Effect of Soft Particle Peening Treatment on Fatigue Strength of Copper Alloy

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Abstract

This study examined the effect of soft particle peening treatment on the fatigue strength properties of copper alloys. Walnut, apricot, peach, and polyethylene particles were used as the projectiles in the soft particle peening treatment. The hardness of these projectiles was lower than that of copper alloys, and the particles were softer. Plane bending fatigue tests showed that the number of cycles to failure increased at stresses of 140 MPa and 120 MPa regardless of the projectile material. In addition, it is considered that apricot and polyethylene particles are particularly effective in improving fatigue strength when compared with each projectile material. The results of hardness measurement showed that the hardness increased in all the projectile materials. In addition, apricot and polyethylene showed particularly large increases in hardness. Surface roughness measurements showed that surface roughness increased for all projectile materials. The increase in surface roughness was the smallest for polyethylene. The results show that polyethylene particles are effective in improving the fatigue strength of copper alloys among the particles used in this study. The results of this study suggest that the soft particle peening treatment is effective in improving the fatigue strength of copper alloys.

Keywords Shot peening, Soft Particle, Fatigue, Copper alloy

1. Introduction

In recent years, the electrification of automobiles and other transportation equipment, such as EVs and hybrids, has been promoted. From this perspective, the use of copper alloys is increasing, not only in connectors, but also through the use of joining techniques such as dissimilar metal joining. Copper alloys have excellent heat transfer and electrical properties, but they have lower strength than alloys used for structural components such as steel and aluminum alloys. In addition, copper alloys have not received much attention for use as structural members, and little research has been conducted on methods to increase the strength of copper alloys because of the difficulty of increasing strength through heat treatment and other methods. In addition, the methods for strengthening copper alloys have not been studied extensively because it is difficult to increase strength by heat treatment.
In this study, we focused on shot peening, which utilizes work hardening by particle impact, as a method for improving the fatigue strength of copper alloys.[1-3]

Shot peening improves fatigue strength by increasing hardness and imparting residual stress through work hardening, and is thought to be effective in improving fatigue strength even in copper alloys with low melting points.

On the other hand, conventional shot peening treatments generally use ceramic or steel particles as the projectile. When such hard particles are used, there is a possibility that the impacted particles may penetrate the surface of the work piece, as reported by the authors and Kameyama et al.[4,5]

This impinging effect may cause microcracks and other factors that reduce fatigue strength. In addition, the increase in surface roughness caused by the use of hard particles is a factor that reduces fatigue strength. Therefore, in this study, a "soft particle peening treatment" using softer particles than those used in the conventional shot peening treatment was performed. The objective of this study was to clarify the effect of the soft particle peening treatment on the fatigue strength of copper alloys by using naturally occurring particles with lower hardness than copper alloys as the projectile material.

2. Treatment and Experimental Methods

2.1 Specimens

Oxygen-free copper (JIS C1020) was used as the test material. The chemical composition of the material is shown in Table 1. The specimens were plane bending fatigue specimens as shown in Figure 1, and were machined by electrical discharge machining. The specimen surfaces were not polished.

Table 1 Chemical Compositions

	Cu	Pb	Fe	Sn	Zn	Al	Mn	Ni	P
C1020	99.96%over	–	–	–	–	–	–	–	–

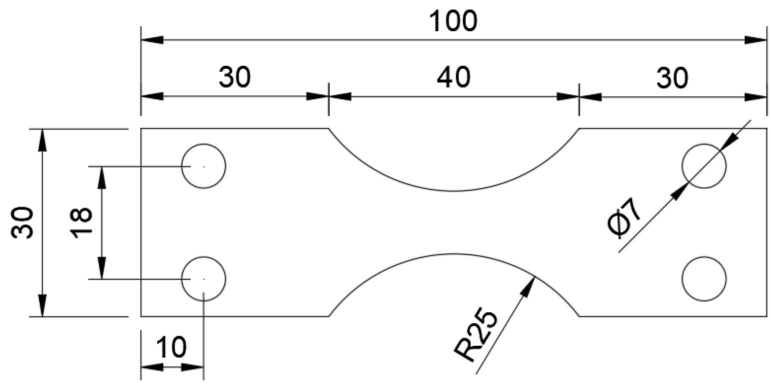

Figure 1 Bending fatigue specimen

2.2 Soft particle peening treatment

A pneumatic sandblasting machine was used for the soft particle peening treatment. Walnut, apricot, peach, and polyethylene were used as the projectiles. The particle size and hardness of each projectile are shown in Table 2. Figure 3 shows an optical micrograph of each particle. The projectile pressure in the soft particle peening treatment was 0.5 MPa, and the treatment time was 120 seconds.

2.3 Test method

The fatigue test was performed by plane bending fatigue test. The number of cycles was 10^6, and the number of specimen fractures was measured at stresses ranging from 160 to 100 MPa. Hardness tests were conducted using a Shimadzu dynamic hardness tester. DHT-115 was used as the unit of hardness measurement. Surface roughness was measured by non-contact measurement using a laser microscope.

Table 2 shot particles

	Walnut	Polyethylene	Peach	Apricot
Diameter (μm)	80	180	150	110
DHT-115	1.6	5.6	2.4	0.6

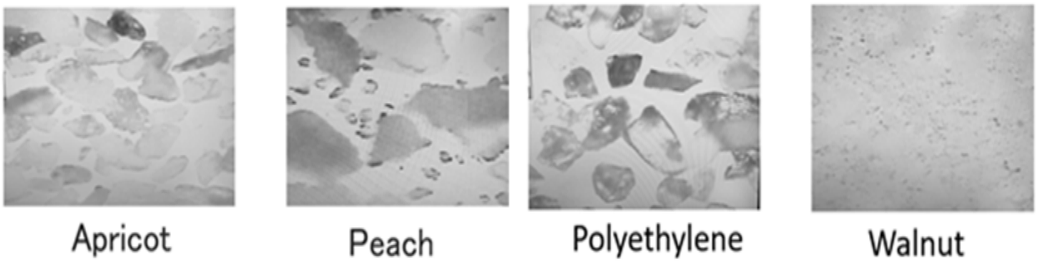

Figure 3 Optical micrographs of each particle

3. Experimental Results and Discussion

3.1 Results of Plane Bending Fatigue Tests

Figure 2 shows the fatigue test results. The fatigue limit was 110 MPa for both the untreated material and the material treated by soft particle peening. Next, let us focus on the 140 MPa limit. Compared with the fracture frequency of the untreated material, the fracture frequency of the soft-particle peened material increased regardless of the projectile material, indicating that the time strength increased. The time strength of the soft-particle peening material at 120 MPa was also higher than that at 140 MPa. These results suggest that the soft-particle peening treatment is effective in improving the time strength of copper alloys.

At these stresses, differences in the soft-particle peening material projectile are discussed. At 140 MPa, the order of the soft particle peening materials was apricot, peach, walnut, and polyethylene. At 120 MPa, the order was polyethylene, peach, apricot, and walnut. In terms of the hardness of the projectile, polyethylene has the highest hardness of 5.6 DHT115, but the hardness of the copper alloy is sufficiently small compared to 140 DHT115. In addition, since there was only one measurement point in the fatigue test, it is considered that there is some variation in the test results.

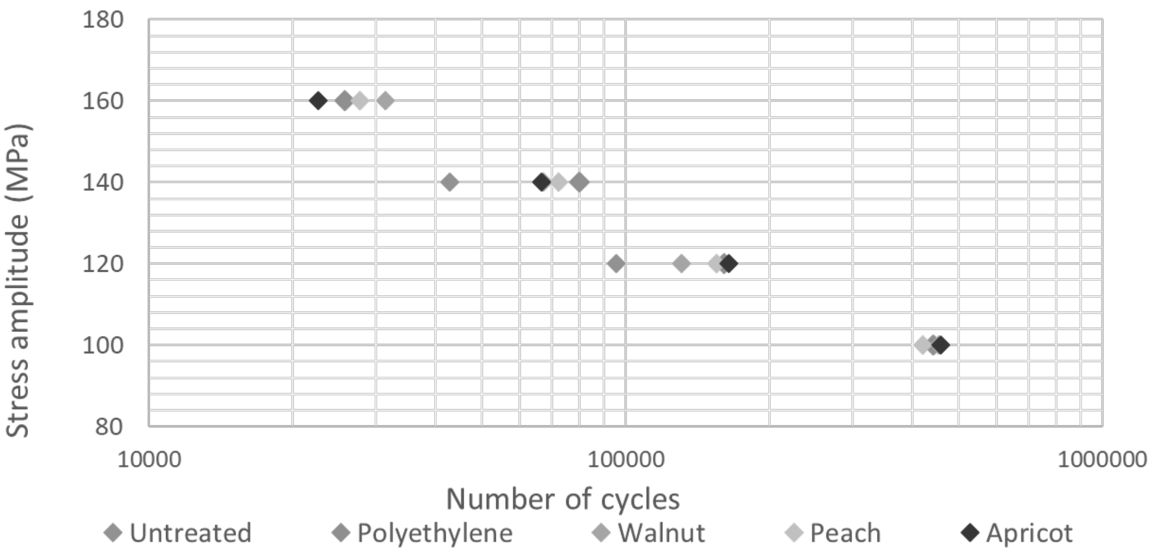

Figure 2 Result of fatigue experiment

3.2 Hardness Measurement Results

Figure 3 shows the results of hardness measurements. The hardness of the untreated material decreased from the surface to a depth of 20 μm, which is thought to be due to work softening that occurred during cutting or rolling.

No decrease in near-surface hardness is observed for any of the soft particle peened materials. This result indicates that near-surface hardness is not reduced by soft particle peening in the vicinity of the surface where the hardness is reduced by work softening.

This result suggests that the soft-particle peening treatment improved the hardness in the vicinity of the surface where the hardness decreased due to work softening.

On the other hand, as mentioned above, the hardness of the projectile materials used in the soft-particle peening treatment is lower than that of the copper alloys. It is believed that the hardness is conventionally increased by work hardening due to plastic deformation in the shot peening treatment.

The hardness of the shot peening treatment is said to be improved by work hardening due to plastic deformation. In the present study, plastic deformation is not considered to have occurred in the soft-particle peening treatment. Therefore, the mechanism of hardness improvement by soft particle peening treatment may be different from that by conventional shot peening treatment. Therefore, the mechanism of hardness improvement by soft particle peening treatment is expected to be different from that by conventional shot peening treatment. The mechanism of hardness improvement should be further investigated.

Next, a comparison of the projectile materials showed that the hardness increased the most when polyethylene particles were used, followed by polyethylene, apricot, walnut, and peach.

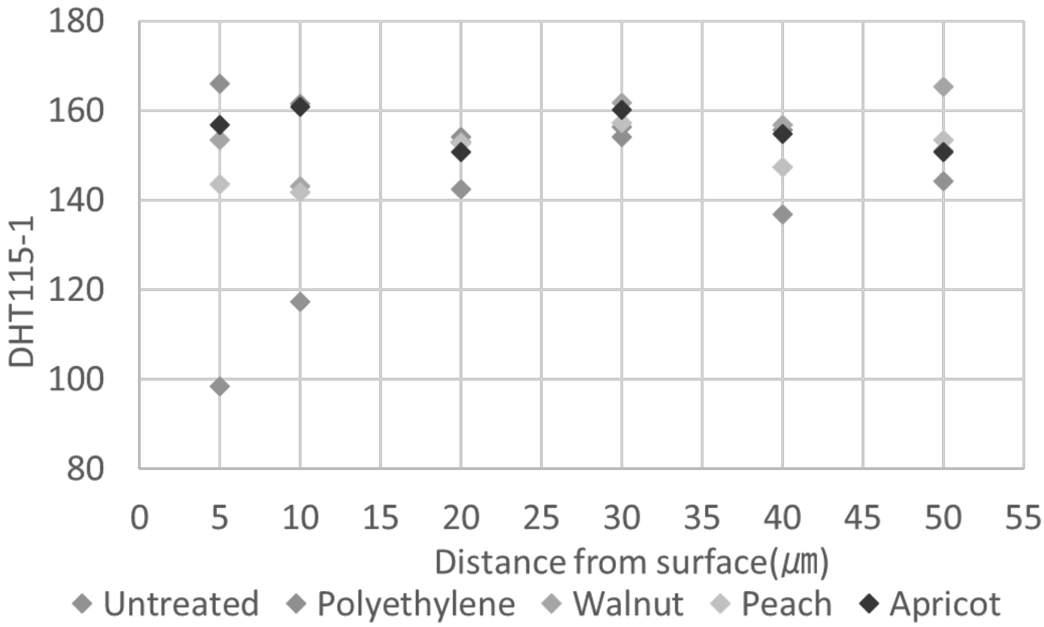

Figure 3 Result of hardness measurement

3.3 Surface Roughness Measurement Results

Figure 4 shows the results of surface roughness measurements. The surface roughness of the soft particle peening treated material increased compared to the untreated material. The surface roughness of polyethylene, which has the highest hardness of the projectile, was lower than that of the other projectile materials. On the other hand, the surface roughness of apricot, which has the lowest hardness of the projectile, also increased. It is not clear whether this is due to the properties of the copper alloy or the properties of the projectile. It is expected that the behavior of these projectile materials during particle impact differs from that of conventional metallic and ceramic particles. The collision behavior of these materials should also continue to be investigated.

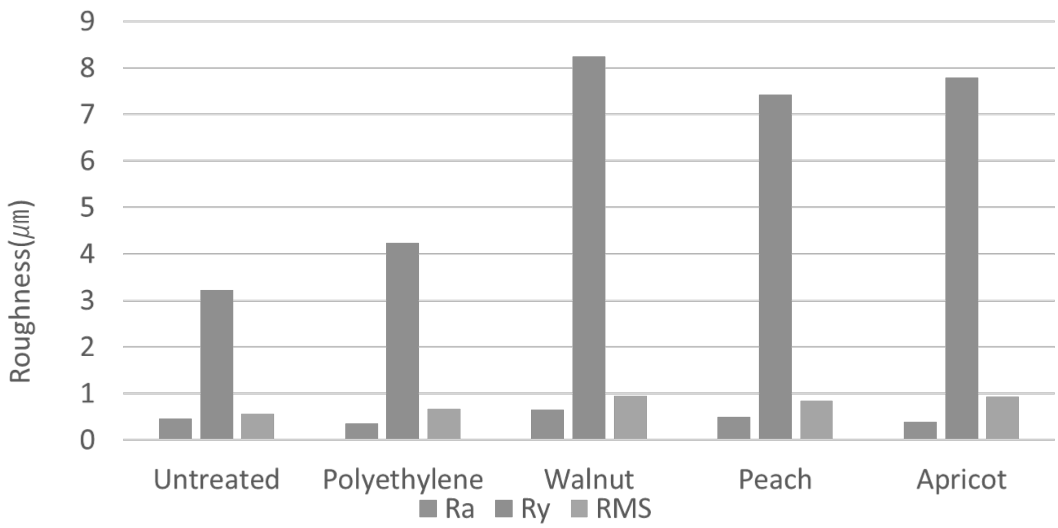

Figure 4 Result of surface roughness measurement

4. Conclusions

The effects of soft particle peening treatment on the fatigue strength properties of copper alloys were investigated and the following conclusions were obtained

1. Soft particle peening treatment is effective in improving the fatigue strength of copper alloys regardless of the type of projectile.
2. Even when softer particles than the work material are used, the hardness in the vicinity of the surface is improved.
3. Surface roughness increased regardless of the type of projectile.
4. Factors that increase hardness and surface roughness will continue to be investigated in the future.

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