

Distortion Prediction in Machined Aerospace Components

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Abstract

Machined monolithic components provide the foundation for modern aircraft structures requiring high performance designs in terms of weight, strength and fatigue properties. Part distortion and warpage arising from bulk material and machining-induced stresses frustrates manufacturing and assembly processes and necessitates expensive trial-and-error methods, shot peening and heat treating to minimize distortion. Strict weight requirements are exacerbated by thicker component section designs as a distortion control mechanism.

We present a physics-based model which takes into account the pre-machined bulk stress state and machining-induced stresses for monolithic parts. Sources of stresses include heat treatment, quenching, forging and machining operations. A customized solid model representation of the initial workpiece geometry is developed. Bulk stresses are mapped onto the solid model. CNC toolpath programs, along with corresponding tooling geometry, are read and analyzed. Bulk stresses are removed from the component as material is machined away, while machining-induced stresses are applied to the final surfaces. The final workpiece geometry is meshed automatically with finite elements and equilibrium solutions calculated. Minimum distortion configurations and strategies are analyzed. Distortion prediction, measurement and validation are presented for a number of monolithic, thin-walled components.