INFLUENCE OF SHOT PEENING ON FATIGUE STRENGTH OF ALUMINUM-ALLOY PARTS

H. Suzuki 1, Dr. H. Makino 1, K. Mizuno 1, T. Tomita 1

1 SINTOKOGIO, LTD., Nagoya, Japan

ABSTRACT

Considering energy savings and the growing environmental concerns, light weight components are increasingly becoming popular in various fields of engineering applications. The use of light-alloy parts has been a common approach to meet the above requirements. However, most light-alloy parts cannot be widely used because of their short fatigue life. Improvement of fatigue life of light-alloy parts is imperative. One way to improve fatigue life is by shot peening which is currently used to produce automobile gears and springs among other parts. However, in case of light alloys, only shot blast treatment is used during surface finishing process to improve the surface condition and perform painting preprocessing. Shot peening is seldom used to improve fatigue life. In this study, shot peening of aluminum-alloy (AC4CH) is performed under different peening conditions and the effects in improvement of fatigue life are investigated.

KEY WORDS

Fatigue Strength, Aluminum-Alloy Casting, Shot Peening

INTRODUCTION

Lighter weight components are increasingly becoming popular in various fields of engineering applications today in considerations of energy-saving and environmental issues. Under this circumstance, the use of light-alloy parts, small-sized and thin-walled castings has been a common practice to meet the above requirements. This tendency is particularly positive in the field of automotive-related industries which are directly connected to the social proposition of CO2 reduction, and the current material attributes indicates that the applicable shifting to aluminum-alloy has been almost saturated.

However, there are still many numbers of parts left behind in the shift to light-alloy materials due to the severe demand of fatigue strength. To cope with this problem, most industries are keen in searching for the better selection of materials matching the required properties and in developing various composite materials. This, however, is not easy because it always accompanies the problems of recycling feasibility such as waste separation and reclamation method.

One of the technologies to improve fatigue life is shot peening. However, in case of light-alloy parts, normal shot blasting treatment is used during surface finishing process for improving the surface finish condition and for preprocessing for paint coating.

Shot peening is seldom used for light-alloy parts for the purpose of improving fatigue strength. Optimization of peening treatment condition is not pursued sufficiently either. In this study, among light-alloy materials, aluminum-alloy is selected as the target work and the peening test is performed under different peening conditions to investigate the effect in improving the fatigue life.

METHODS＆RESULTS

〔VERIFICATION IN ALUMINUM ALLOY CASTING〕

METHODS

The base material used for the test is the continuous cast bar (AC4CH-T6 processed) having diameter of 150 mm approx. and the chemical composition of this specimen is shown in Table 1. The fatigue life test specimen having shape and dimensions shown in Fig 1 was machined from continuous cast aluminum-alloy bar. The section of bar material with stable hardness was selected for machining the specimen. The central and the surface areas of the bar material were avoided because the former carried a higher possibility of hardness fluctuation, while the latter was with dense concentration of casting rejects. Centrifugal blasting wheel type machine was used for shot peening the test specimen with the processing conditions shown in Table 2. The projection velocity is a function of and was determined by the RPM of the wheel. For verifying the peening effect, Shenk type fatigue tester was used. Complete 2-way swinging fatigue test was conducted at room temperature, and the result was evaluated by setting the fatigue limit at 1 x 10^7. In addition, the test specimen underwent Vickers hardness testing and metallographic evaluation.

Table 1 Composition of Aluminum Alloy (AC4CH-T6)

Chemical composition	Si	Mg	Fe	Mn	Ti	Zn	Cu	Ni	Pb	Sn	Cr
mass,%	6.95	0.38	0.10	0.00	0.13	0.00	0.00	0.01	0.00	0.00	0.00

【T6 Treatment】

793K-8h Solution Heat Treatment→Water Quenching→12h Natural Ageing→433K-6h Precipitation Heat Treatment

Table 2 Test Conditions

Condition	Abrasive		
	Average particle size ,mm	Hardness ,HV	Material
A	1	90 - 100	Zinc base (Original)
B	0.3	400 - 500	Cast steel (S-110)
C	1.7	400 - 500	Cast steel (S-550)
D	0.6	440 - 480	Stainless steel (CW-20)

Projection Velocity：60m/s

Coverage：250%

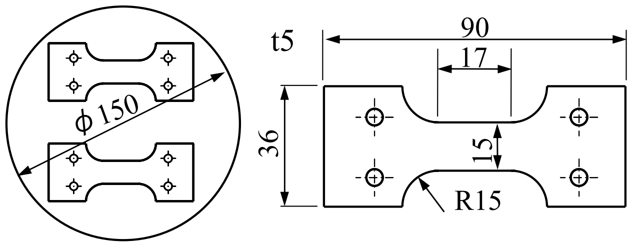

Fig.1 Position of fatigue test piece machined from Al bar and the dimensions of test piece.

RESULTS

Fig. 2 shows the results of investigation of the effect of different blasting media (shot) on fatigue strength improvement. In case of condition B, C, D, the large particle size shot can achieve the better effect of improving fatigue strength. It is verified that effect of condition C (Particle diameter 1.7mm, Cast steel) is remarkable. The fatigue strength achieved by condition C was 129MPa compared to the fatigue limit 108MPa of untreated test piece. However, in condition of B (Particle diameter 0.3mm, Cast steel), a slight improvement of fatigue strength was observed at lower cycle range, but it came down to almost equal to untreated

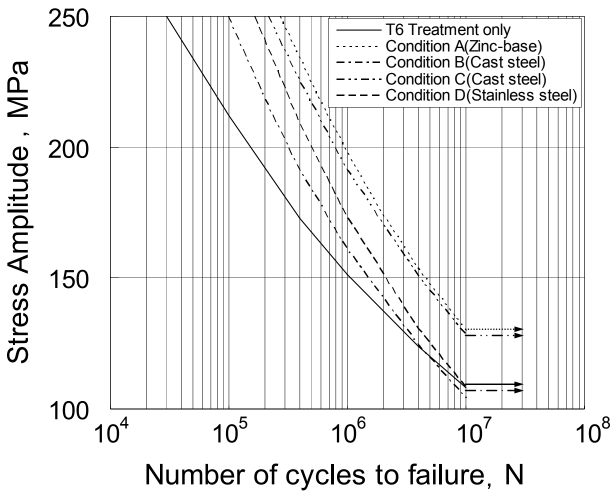

Fig.2 Influence of Shot Peening on Fatigue Life of Aluminum Alloy Casting.

specimen at 3.5 x 10^6 cycles. Furthermore, the fatigue strength becomes lower than untreated specimen at higher cycle where the fatigue limit was lowered to 105MPa. The fatigue strength of Conditions A (Particle diameter 1.0mm, the hardness of shot material is the same as the test piece.) improves to the same 130MPa as Conditions B (Particle diameter 1.7mm).
Fig. 3 shows the measuring result of hardness distribution for depth direction. All condition compared here achieves the highest hardness in the periphery closer to the surface, and the hardness tends to go down to the same level as the base material at the deeper area. It was recognized that the highest value of hardness achieved by any of the condition was about 120 HV, higher by about 18 HV compared to that of the base material.
The influence to the depth direction is deeper when the size of blasting media is larger. It was recognized that the influenced layer of condition C (average grain size 1.7 mm) to the depth direction reached to more or less 550 μm.
Fig. 4 shows the measuring results of surface roughness. It is possible to verify that the roughness is imparted by any peening condition. It was recognized that zinc-base B and cast steel B which achieved higher fatigue strength improvement imparted comparatively large roughness, but no particular correlation between surface roughness and fatigue limit was verified.

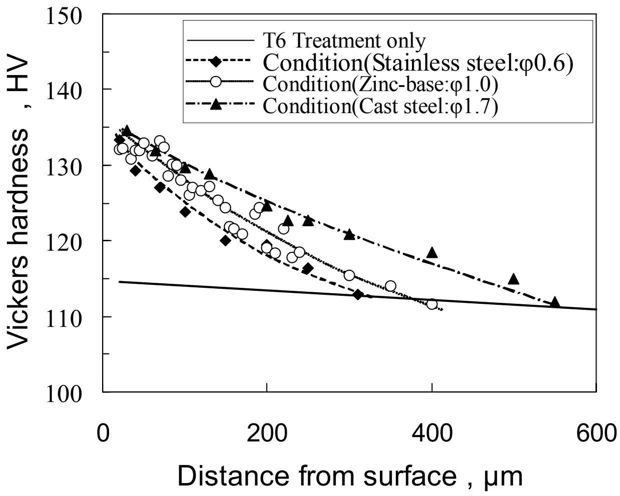

Fig.3 Influence of Shot Peening on Hardness Distribution

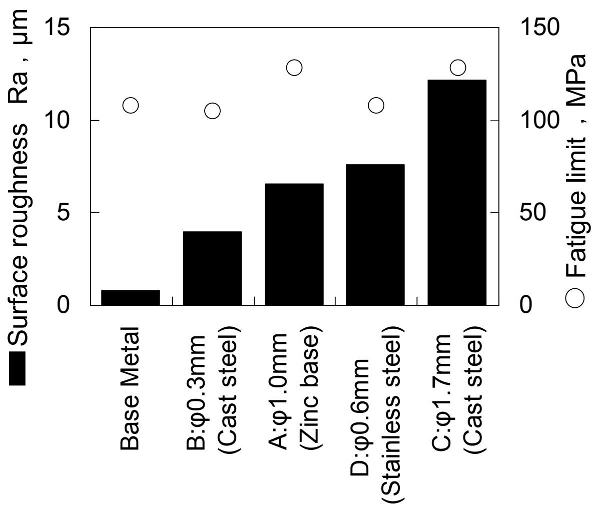

Fig.4 Effect of shot peening on Surface roughness and Fatigue limit.

〔EVALUATION OF INFLUENCE ON ALUMINUM-ALLOY PLATE MATERIAL〕

METHODS

The base material used for the test is aluminum-alloy plate (A-5083-PO) having thickness of 5 mm, and the chemical composition of this specimen is shown in Table 3. The fatigue life test specimen having shape and dimensions shown in Fig 4 was machined from aluminum-alloy plate. For the test piece, the shot peening was conducted by using zinc-base blasting media having different hardness as shown in Table 4. For verifying the peening effect, Shenk type fatigue tester was used. Complete 2-way swinging fatigue test was conducted at room temperature, and the result was evaluated by setting the fatigue limit at 1 x 10^7. In addition, the test specimen underwent Vickers hardness testing and X-ray Residual stress measurement.

Table 3 Composition of Aluminum Alloy (A5083-PO)

Chemical composition	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
mass,%	0.15	0.18	0.02	0.63	4.49	0.12	0.00	0.01	RE.

Table 4 Test Conditions

Condition	Abrasive		
	Average particle size mm	Hardness HV	Material
E	0.6	90 - 100	Zinc base (Original)
F	0.6	45 - 50	Zinc base (Original)

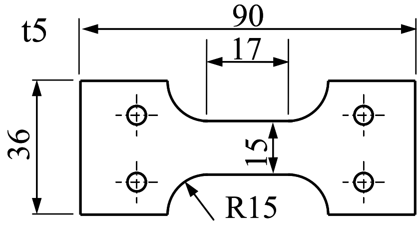

Fig.5 Dimensions of test piece.

RESULTS

Fig. 6 shows the results of fatigue life test. It is verified that condition E having hardness closer to 100 HV equivalent to the hardness of untreated material can achieve the better effect of improving fatigue strength. It is verified that the fatigue strength obtained by Zinc-base media B is 105 MPa, improved by 15 MPa against 90 MPa of the fatigue limit of untreated base material. However, in case of condition F, the fatigue strength obtained after peening is 97 MPa where no obvious effect is observed.

Fig. 7 shows the measuring result of hardness distribution for depth direction. All condition compared here imparted the hardness of about 20 HV to the depth of 180μm from the surface, and the hardness tends to go down to the same level as the base material at the depth of about 320μm.

Fig. 8 shows the measuring result of residual stress distribution for depth direction. Almost similar distribution is observed to the depth of about 150μm from the surface, but it is recognized that condition E having higher hardness achieves to impart the residual stress to the deeper area.

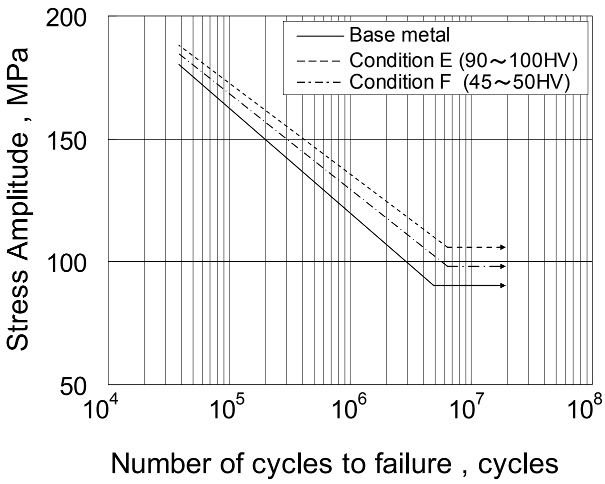

Fig.6 Influence of Shot Peening on Fatigue Life of Aluminum Alloy Plate Material.

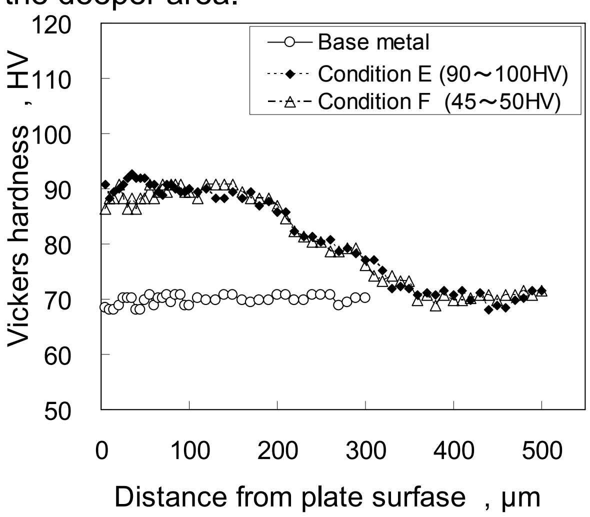

Fig.7 Influence of Shot Peening on Hardness Distribution.

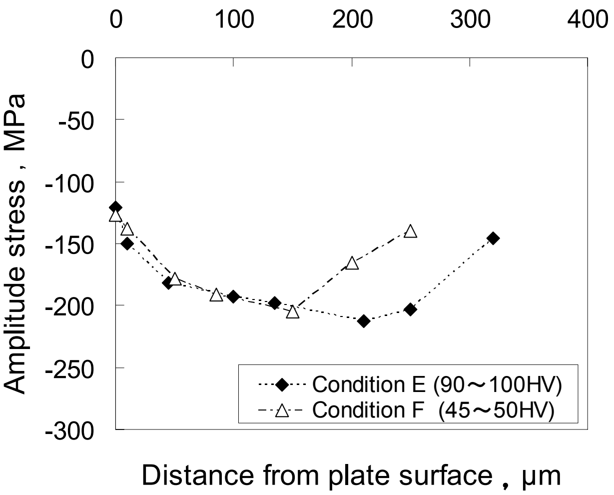

Fig.8 Influence of Shot Peening on Amplitude stress.

DISCUSSION

Generally, the total fatigue life is consisted with such factors as crack initiation life and crack propagation life. In high cycle fatigue field, the longer the fatigue life is, the larger the ratio of crack initiation life against total fatigue life becomes. In the low cycle fatigue field, the crack propagation life is dominative. In Fig. 2 and 4, it was recognized that the effect of fatigue strength improvement was greater in low cycle fatigue field. Therefore, the peening under this treatment condition is considered effective mainly for crack propagation life.

In case of shot blasting treatment to obtain fine surface finish or for pre-coating surface treatment using iron-base blasting media, the application of the grain size of about 0.6 mm is preferable. This results to the simultaneous fatigue strength improvement effect irrespective of the treating conditions. However, attention should be paid for the possibility of obtaining lower fatigue strength when finer media are used.

It is general understanding that imparting roughness will decrease the fatigue strength. However, in our experiments, this tendency was not observed. It is considered and understood that the effect of fatigue strength improvement achieved by imparting of hardness and repairing of casting defects by peening impact was greater than the effect of decreasing fatigue strength by imparting surface roughness. Furthermore, as shown in Fig. 5, the effective zone exists to the depth of about several hundred μm from the surface depending on the peening conditions. Accordingly, it is considered that the better result of fatigue strength improvement is obtained by increased peening intensity than imparting surface roughness depending on the property of work as far as the aesthetic restriction permits. Pay close attention to treatment of work which needs tensile property more than hardness.

CONCLUSION AND IMPLICATIONS

(1) The improvement in a fatigue life of aluminum alloy by shot peening treatment is confirmed.

(2) The effect of fatigue strength improvement achieved by imparting of hardness and repairing of casting defects by peening impact was greater than the effect of decreasing fatigue strength by imparting surface roughness. However, we need to keep in mind that it is dependent on the quality and the loading state of products.

(3) In the case of the work piece of this exam, on all the projection conditions, the effect of the improvement in fatigue strength by shotpeening in lower cycle range is high.

REFERENCES

K.Masaki,Y.Ochi,T.Matsumura,Transactions of the Japan Society of Mechanical Engineers,A69, 678, (2003),pp.116-171(in Japanese).

S.Iwamuro,T.Konaga and K.Saruki,J.Soc.mater.Sci, Japan,35-394(1986)pp.731-736(in Japanese).

S.Wang,Y.Li,X.Changl,Y.Yang,M.Yao et al, Metal materials,2-2(1996,pp.93-96).

K.Takeuchi,K.Sasaki and H.yamamori,J.Soc. Mater. Sci.,Japan,15-154(1996),pp.492-498(in Japanese).

K.Shiozawa,S.Nishino,Y.Tohoda and et al. , Trans. Jpn Soc. Mech. Eng., 60-571, A(1994),pp.663-670(in Japanese).

N.Kawagoshi,H.Nishitani,T.toyohiro et al, Trans. Jpn Soc.Mech. Eng, 60-570,A8(1994),pp.358-363(in Japanese).

H.Ikeda,T.Toriyama and Y.Murakami,Trans Jpn Soc.Mech.Eng.,57-538, A(1991),pp.1320-1325(in Japanese).

H.Suzuki, G.Weimin, H.Dewa et al, Strength of Ductile Cast Iron and Other Cast Metals '93,JSME-MMD(1993),pp.202-207.

M.Kobayashi and T.Matsui, Trans.Jpn.Soc. Mech. Eng., 62-594, A(1996)pp.341-346(in Japanese).