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Evaluation of Fatigue Properties of SWOSC-V Spring Steel in Very High Cycle(VHC) Region using Ultrasonic Fatigue Test

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1. Introduction

Fatigue properties of material are considered as major parameters assessing the reliability of structures. Especially, very high cycle fatigue (VHCF) is becoming more important in many mechanical components. It was reported that steels show fatigue limits at 10^7 cycle but recent researches have shown that metals can fail after 10^7 cycles. For example, fatigue life of express train is over 10^9 cycles and 10^{10} cycles for turbine engines [1]. With conventional fatigue test methods, it is almost impossible to conduct gigacycle fatigue tests. In 1950, the first 20 kHz ultrasonic machine was built by Mason. Using piezoelectric converter, Bathias and his colleagues constructed ultrasonic fatigue tester. The machine produces mechanical vibration from electrical signal. It has been shown that ultrasonic fatigue test is an efficient method to investigate gigacycle fatigue properties of materials [1-6].

2. Materials and methods

In this study, ultrasonic fatigue tests were conducted for SWOSC-V steel. Table 1 shows the chemical composition of the alloy.

Ultrasonic fatigue test specimen should be fabricated into correct dimensions to satisfy resonance condition. Resonance length L_1 is determined as in Eq. (1) [3].

$$L_1 = \frac{1}{k}\arctan\left\{\frac{1}{k}[\beta\coth(\beta L_2) - \alpha\tanh(\alpha L_2)]\right\} \quad (1)$$

where k, α and β are material and dimensional constants. L_2, R_1 and R_2 are dimensional parameters.

Stress amplitude σ_a applied at the specimen can be calculated from the displacement at the end of the specimen;

$$\sigma(x) = E_d A_0 \varphi \frac{[\beta\cosh(\beta x)\cosh(\alpha x) - \alpha\sinh(\beta x)\sinh(\alpha x)]}{\cosh^2(\alpha x)} \quad (2)$$

where

$$\varphi(L_1, L_2) = \frac{\cos(kL_1)\cosh(\alpha L_2)}{\sinh(\beta L_2)} \quad (3)$$

Stress amplitude was controlled by output energy level of the piezo converter and stress ratio R was -1.

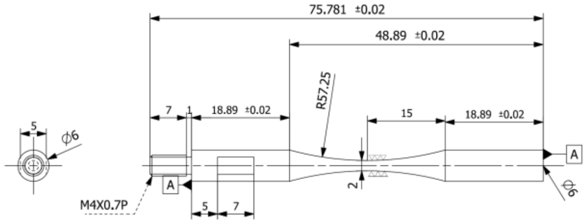

Fig. 1 Schematics of ultrasonic fatigue test specimen

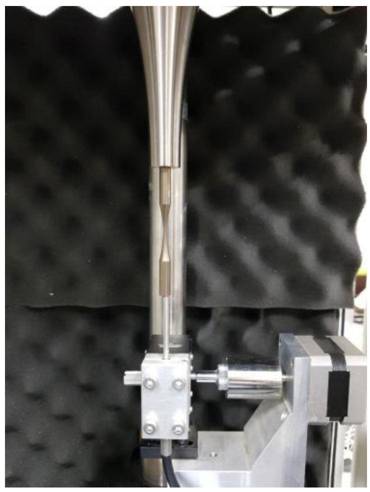

Fig.2 Specimen installation

Table 1 Chemical composition of the alloy

Element	C	Si	Mn	P	S	Cr	Cu	Al	V
%	0.60~ 0.68	1.30~ 1.60	0.60~ 0.80	<0.025	<0.025	0.50~ 0.80	<0.20	<0.003	0.10~ 0.25

3. Results and discussion

S-N curve was obtained from ultrasonic fatigue tests. Specimens failed at various cycles from 10^5 to 10^8 cycles. It was reported that high strength steels show surface fatigue fracture mode until high cycle region and subsurface fatigue fracture between 10^7 to 10^9 cycles [5]. However, fracture surfaces of the specimen used in this study showed surface fatigue fracture modes.

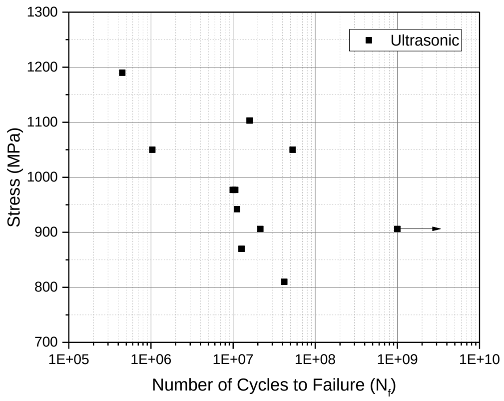

Fig.3 S-N curve of SWOSC-V alloy

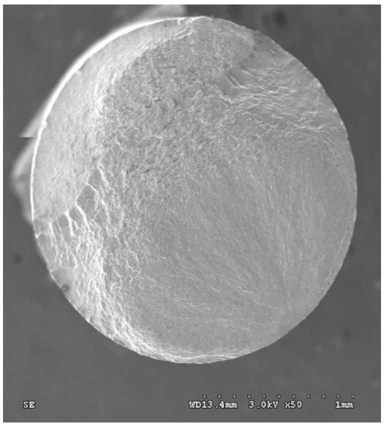

Fig. 4 Fracture surface of the specimen

4. Conclusions

To evaluate fatigue characteristics of SWOSC-V spring steel, ultrasonic fatigue tests were conducted. The results show that surface fatigue fractures occur even after 10^7 cycles. It is necessary to evaluate the effect of inclusion.

Acknowledgment

References

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