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Design of individual re-contouring processes

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Abstract

The re-contouring process of turbine blades is performed subsequently to the material deposit and restores the shape of the blade. Each process within the process chain has to be adapted to an individual repair case depending on size, location and specification of the damage. Each damaged blade represents a batch size of one. Hence, there is no run-in on the machine tool. This leads to the requirement of an error-free process from the very beginning. Therefore, a reliable process design is needed, including an evaluation of technological blade properties. This paper introduces an integrated method for the design of re-contouring processes. The presented conceptual design considers special requirements regarding an individual repair case, e.g. an individual blade shape, blade properties and material deposit. The method encompasses the definition of an individual repair case and the tool path planning using an interface of a commercial software for computer aided manufacturing (CAM). For evaluation of the tool path, the method contains a high-resolution material removal simulation and a downstream analysis of engagement conditions.

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Keywords: Process design; Process simulation, Milling, Re-contouring

1. Introduction

The international MRO (Maintenance, Repair and Overhaul) market has an expected growth rate of 4.1% per year until 2025. Especially the annual spending in the sectors "engine repair" and "engine overhaul" will increase about $13.7 Billion each year.

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Therefore, aerospace companies will extend their financial effort in new MRO technology [1]. This necessitates cost-saving repair methods, which forces automation in MRO processes. Due to the variety in components regarding engine repair, the automation is a tough issue. Engine components, e.g. turbine or compressor blades, exhibit a wide range of individual damages. Carter describes and quantifies possible blade failures [2]. The various types of damages represent big challenges in process design, compare Fig. 1. Currently, MRO processes include many manual working steps. Thus, MRO can be compared to a workshop production. Therefore, automation aims for prevention of errors due to uncontrollable manual processing of the blades [3].

Necessary steps in repair of turbine or compressor blades
are the material deposit, which includes laser beam welding, and the restoration of the blade shape, called re-contouring. The latter includes machining, e.g. 5-axis ball end milling, and significantly affects the blade and its surface properties. Moreover, the re-contouring is a process step that directly affects the final shape of the blade and the performance of the regenerated engine. Hence, the requirements for the accuracy are as high as in the manufacturing of new blades [4]. Eberlein gives an overview of the patch repair of a single compressor blade. This industrial approach shows the positioning of the patch using FEM and the quality assurance, including geometry, residual stresses and an FE-based vibration test [5]. In general, research considers automation and optimization of the material-deposit and the re-contouring. This particularly includes upstream and downstream treatment of the blade like optical measurement, geometry reconstruction and machine tool devices. Huang *et al.* introduce a robotic belt grinding and polishing for the repair of turbine blades. This includes an automated handling

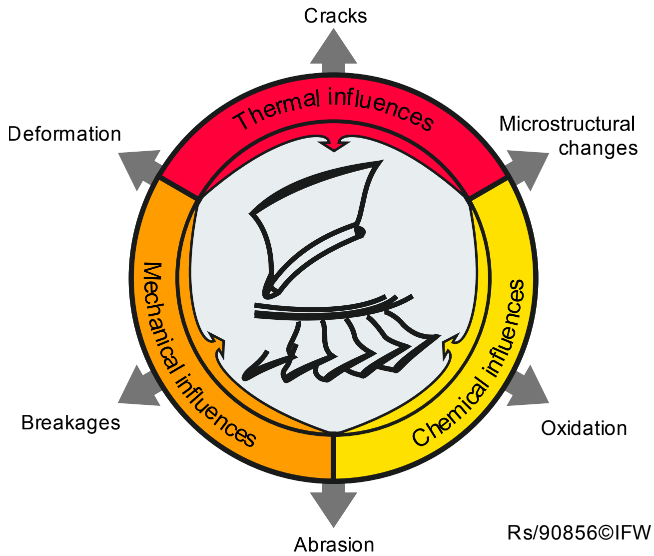

Fig. 1: Causes for damages on blades

of the blade between the blade measurement, grinding and polishing. The application is supposed to save up to 42% of the process time [6; 7]. Uhlmann *et al.* present a robotic belt grinding, including an automated path planning. The path planning provides an autonomous definition of machining offsets and divides the process into a roughing and a finishing step [8]. Denkena and Floeter show how to cope with changing engagement conditions in re-contouring by the use of an adaptive force control [9]. Bremer points out the need of connected machine tools. Hence, he introduces a web-based data management system, being able to connect processing cells even across different locations. The presented commercial system has the objective to reduce repair cost and process time by 40% each [3]. Gao *et al*. show an automated repair process chain based on reverse engineering (RE) of the blade shape and the derived tool path for re-contouring. Furthermore, they use a clamping system, which keeps the blade in a stationary position all over the repair process. Still, a critical aspect is the time dependent RE process, which also predominantly affects the accuracy of the whole repair process [10]. The RE process represents a bottleneck in blade repair. Taking into account the several different damages and the twisted blade shape, RE will hardly be automated in the near future