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A high efficient surface-based method for predicting part distortions in machining and shot peening

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Abstract: The distortion of machined part caused by the introduction of surface residual stresses in machining and shot peening is a major concern in the manufacture of large structural components. Prediction of those distortions is the key to understand the distortion mechanism and derive optimized machining strategies. In this paper, a high efficient surface based method was proposed to predict the part distortion in machining and shot peening. In this method, the surface residual stress field is mathematically analyzed and equivalent to a group of face and edge loads. The part distortion problem is equivalent to an elastic deformation problem and is solved by the FEM software. The knowledge of surface differential geometry is used so that the method could handle part with curved surfaces. Compared with the existing method, the refinement of mesh in the surface-affected layer is not needed, which not only greatly decreases the workload and difficulty of mesh generation but also significantly reduces the amount of computation. What is more, the method was found to be particular fit for large curved surface parts such as propellers and blades. Software system was developed further to implement the method. Two examples were given to show the advantages of the proposed method. Finally, the method was verified by comparing the simulated results with the experimental data with a marine propeller example.

Keywords: Residual stress; Part distortion; Machining; Shot peening; Curved surface

1 Introduction

Surface finishing processes such as machining and shot peening introduce residual stresses into the part surface and subsurface layers. The residual stresses act as a source of cross-sectional residual stresses and shape deviations[1, 2]. Those deviations are usually on the order of micrometers, but in the case of large parts or thin parts, the deviations can be on the order of millimeters and can cause serious problems for their manufacturing and assembling processes [3]. In the modern aerospace and ship building industries, due to their large shape deviations and tight shape tolerances, the distortions of large parts or thin parts have received much attention [4-6]. A study by Boeing, based on four aircraft program data, said that part distortion had become a major problem for aerospace manufacturing that 47% of thin-walled parts had the problem of distortion, the “rework” and “scrap” costs related to part distortion were over 290 million dollars per year [7].

For the purpose of understanding the distortion mechanism and minimizing those shape