Enhancement of Fatigue Performance of Commercially Pure Aluminum 1050 by Shot Peening and Ball-Burnishing

M. Abdulstaar, M. Mhaede, M. Wollmann, L. Wagner
Institute of Materials Science, Clausthal University of Technology, Germany

Abstract

In this study, the effects of shot peening (SP) and ball-burnishing (BB) on the fatigue performance of commercially pure (cp) aluminum Al 1050 was investigated. SP was conducted using spherically conditioned cut wire (SCCW14) with an Almen intensity of 0.20 mmA. A surface rolling system using a hard metal ball (HG6) and a burnishing pressure of 100 bar was used for BB. Surface layer property (surface roughness) and near-surface layer properties (microhardness depth profiles) were evaluated. SP and BB markedly enhance the fatigue performance of the electropolished reference condition. The fatigue enhancement due to surface treatments is mainly attributed to the high work-hardening capability of cp- Al.

Keywords Al 1050, shot peening, ball-burnishing, fatigue, work-hardening capability.

Introduction

Commercially pure aluminum 1050 belongs to 1XXX aluminum alloys series and is generally characterized by low strength in comparison to other aluminum series. The low strength is due to the absence of solute atoms and precipitations that otherwise could offer a barrier against dislocation movements [1]. Ball-burnishing (BB) and shot peening (SP) are widely used mechanical surface treatments to enhance the performance of structural components of high-strength steels, aluminum and titanium alloys, i.e. to improve their fatigue and corrosion fatigue performance as well as increase their resistance to stress corrosion cracking [2]. These surface treatments lead to a characteristic surface topography, an increase in dislocation density and development of residual compressive stresses in the near surface regions and work hardened surface layers which serve to inhibit or retard surface crack nucleation as well as fatigue crack growth; therefore, fatigue and corrosion fatigue life of metallic materials can be considerably enhanced [3-5].

BB leads to a surface smoother and residual compressive stresses higher than those caused by a SP process [6]. Disadvantages of this process are difficulty in tooling development and poor access to some locations, for example, on engine components.

In this study, the effects of shot peening and ball-burnishing on the surface and near-surface layer properties in addition to fatigue performance of Al 1050 in as-received condition were investigated.

Experimental procedure

The investigation was performed on commercially pure aluminum Al 1050. The material was received as hot extruded bar with chemical composition as given in Table 1.

Table 1: Chemical composition of Al 1050 (wt%).

Fe	Si	Mn	Mg	Al
0.14	0.09	0.05	0.02	bal.

Tensile tests were performed using threaded cylindrical specimens having gage lengths and diameters of 25 and 5 mm, respectively.

Shot peening (SP) was conducted using a direct air pressure system (Gravi 2000, OSK Kiefer, Oppurg) and spherically conditioned cut wire (SCCW14) having a hardness of 580 HV and an average shot size of 0.36 mm. Peening was performed to full coverage using various Almen intensities. Ball-burnishing was performed by means of a conventional lathe using a device from ECOROLL company, by which a hard metal ball of Ø 6 mm (HG6) is hydrostatically pressed onto the rotating specimen surface. Electrolytically polished (EP) samples were taken as the baseline to which the SP and BB conditions are compared.

The surface roughness of the various conditions was determined by means of an electronic contact (stylus) profilometer instrument (Perthometer). Microhardness was determined by using a Struers Duramin tester with a force of 50 ponds (HV0.05) and a loading time of 10 seconds.

Hour-glass shaped fatigue samples with a minimum diameter of 6 mm were used for fatigue testing, the tests were performed with rotating beam loading (R = -1) in air at a frequency of 50 Hz.

Results and discussion

Figure 1 shows the microstructure of the as-received material in a plane normal to the extrusion direction, with a relatively coarse grain size of about 150 µm.

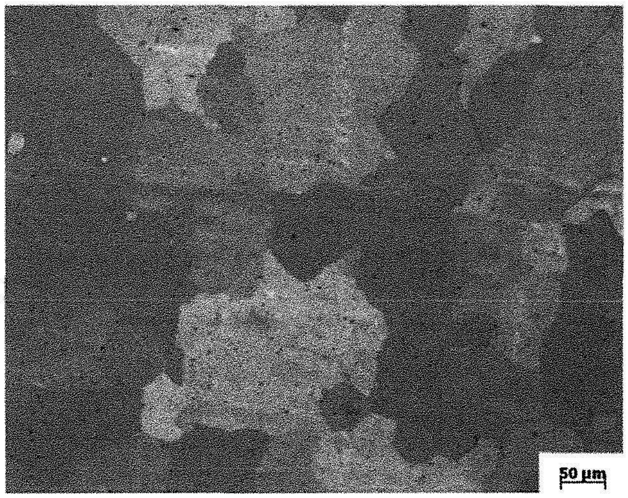


Figure 1: Microstructure of Al 1050 in as-received condition.

Table 2 summarizes the tensile and hardness properties of the as-received condition. The work-hardening capability which can be roughly estimated by (UTS – YS) corresponds to 50 MPa.

Table 2: Tensile properties of Al 1050 in as-received condition.

Condition	YS (MPa)	UTS (MPa)	UTS–YS (MPa)	El (%)	HV 10
As-received	20	70	50	120	28

Typical roughness profiles for the various surface treatments of Al 1050 in both SP and BB conditions are given in Figure 2. The surface roughness after SP is significantly increased relative to EP. As opposed to SP, the surface roughness after BB is much lower (Fig. 2).

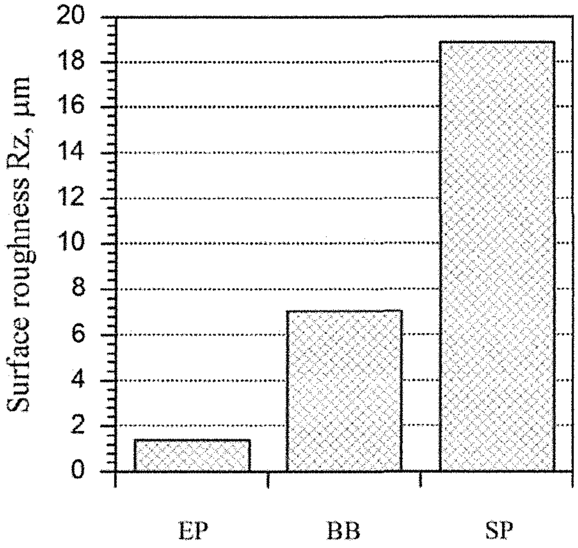


Figure 2: Roughness values of the various surface treated conditions.

The micro-hardness-depth distributions in Al 1050 after SP and BB are given in Figure 3. Obviously, there is a pronounced near-surface hardness increase relative to the bulk hardness. The micro-hardness at the surface increases by about 20 HV and 25 HV after SP and BB, respectively.

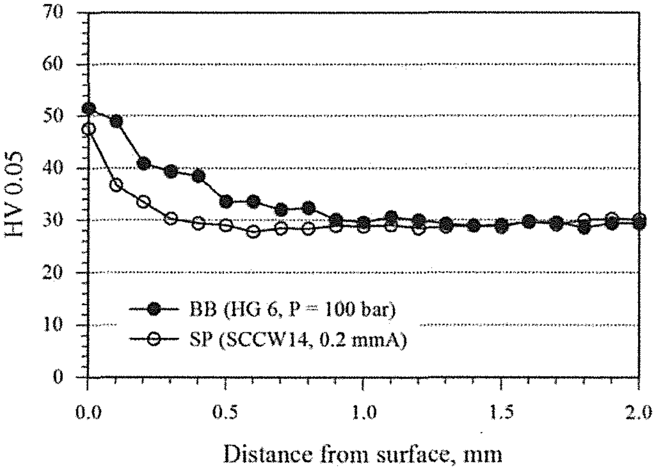
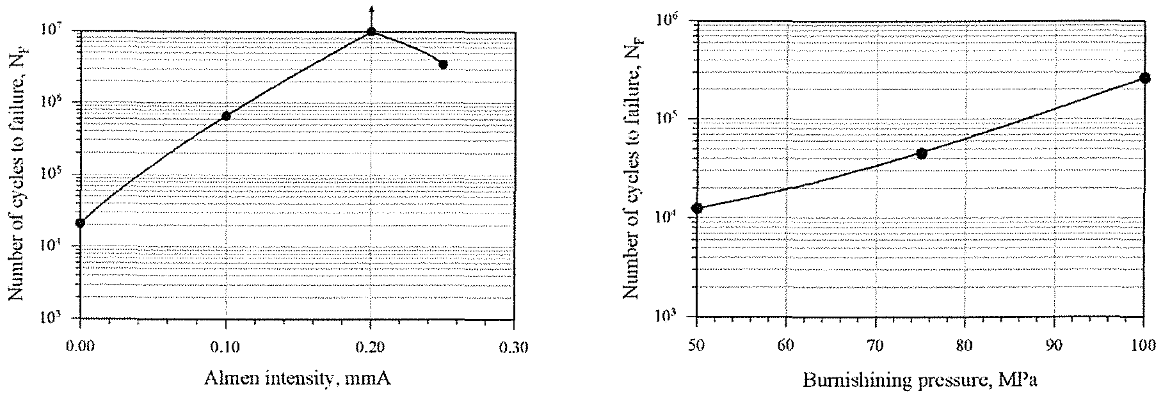


Figure 3: Micro-hardness-depth profiles after mechanical surface treating Al 1050.

The effect of various Almen intensities and burnishing pressures on HCF was also investigated to ensure that the selected shot peening and ball-burnishing process parameters were optimum (Figure 4). Almen intensities of 0.20 mmA and burnishing pressures of 100 bar resulted in highest fatigue life among the tested process parameters. A drop in fatigue life after peening with 0.25 mmA intensity was observed that could be attributed to the high surface roughness (over-peening).



(a) SP: σ_a = 50 MPa (b) BB: σ_a = 75 MPa

Figure 4: Effect of Almen intensity (a) and burnishing pressure (b) on fatigue life

The effect of ball-burnishing and shot peening on the S-N curves in air of Al 1050 in as-received condition is shown in Figure 5. The 10^7 cycles fatigue strength of EP condition was 25 MPa. The improvement in HCF relative to EP condition corresponds to 100% and 140% after SP and BB, respectively. The marked enhancement of the fatigue strength is attributed to the pronounced work hardening-capability which can be estimated from marked increase in hardness (Figure 3).

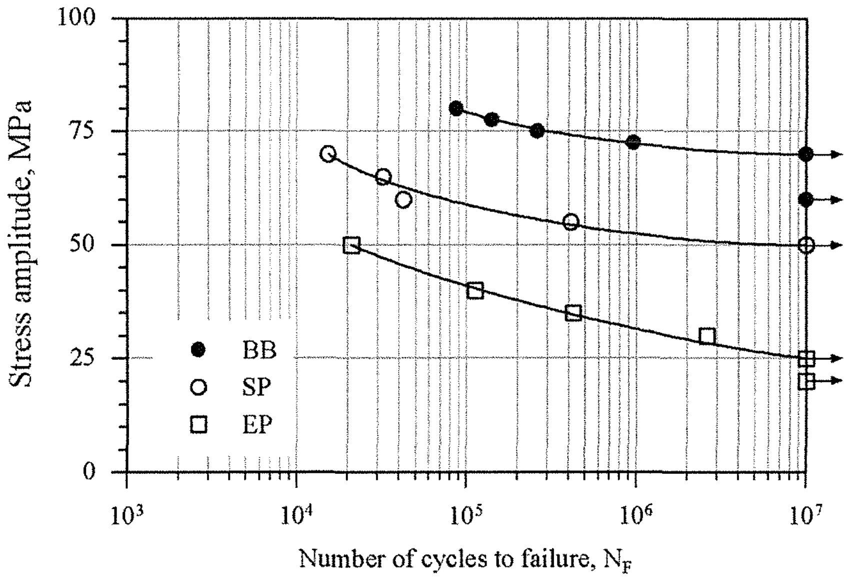


Figure 5: S-N curves of Al 1050 in rotating beam loading (R = -1) in air, effect of various surface conditions.

Conclusions

The fatigue life of CP Al 1050 was markedly enhanced after applying BB and SP in comparison to the reference EP condition. This is a result of the induced compressive stresses which retard fatigue micro-crack propagation. The fatigue strength of EP condition was improved from 25 to 50 MPa after SP and to 90 MPa after BB. The higher improvement of the fatigue performance after BB as compared to SP is explained by the deeper depth of plastic deformation and lower surface roughness.

Acknowledgments

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