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Efficient Workpiece Clamping by Indenting Cone-shaped Elements

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Machining fixtures which utilize screw-or strap clamps are widely used in manufacturing. Typical for them is that the cutting forces are balanced by the friction forces which act on the contact surfaces (interfaces) between clamping elements (screw- or strap clamps) and workpiece. This paper analyses load capacity and compliance of these interfaces. In order to increase their load capacity and reduce compliance, a method is proposed which is based on indenting sharp cone-shaped clamping elements into workpiece material using appropriate surfaces which are not machined, and are not expected to satisfy any particular aesthetic demands (most often castings and forgings). The results of numerical simulations and experimental investigation reveal substantial advantages of the proposed clamping method, offering possibility for industrial application and further investigation.

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1. Introduction

With the recent rapid development of industry, the need has increased for precision cutting of various kinds of machine parts. In particular, in the cutting industry, it is important to enhance cutting efficiency and precision simultaneously.[1] Within a manufacturing system, there are several factors which most prominently influence the quality of process plans: blanks, sequence and structure of machining processes, concentration of machining operations, machine tools, cutting tools, fixtures, measuring devices, etc. Enhancement of process planning procedure requires optimization of these parameters.[2]

The demand to manufacture low cost products with better quality has forced the manufacturing industry to continuously progress in machining technologies.[3] In the chain of factors which influence the quality of final product, fixtures are of exquisite importance. Machining fixture is a precision device used to locate and hold a workpiece firmly in the proper position during manufacturing operations.[4] The design of a fixture is a highly complex and intuitive process, which requires knowledge and experience. Fixtures have direct impact upon product quality, productivity and cost. The costs associated with fixture planning, design and manufacture can account for 10-20% of the total cost of a manufacturing system.[5] This influenced emergence of a number of methodologies aimed at providing fixture layout optimization. Numerous researchers have been focused on the influence of workpiece-fixture system on the total machining accuracy. In that respect, two basic methods can be distinguished:[6]

- configuration optimization of fixture elements and optimization of clamping forces, and
- prediction of workpiece displacement due to the effect of geometric errors and deformation of the workpiece-fixture system.

Deformation analysis has been a key problem in the past decade and has been studied extensively. Within the analysis of workpiece deformations attention has mostly been focused on: kinematic analysis, force analysis, finite-element analysis (FEA), contact analysis, etc. Deformation analysis pertains to the study of local and total deformation.

Amaral et al.[7] used ANSYS parametric design language code to verify fixture design integrity. They employed 3-2-1 locating method and developed an algorithm to automatically optimize fixture support, clamp locations, and clamping forces, to minimize workpiece deformation, subsequently increasing machining accuracy. Asante[8] presented a model that combines contact