Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 60 (2017) 32 – 37

www.elsevier.com/locate/procedia

27th CIRP Design 2017

Optimization of machining fixture for aeronautical thin-walled components

M. Calabrese[a], T. Primo[b,*], A. Del Prete[c]

[a,b,c]Department of Engineering for Innovation, University of Salento, Via per Arnesano, Building "O", 73100, Lecce, Italy

* Corresponding author. Tel.: +390832297807; fax: +390832297825. *E-mail address:* teresa.primo@unisalento.it

Abstract

The aim of this work has been the optimization of the fixtures performance used in thin-walled workpiece machining depending on the local rigidity characteristics of the component to be machined. An extensive topology optimization activity has been performed both on fixture-workpiece systems modelled with shell elements and on fixture-workpiece systems modelled with solid elements, varying the topology design variables and/or optimization constraints for each optimization problem, in order to provide a new design of fixture. Finally, a new blended Solid-Lattice design of the fixture, starting by the design topologically optimized, has been created. In this way, it has been possible to identify void regions in the design space, where the material can be removed, regions where solid material is needed, and regions where lattice structure is required. This has allowed to generate the optimal hybrid or blended solid-lattice design based on desired functionality of the part having as natural consequence the definition of a new method for fixtures design.

© 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the scientific committee of the 27th CIRP Design Conference

Keywords: Topology Optimization, Thin-walled aeronautical structures, Fixtures.

1. Introduction

Fixtures and clamping devices are an essential part of machining systems for material removal processes. But their importance is often neglected or underestimated during the layout of manufacturing machinery and processing solutions. The relevance of fixtures regarding productivity, efficiency and quality is mostly not considered properly, e.g. with respect to the planning of production systems and related costs. Main tasks of fixtures and clamping systems are [1], [2]:

- to define the location (position and orientation) of a clamped workpiece in the workspace of the machine tool
- to maintain this defined location even under the influence of static and dynamic mechanical and thermal loads
- and to guide these loads as an integral element of the machine structure inside the force flux.

The accuracy, performance and reliability of a clamping scenario involving workpiece and fixture depends on the number, distribution and configuration of clamping devices and contact points including support pins or referencing elements. The layout of a fixture and the arrangement of clamps is a challenging task which can be accomplished by means of computer aided methods [3]-[5]. Since fixtures are part of the accuracy path of the machining system, their tolerances affect the quality of the processing result [6]-[8]. Fixture design can be supported by numerical calculation and simulation [9]-[11]. An essential aspect is the avoidance of workpiece deformations which can be caused by the clamping system itself [12]. The process-workpiece-fixture interaction has to be considered in assessing the performance of the fixture and to estimate the influence of a fixture layout on the machining process [13]-[15]. Modelling of the process-workpiece-fixture system allows the implementation of optimization strategies for attaining a suitable fixture layout.

A significant number of studies therefore aim in automated fixture configuration systems. However, fixture design is dominated by the experience and knowledge of the designing engineer [16]. In the present paper several topology

2212-8271 © 2017 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the scientific committee of the 27th CIRP Design Conference
doi:10.1016/j.procir.2017.02.008

optimization problems have been performed in order to create a new fixture design such that the stiffness of the structure is maximized. The component examined has been a part of an aircraft engine: Low Pressure Turbine Casing (LPT).

Considering the results obtained with topology optimization, three preliminary case studies of blended Solid-Lattice structures have been implemented. A linear static analysis has been carried out in order to evaluate the stiffness of each proposed fixture.

2. Topology optimization

The aim of the present work has been to define a new methodology to design the machining fixture that allows to take in account of the following aspects:

- Workpiece local stiffness variation: the machined components have thin walls, non-constant sections and large diameters;
- Cutting forces: the equipment must be able to stiffen the workpiece during machining process;
- Avoid the traditional trial & error approach.

Design methodologies for fixtures can be regarded as an ongoing topic, in fact, currently, fixture design is based on the experience and knowledge of the designer**,** then, the final fixture design is the result of a trial & error process.

The workpieces are effectively “thin walled structure” because they can be described as: truncated cone shape, large diameters and thin walls. Those are a typical geometric features of low pressure turbine casings which are the part of interest in the developed activity. For confidentiality reasons, it cannot be possible to indicate further information about it. In any case, the average thickness is of few millimetres.

The vibration problems for the fixture of the thin walled components are typically solved by means the introduction of some damping systems (hydraulic actuators and rubber strips) in order to dissipate vibration energy and to damp the part during the working phase. For these reasons the aim of this paper has been to study and define, through the new defined methodology, a solution characterized of an optimal mass distribution taking into account the operative conditions (such as cutting forces) and local workpiece stiffness.

Different topology optimization problems have been performed both on fixture-workpiece systems modelled with shell elements (2D) and, on fixture-workpiece systems modelled with solid elements (3D), varying the topology design variables and/or optimization constraints for each optimization problem. The purpose has been to redistribute a given amount of material in a design domain, such that the stiffness of the structure is maximized. A simplified assumption has been to consider only a quarter of fixture-workpiece system modelling with solid elements for computing reasons. For the numerical simulations have been used OptiStruct® of HyperWorks suite. For all topology optimizations a manufacturing constrain, minimum member size, has been used. It controls the smallest dimension to be retained in topology design, as well as minimizing the checker board effect caused by the mesh and giving a more discrete design.

The solver calculates an equivalent density for each element, where 1 is equivalent to 100% material, while 0 is equivalent to no material in element (voids).

The solver then seeks to assign elements that have a low stress value a lower equivalent density before analyzing the effect on the remaining structure. In this way extraneous elements tend towards a density of 0, with the optimum design tending towards 1.

2.1. Case studies of 2D topology optimization

As mentioned above, topology optimization has been performed on fixture-workpiece system modelled with shell elements (thickness 1 mm). The structural model with applied loads, constrains and optimization constrains, for three case studies are shown in Fig. 1.

The objective has been to minimize the weighted compliance. 2D topology optimization has been performed to find preliminary the optimal material placement and reduce the mass of fixture.

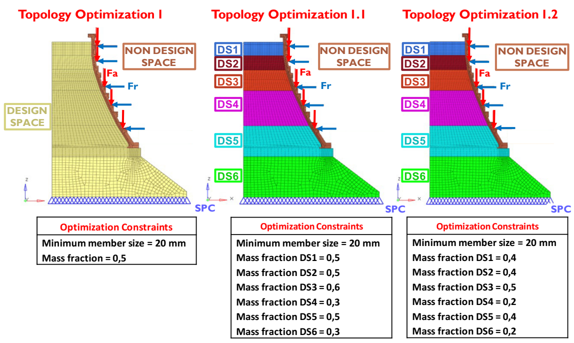

Fig. 1. 2D FE Model and optimization constraints

Fig. 2 shows element density contour plot of final iteration of 2D topology optimization and for assigned element densities for the three studied cases. Element densities equal to 1 refer to structurally important elements and density value close to 0 indicate voids.

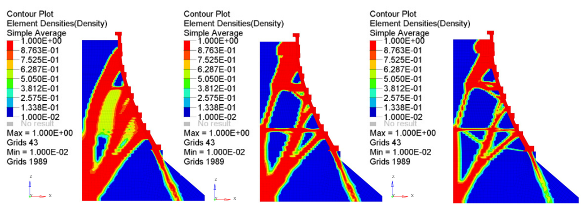

Fig. 2. Element density of 2D topology optimization

These results allow to understand what preliminary could be the “effect” of a topology optimization applied to fixture-workpiece system modelled with solid elements.

Download English Version:

https://daneshyari.com/en/article/5470579

Download Persian Version:

https://daneshyari.com/article/5470579

Daneshyari.com