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Numerical research on stress peen forming with prestressed regular model

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Abstract

Stress peen forming is widely used in aerospace industry to form the thin components with complex geometry. In the stress peen forming, the prestressing condition is a critical factor that need to be precisely controlled. In this study, the effects of the prestress on the peening deformations are investigated by using static and dynamic simulations. A regularly parked four-shot model is used to study the interactions of adjacent shot treatments. To verify the finite element model with precisely controlled parameters, regularly indenting tests are adopted. The analytical results reveal that the tensile prestress enhances the shot dimple and the plastic region sizes. The contributions of the prestress to the induced bending moments and stretching forces are indicated with two scale factors. Comparison of the single-shot model and regular parked four-shot model shows the peening effects can be equivalent within certain averaging regions. The static and dynamic simulations are compared on dimple sizes and forming effects. Finally, the indenting and peening tests are carried out to verify the analytical results.

Keywords: Stress peen forming, Indentation, Finite element simulation, Residual stress, Experiment

1. Introduction

Shot peen forming is a dieless process for forming metallic components. It is especially suitable for forming large panel contours where the bend radii are within the metal's elastic range. In the forming process, numerous shots impact the surface of the component. Each impact induces an elastically-plastically deformed dimple which results in a compressive stress field near the treated surface. The compressive stress cases the material to develop a convex shape to the treated surface.

The conventional peen forming process induces isotropic compressive stresses resulting in identical curvatures in all directions. To form the component such as a wing panel that has a larger curvature in chordwise direction, stress peen fixtures are usually used. Li (1981) applied the stress peening forming process on forming integrally stiffened wing panels. Meyer et al. (1987) formed stringer-reinforced workpieces with the stress peen forming.

The determination of the stress forming parameters is mainly dependent on trial and error. Many experimental works on the stress peen forming have been carried out. Barrett and Todd (1984) measured the residual stresses by x-ray diffraction while peen formed plate remained in curved condition. Xie et al. (2012) measured the residual stress profiles along different directions in titanium matrix composites treated by stress peening with various prestresses. Miao et al. (2010) investigated the relations between the prebending moment and the resulting arc height.

Al-Hassani (1981) expressed the peening induced stress profile with a cosine function. Li et al. (1991) developed a simplified analytical model to calculate the induced stress for 100% peening coverage. Xiao et al. (2014) developed a cavity model to calculate the induced stress filed. However, it is difficult to involve the prestress in the analytical models mentioned above. Finite element (FE) method can be used to investigate the stress peen forming. For example, Miao et al. (2011) utilized the FE simulation to obtain the induced stresses with various prebending moments. Gariépy et al. (2013b) experimentally and numerically investigated the influence of initial stresses in the plate on the resulting curvatures.

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