Effect Of Shot Peening On Fatigue Behavior Of 7055-T77 Aluminum Alloy

Jilai, Ru (Metals & Chemistry Institute of China Railway Science Academy)
Renzhi, Wang (Beijing Institute of Aeronautical Materials, China)

Abstract: The effect of shot peening on 7055-T77 aluminum alloy has been investigated. It has been shown that 7055-T77 aluminum alloy is a high strength alloy with microstructure of coarse grains and texture. This kind of microstructure can be greatly changed by shot peening. It is concluded that the improvement of fatigue property of the aluminum alloy can be achieved with the changes of microstructure and the introduction of compressive residual stresses due to shot peening. Moreover, a useful method, X ray radiography, was presented in this paper to measure the depth of plastic deformation layer of shot peening for the aluminum alloy with coarse grains and texture, which is very difficult to measure by means of regular X-ray stress diffractmeter using successive material removal by electro-polishing.

Keywords: shot peening; texture, fatigue, residual stresses

1 INTRODUCTION

7055-T77 aluminum alloy is a kind of high strength alloy mainly used in aircrafts as important components which are always required high fatigue performance. Shot peening is a surface cyclic deformation process and a very effective technology employed to improve the fatigue properties. In this paper, the microstructure with coarse grains and texture of this alloy and the effect of shot peening on the microstructure has been measured. Residual stresses, microstructure, the fatigue properties before and after shot peening have been systematically investigated and the shot peening strengthening mechanisms have been discussed.

2 MATERIAL AND EXPERIMENTAL PROCEDURE

The main chemical compositions of 7055-T77 aluminum alloy and its mechanical properties are listed in Table 1 and Table 2 respectively.

Table 1 Chemical compositions of 7055-T77 aluminum alloy (wt %)

Zn	Cu	Mg	Zr	Fe	Si
7.81	2.22	2.07	0.18	0.09	<0.05

Table 2 Mechanical properties of 7055-T77 aluminum alloy

direction	σ_b , MPa	$\sigma_{0.2}$, MPa	δ_5 , %
Longitudinal	607	586	12.7
Transverse	571	545	6.1

The heat treatment specification of 7055-T77 aluminum alloy is: 470℃ quenching→ 120℃/24h→175℃/2.5h→120℃/24h

Residual stresses and half widths were determined on X3000 type X-ray stress diffractometer. The microstructures with coarse grains and texture of the aluminum and the deformation layer due to shot peening were measured on D9-C type X-ray diffractometer by means of X ray radiography.

Shot peening was processed with glass bead of 0.3mm in diameter and an Almen intensity of 0.2A[mm].

Tensile-tensile fatigue test with stress ratio R=0.1 was carried out with round notched (stress concentration factor $K_t = 3$) specimens with 8.5mm in diameter.

3 RESULTS AND DISCUSSION

3.1 Fatigue property

The results of tensile-tensile fatigue test were listed Table 3. The fatigue limit was obtained by means of up-and-down method. It was shown that the fatigue limits ($N=10^7$) before and after shot peening are 131 MPa and 185 MPa respectively. The fatigue limit is increased 41.2% by shot peening.

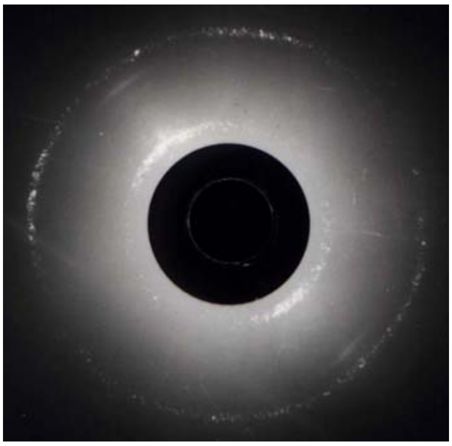
Table 3 Testing results of tensile-tensile fatigue

Surface conditions	Fatigue limit, σ_e MPa	$\Delta\sigma_e/\sigma_e$ %
Unpeened	131	—
Peened	185	41.2

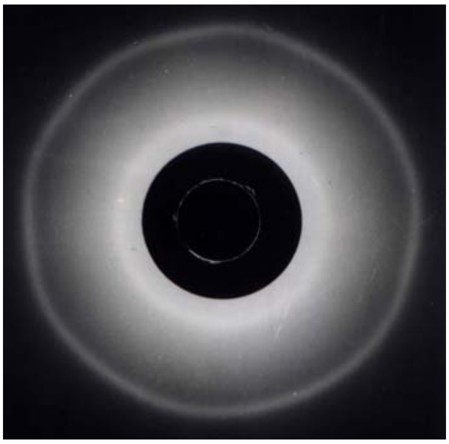
2.2 Factors affecting fatigue properties

Shot peening is a cold working process in which great plastic deformation has taken place in the surface layer of the specimens. Residual compressive stresses and deformed microstructure are two main changes in the deformed layer, which are the two main factors improving the fatigue properties of the materials.

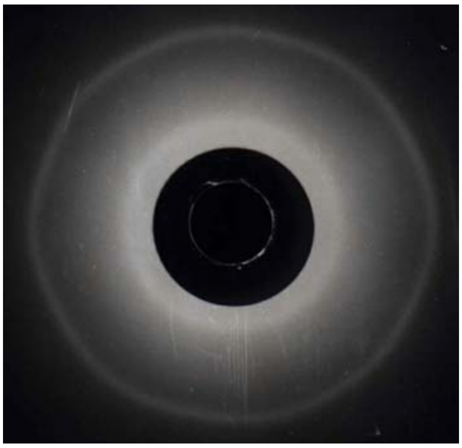
X-ray analysis technology is a very useful method to study microstructure and residual stresses of the deformed layer due to shot peening. In general, by means of X-ray stress diffractometer, both residual stresses and half width can be measured quantificationally for the materials with fine grains and without texture. However, it is very difficult to use this method for 7055-T77 aluminum alloy because it has coarse grains and texture. In order to study this kind of microstructure, X ray radiography was employed. Photos of X ray back reflection patterns with different depths were shown in Fig. 1 by means of material removal using electro-polishing. There are two Debye diffraction rings in each photo. The larger ring corresponds to the diffraction plane (311) and the smaller one corresponds to (222).



(a)



(b)



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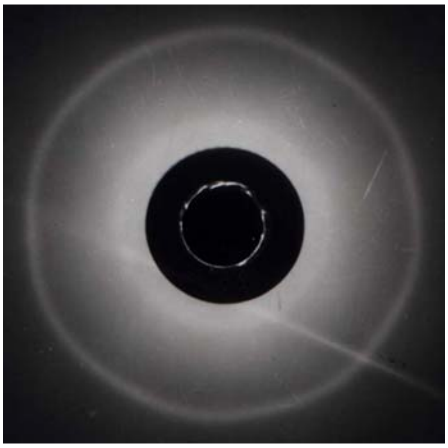

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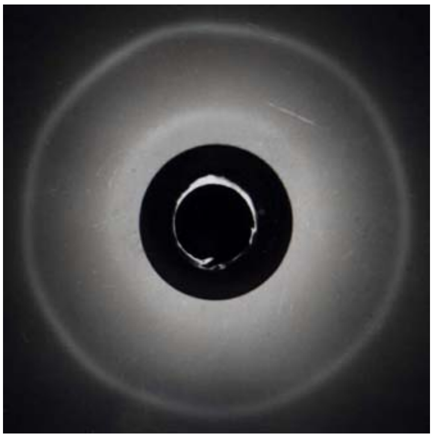

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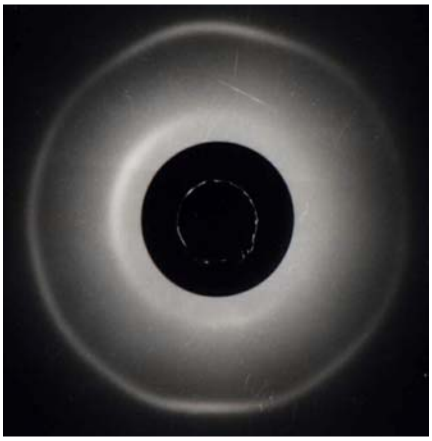

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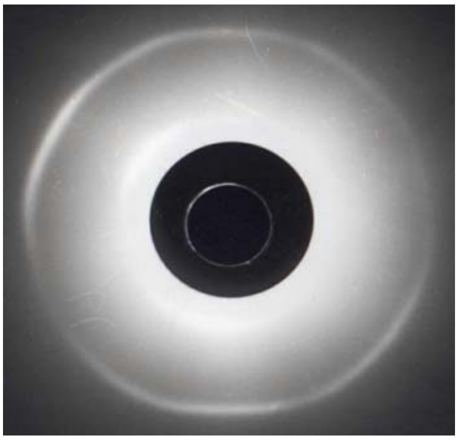
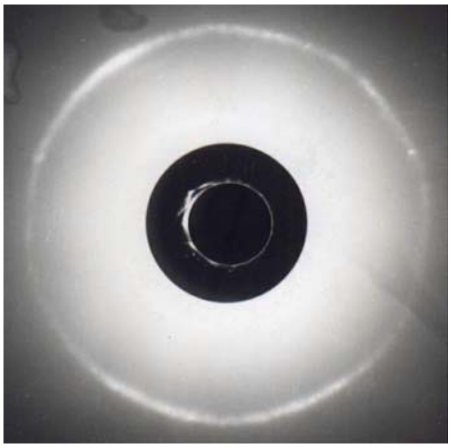
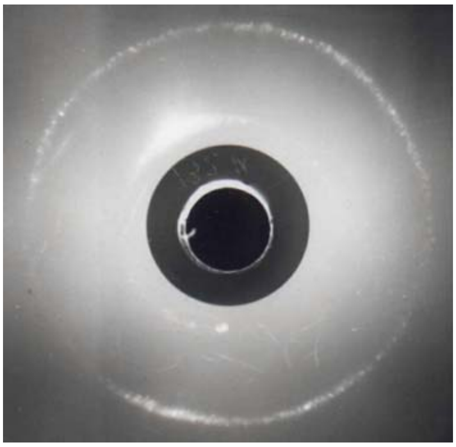


(g)



(h)



(i)

(j)

(k)

(l)

Fig. 1　　Photos of X-ray back reflection patterns
for unpeened and peened specimens

(a)—unpeened；(b)—peened (0 μ m)；(c)—peened (12 μ m)；

(d)—peened (26 μ m)； (e)—peened (51 μ m)； (f)—peened (75 μ m)；

(g)—peened (89 μ m)； (h)—peened (109 μ m)； (i)—peened (132 μ m)；

(j)—peened (184 μ m)； (k)—peened (244 μ m)； (l)—peened (273 μ m)

It can be seen from Fig. 1(a) that both (311) and (222) have obvious preferred orientation microstructure which is so called “texture”. There are also obvious bright spots scattered on both (311) and (222). These phenomena indicate that the microstructure of unpeened 7055-T77 aluminum alloy has coarse grains and texture microstructure.

However, great changes have taken place from discontinuous and spotted diffraction rings (Fig. 1a) of the unpeened specimen into continuous diffraction rings without spots (Fig. 1b) due to shot peening. The main reasons resulting in the difference of diffraction patterns are coming from the increase of lattice distortion and the fine subgrains in the deformed surface because of shot peening. With the increasing depth of deformed layer, the diffraction patterns of the peened specimen changed gradually. For the depth of 0-26 μ m (Fig. 1 b-d), the diffraction rings are getting weaker with the increase of the deformed depth but there is no appearance of diffraction spots and texture. Therefore, X-ray stress diffractmeter may be employed to measure parameters of deformed layer due to shot peening. The parameters include residual stresses and half widths that reflect the changes of lattice distortion(Δ a/a, a- lattice constant) and the size of subgrains. According to the experiment (Table. 4), the depth in which X-ray stress diffractmeter can be used to measure residual stresses and half widths is as far as 30 μ m. For the depth of 51-89 μ m (Fig. 1 e-g), texture appeared in the diffraction rings but no diffraction spots was found. At the depth of 109 μm (Fig. 1 h), diffraction spots appeared obviously on the background of the rings. With the depth further increasing, the background of the rings is getting disappeared and diffraction spots are getting more and more. When the depth is 273 μm (Fig. 1 l). The diffraction patterns is as almost the same as that of unpeened specimen (Fig. 1 a). In this way, the depth of the deformed layer due to shot peening was determined which is about 273 μm.

It has been indicated above that residual stresses(σ_r) and half width(β) of deformed layer due to shot peening can be measured by means of X-ray stress diffractmeter with the depth less than 30 μm. The results were shown in Table. 4.

Table. 4 Residual stresses(σ_r) and half width(β)

Depth from the surface (μm)	σ_r, (MPa)	β, (deg)
0	-229	4.25
17	-305	5.12
30	-295	3.62
>30	—	—

It can be seen from Table. 4 that the maximum σ_r is –305MPa. The roles of the high compressive residual stresses are: (1) to decrease tensile stress level of applied alternating stress, (2) to force the fatigue sources from the surface into the subsurface, obtaining the higher internal fatigue limit [1]. All these effects mentioned above can lead to the increase of fatigue limit.

The maximum half width is 5.12 degree, which indicates the increase of lattice distortion of alloy. The increase of lattice distortion, in fact, results in the raise of microstresses (σ_{mic}). The raise of σ_{mic} means the increment of dislocation density within crystal, which increases the difficulty of dislocation movement and the fatigue crack initiation [2].

Conclusion

1. 7055-T77 aluminum alloy is a high strength alloy with microstructure of coarse grains and texture. This kind of microstructure can be greatly changed by shot peening.

2. The main factors to increase the fatigue strength of 7055-T77 aluminum alloy have been found to be the residual compressive stress, microstructure changes in the surface deformed layer due to shot peening.

3. A useful method, X ray radiography, was presented to measure the depth of plastic deformation layer of shot peening for 7055-T77 aluminum alloy with coarse grains and texture.

Reference

[1] Yao Mei, Wang Renzhi etc, Fatigue Strength Analysis of Surface Strengthening Specimens and Internal Fatigue Limit of Metals, Acta Metallurgica Sinica , Vol ,29, NO11 , 1 993 (in Chinese)

[2] Wang Renzhi, Shot Peening and Fatigue Behavior of Materials, Proceedings of Shot Peening and Blast Cleaning, India, 66- 79,1996