Accepted Manuscript

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PII: S0142-1123(17)30263-3
DOI: http://dx.doi.org/10.1016/j.ijfatigue.2017.06.013
Reference: JIJF 4369

To appear in: *International Journal of Fatigue*

Received Date: 13 March 2017
Revised Date: 6 June 2017
Accepted Date: 7 June 2017

Please cite this article as: Yuan, X., Sun, Y., Li, C., An engineering high cycle fatigue strength prediction model for low plasticity burnished samples, *International Journal of Fatigue* (2017), doi: http://dx.doi.org/10.1016/j.ijfatigue.2017.06.013

An engineering high cycle fatigue strength prediction model for low plasticity burnished samples

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Abstract: High cycle fatigue performance is significantly affected by the surface conditions of mechanical components. Traditionally, one major effect of low plasticity burnishing process in promotion fatigue resistance has been ascribed to the generation of compressive residual stresses and the formation of gradient structure in the top-treated surface layer. However, the prediction model of fatigue performance considering the effects of roughness, microhardness and residual stress has not been well established. Thus, the aim of this work is to develop a model predicting the fatigue strength of high cycle fatigue for burnished metallic components. First, the main parameters affecting the fatigue performance of burnished components are investigated by dimension analysis method. Then, by introducing the influence factors of stress gradient and microhardness gradient, a fatigue strength prediction model is proposed to correlate the fatigue strength of untreated and treated samples. This model considers the effects of residual stress, microhardness, roughness, gradient and size. In order to verify the validity of the model, double faces low plasticity burnishing and tension-tension fatigue tests are carried out on TA2 alloy samples with center hole. In addition, to investigate the effect of low plasticity burnishing on the fatigue performance when the direction of crack propagation is perpendicular to the burnished surface, one face burnishing and three-point bending fatigue tests are also performed. The tension-tension fatigue strength and bending fatigue strength after low plasticity burnishing are 144 MPa and 329 MPa, respectively. The predicted tension-tension fatigue strength and bending fatigue strength after low plasticity burnishing are 133 MPa and 313 MPa, respectively. The error between the measured value and the predicted value is less than 15%. At last, fatigue comparison tests using new burnishing process parameters are carried out. The fatigue strength after treatment is 309MPa. The predicted fatigue strength after treatment is 322MPa. The prediction error is less than 10%. This demonstrates that the proposed model is effective in the high cycle fatigue strength prediction model for low plasticity burnished samples.

Keywords: fatigue strength, low plasticity burnishing, residual stress, microhardness;

1 Introduction

Engineering structures and components due to serving under cyclic loading, prone to fatigue damage. Fatigue cracks generally initiate at the stress concentration of the components surface. The subsequent fatigue crack growth determine the fatigue life of the components. Therefore, techniques that improve the fatigue resistance of the components are significant.

Existing studies have shown that surface modification or treatment technologies are effective for improving the fatigue performance, such as shot peening, deep rolling, laser shock peening(or laser peening), ultrasonic surface rolling, machine hammer peening. Shot peening is a surface treatment method, which uses the plastic deformation layer on the surface of the material to improve the performance of the material. After shot peening process, the introduced residual compressive stress field in the surface layer can effectively restrain the cracks initiation and propagation, and then improve the fatigue strength and fatigue life. Such method is widely used in the manufacture of aviation, spaceflight, automobile, electric power station and so on. The advantage of shot peening is that the cost is low. Moreover, it can be used to the surface strengthening treatment of large parts. However, in addition to the properties of the component materials, the effects of shot peening are related to many process parameters, such as the size of the shot, shape, hardness, shot peening velocity and peening flow. Therefore, it is difficult to accurately predict the effect of shot peening. In addition, the surface roughness of the shot peened component is not as good as that produced by ball burnishing. In contrast, laser peening is a new surface modification technology. During the process of laser peening, a deep layer of compressive residual stresses can be introduced by high energy and short pulsed laser [1]. Compared to shot peening, there is a sacrificial layer known as protective coating or ablative material on the surface of the workpiece. This coating can reduce the thermal effects of the laser beam on the part. After operating more three times, the protective coating must be removed. Thus, laser shock peening is costly. In contrast, low plasticity burnishing (also called ball burnishing or deep rolling) is a competitive and effective surface finishing process. This process produces surface plastic deformation by a free rolling ball. This ball is pressed on the surface of the component. In the burnishing process, the applied burnishing load force the surface material spread and flow from the peaks to the valleys on the component surface. This plastic deformation can improve the component surface roughness. At the same time, a hard layer on the finishing surface can be formed. Previous works paid attention to the burnishing process parameters on the surface integrity, including surface roughness, hardness, distribution of residual stress and sub-surface characteristics of burnished components. In literature [2] the influence of process parameters (force, speed and feed) on the surface

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