteristics of fatigue behavior are as follows; i) The strain amplitude maintains almost constantly except the vicinity of failure. ii) The total strain increases with number of cycles. iii) Elongation of test piece may be due to the plastic deformation of crystal grains.

1. Introduction

Incoloy 800 is used as materials for vessel and tube at high pressures and high temperatures in chemical industries. Recently, this alloy has come to attract attention also as materials for the atomic energy plants[1]. However, because of the short term of history, there are few available data on the fatigue property of this alloy.

Incoloy 800 contains 20% Cr, 30% Ni, 0.5% Ti and 0.5% Al typically. The microstructure after solution treatment consists of austenite phase, and after ageing treatment the gamma prime phase, Ni_3(Al, Ti), precipitates homogeneously in the matrix. The fineness of this particles is almost under 1000 angstrom[2].

We have been interested in the testing method of tension-compression type under controlled stress amplitude, because of the deformation phenomena during fatigue testing which is observed by the recording of stress-strain curves in each cycles. Thus, we have already reported on the fatigue properties of 17-4 PH steel and 18-8 stainless[3].

In this present paper we report the fatigue property of Incoloy 800 investigated and discuss on the difference of deformation phenomena of this alloy with and without the precipitation of gamma prime phase.

2. Material and experimental

Commercial Incoloy 800 alloy was used for this investigation. The chemical composition and tensile properties of the alloy are listed in Table 1. And heat

* 理工学部機械工学科教授　工業材料
** 理工学部機械工学科助教授　機械材料

Table 1. Chemical composition and mechanical properties

Alloy	C	Si	Mn	P	S	Ni	Cr
Incoloy 800	0.04	0.69	1.16	0.017	0.006	33.09	19.30

wt %

Al	Ti	Cu
0.41	0.50	0.21

kg/mm²

Tensile strength	Yield strength
55	15

As solution treated

treatment was made by the instruction of catalogue[4]; solution heat treatment at 1150°C in 0.5 h and age hardening heat treatment at 700°C in 24 h. The fatigue test was made by the tension-compression type testing machine with capacity of 30 ton. The machine is driven by oil pressure and controlled by servo valve. The appearance of the testing machine is shown in Fig. 1. During fatigue testing

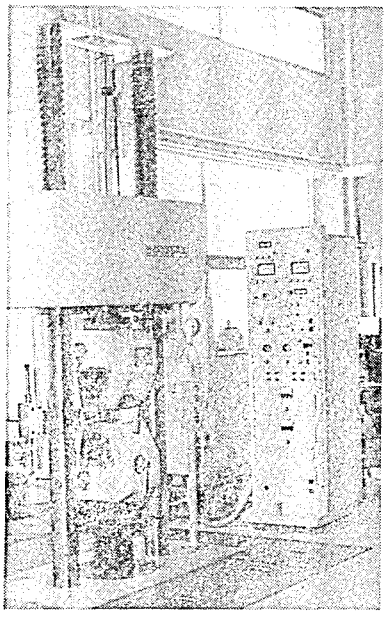

Fig. 1 The appearance of fatigue testing machine.

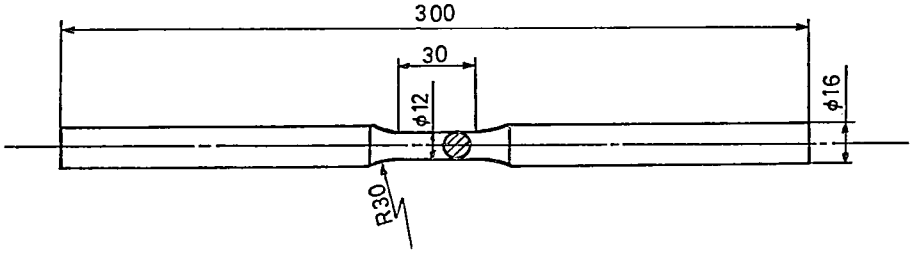

Fig. 2 The size of test piece for fatigue test.

the stress and strain are detected respectively by load cell and differential transformer, and are recorded by the X-Y recorder. In this investigation, test was performed under controlled stress amplitude up to about 10^4 cycles. The cyclic period is almost 1 Hz. The size of test piece is shown in Fig. 2; the gauge length is 30 mm and the diameter is 12 mm.

3. Experimental results and discussion

The S-N curves of Incoloy 800 with and without age hardening heat treatment are shown in Fig. 3. The fatigue strength of 10^4 cycles for solution treated alloy is 25 kg/mm^2 and after age hardening heat treatment it becomes 45 kg/mm^2. The

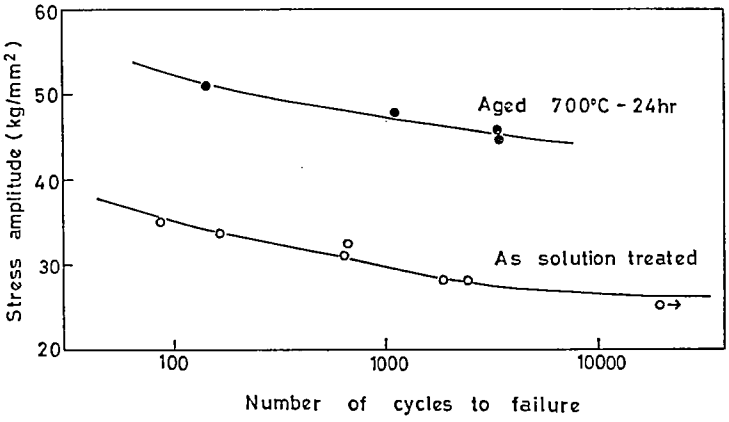

Fig. 3 The S-N curves of Incoloy 800 alloy with and without age hardening heat treatment.

strength level by this investigation is almost similar as that by conventional rotating-beam testing[4]. The Vickers hardness number of 161 and 253 are measured respectively in solution treated condition and age hardening treated. From these results,

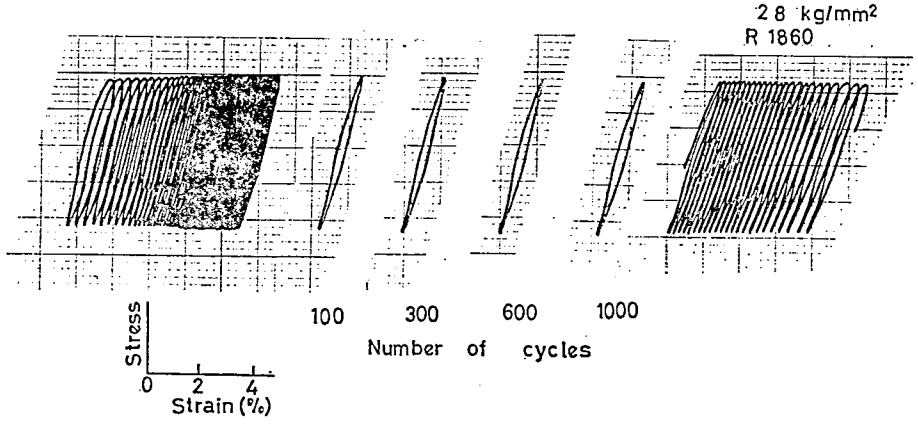

Fig. 4 The stress-strain hysteresis loops at each cycles of alternating stressing.

the age hardening heat treatment is also effective to improve fatigue strength. The both S-N curves show almost flat curves up to 10^4 cycles. So the clear bending or fatigue limit is not observed. In this investigation there is the difficulty of experimental method for higher stress amplitude side. Because the phenomenon of buckling or heterogeneous deformation in test piece arises.

In Fig. 4 the stress-strain hysteresis curves at each cycles for the solution treated specimen are shown. In the starting period the hysteresis loops are not closed and tend to elongate. After several ten cycles the hystresis loops go to be closed. The shape of hysteresis curves changes slightly with number of cycles, that is, the width of loops tends to widen slightly. At the vicinity of failure the hysteresis loops also become loose. At the same specimen, the strain amplitude with number of cycles is shown in Fig. 5. The strain amplitude is maintained almost constantly, however, it increases at the vicinity of failure. On the contrary, as shown in Fig. 6 the total strain increases progressively with number of cycles. This curve is not smooth and shows many steps.

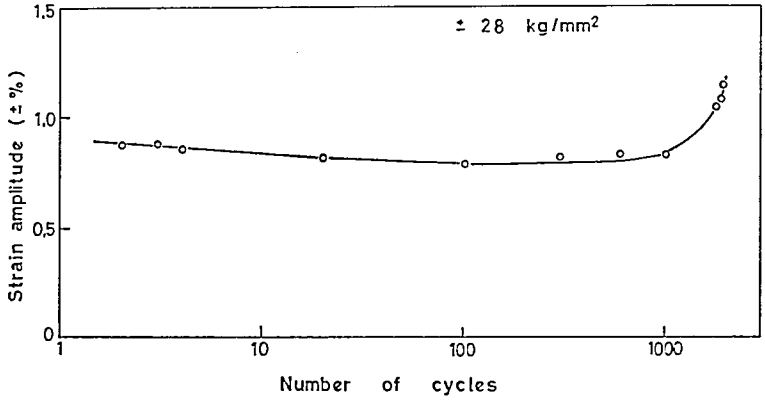

Fig. 5 The change of strain amplitude with number of cycles.

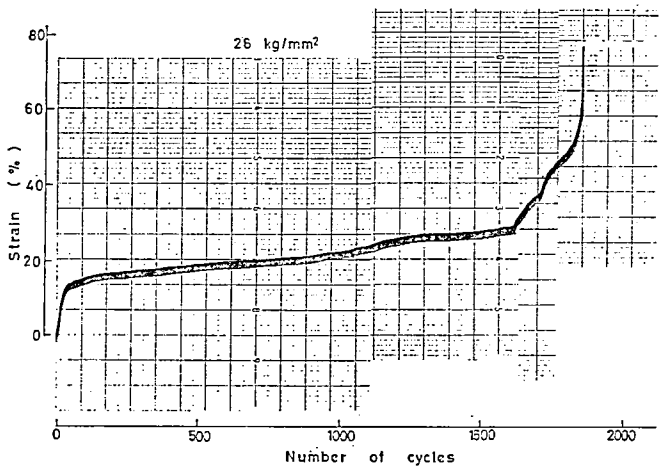

Fig. 6 The total strain of specimen with number of cycles for solution treated alloy.

Almost similar tendency is observed for the age hardened specimens. The total strain with number of cycles for age hardened specimen is shown in Fig. 7. The total strain also increases with number of cycles and containes many discontinuous steps. This fact shows that this alloy can deform plastically by the alternating stressing at the hardened condition. The microstructure of age hardened specimen after fatigue testing is shown in Fig. 8. In this photo, its appearance shows that the grain boundary, twin boundary and crystal grains are deformed.

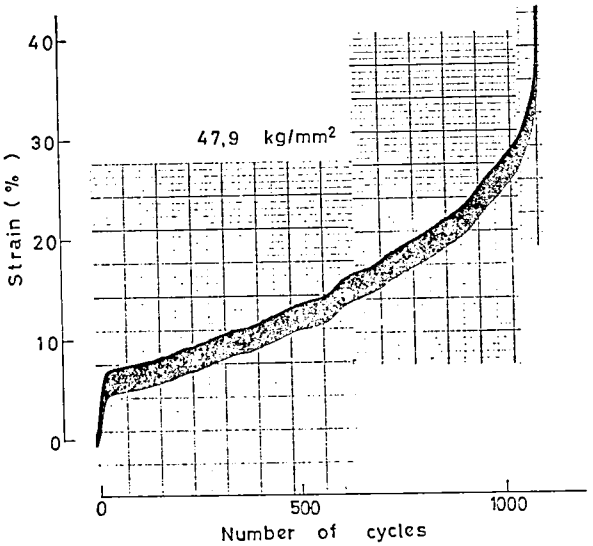

Fig. 7 The total strain of specimen with number of cycles for age hardened alloy.

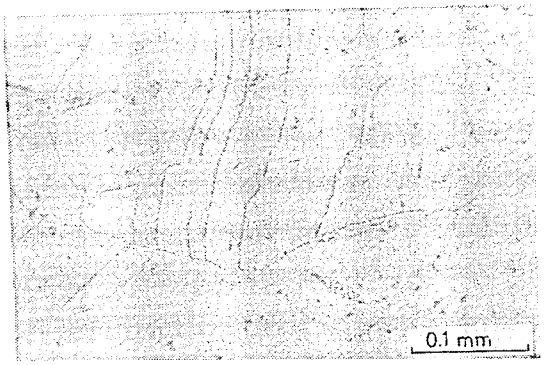

Fig. 8 The microstructure of the specimen after fatigue test.

The fatigue behavior of Incoloy 800 is similar to that of 18-8 stainless steel[8]. The characteristics of this behavior can be expressed as follows; the strain amplitude maintains almost constant except the vicinity of failure, and the total strain increases progressively with cycles. This elongation of specimen can not be explained by the simple mechanism of crack initiation and propagation. In this process, the fatigue should be caused by the plastic deformation of crystal grains, as shown in

Fig. 8. And this plastic deformation can not be disturbed by the precipitated gamma prime particle, because age hardened alloy also shows large amount of elongation as shown in Fig. 7.

4. Conclusion

The fatigue property of Incoloy 800 alloy is investigated by the tension-compression type fatigue testing machine under controlled stress amplitude.

1) The fatigue strength at 10^4 cycles of solution treated alloy is 25 kg/mm^2 and that of age hardened alloy is 45 kg/mm^2.

2) The S-N curves of alloy with and without age hardening heat treatment show no clear bending or fatigue limit in the range of this investigation.

3) The strain amplitude during alternating stressing maintains almost constantly except the vicinity of failure. On the contrary, the total strain increases progressively with number of cycles.

4) In the fatigue process of this alloy, it is suggested that the elongation of test piece during fatigue testing may be due to the plastic deformation of crystal grains.

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2) R. Lagneborg: JISI, (1969) p. 1503

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4) Catalogue of Incoloy "Nickel-Chromium Alloy" (1973), International Nickel Company

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