Assembly Automation

Locating and clamping of complex geometry workpieces with skewed holes in multiple-constraint conditions

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Abstract

Purpose – The purpose of this paper is to propose a general model for locating and clamping workpieces of complex geometry with two skewed holes under multiple constraints.

Design/methodology/approach – Numerous constraints related to application of the proposed model are discussed as prerequisite to design of fixture solution. Based on theoretical model, a fixture was designed and successfully tested in experimental investigation. Experimental results were also verified using FEM simulations.

Findings – This study showed that, opposed to conventional approach, novel solution results in significantly smaller fixture dimensions, while providing greater stability. Insertion of mandrels and supports element sub-assemblies into the workpiece holes significantly increases workpiece stiffness through an increased moment of inertia, while the internal support elements largely diminish the problem of thin wall deformation in the workpiece.

Practical implications – The fixture designed in this case was actually used in industrial application to accommodate a thin-walled casting of gearbox housing, where it proved to be a very stable framework. It can be used in industry without any major readjustments.

Originality/value – According to available literature, this work is the first successful implementation of a fixture solution in which the problem of multiple constraints is solved by attaching centering elements, support sub-assemblies, and other fixture elements to the internal workpiece walls, and then locating them in the second part of the fixture.

Keywords Fixture, Layout optimization, Stability, Skewed holes, Plant layout, Machine tools

Paper type Case study

Introduction

In order to machine surfaces on a workpiece using the desired cutting tools, it is necessary to set up the workpiece and tools on a selected machine tool and give them appropriate primary and auxiliary motions. Moreover, the workpiece and tools must be positioned relative to each other and relative to particular machine tool elements, while the workpiece must be properly located and clamped. Fixtures are devices used for quick and reliable workpiece locating and clamping, to guarantee machining within required tolerance. They are also used for any other operation, e.g. welding, assembly, inspection, etc. (McKeown and Webb, 2011).

Fixtures directly influence machining quality, material removal rate, and manufacturing costs. Costs related to fixture design and manufacture amount to 10-20 percent of the total manufacturing costs (Bi and Zhang, 2001). These costs are also related to fixture design (Vukelic *et al.*, 2011). Thus, fixture design plays an important role at the planning stage before shop floor production. Optimization of fixture layout is a critical aspect of machining fixture design, defining the types, number, and material of fixture elements, and their position relative to workpiece. It is considered optimal if minimizing workpiece deformation.

Literature review

Numerous approaches have been used to determine optimal fixture layout, such as: the finite element approach, mathematical approach, geometrical approach, etc. Also, various computational techniques have been used for optimization of fixture design: genetic algorithms (GA), artificial neural networks (ANN), as well as the combination of methods: finite element analysis (FEA) and GA, GA and ant colony algorithm (ACA), ACA and FEA, etc.

Deng and Melkote (2006) presented a model-based framework for determining the minimum required clamping force that ensures dynamic stability of a fixtured workpiece during machining. Siebenaler and Melkote (2006) presented a FEA fixture-workpiece model to investigate influence of various parameters on workpiece deformation, including the

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