1 Introduction

Einleitung

In the aerospace industry, most of the rotating parts are defined as safety-critical due to the fact that the failure of an airplane part could directly lead to entire engine failure. It could cause the crash of a plane and therefore, the loss of many human lives as a result. On 6th of July 1996, the plane McDonnell Douglas MD-88 experienced an engine failure during the initial part of its takeoff at Pensacola Regional Airport in Florida. Metal debris from the front compressor fan of the left engine penetrated the left aft fuselage and entered the passenger cabin, causing the death of two passengers. The takeoff was rejected, and the airplane was stopped on the runway. Examinations from the National Transportation Safety Board revealed that the probable cause of this accident was a fatigue crack initiating from an area of the altered microstructure that was created during the drilling process by Volvo for Pratt & Whitney. The main cause of the machining-induced abuse was a drill breakage, combined with a loss of coolant and inappropriate chip evacuation. [NTSB98] **Fig. 1.1** shows the cross section of the fan hub depicting fatigue crack origins and crack propagation. In the metallographic investigations could be shown that the grain structure of the hole was distorted in the drilling process. Hence, in later application (especially during the take-off) numerous fatigue cracks occurred parallel to the longitudinal axis of the hole. This tragic event demonstrates clearly that the occurrence of machining-induced anomalies may significantly affect the lifetime of final parts.

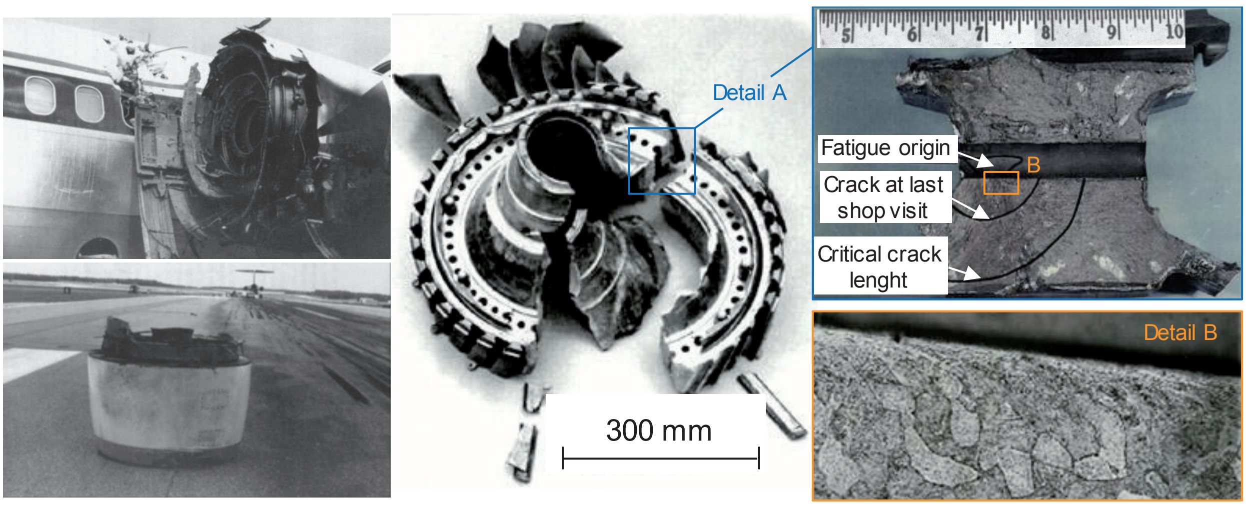

Fig. 1.1: Engine failure due to machining induced surface anomaly [NTSB98]

Triebwerksausfall aufgrund fertigungsinduzierter Oberflächenanomalie

Due to their physical-mechanical properties, most of the materials used in aerospace industry belong to the group of difficult-to-cut materials. Major problems during machining are low applicable cutting speeds, excessive tool wear and the formation of ribbon and snarled chips. Under these conditions, an automation of a production process is limited.

Despite innovative developments in the field of cutting tool materials and coatings, it is still unthinkable today not to use coolants in many machining tasks. In the conventional cooling method, the area of chip formation is most commonly flooded with coolant. In this way, the coolant does not significantly reach the cutting edge. Instead, the coolant flows uncontrollably around the cutting zone and preliminarily hits the chip's top side. In recent years, innovative cooling strategies were developed in order to increase the productivity and process stability. Beneath the process cooling with cryogenic media (CO_2 or LN_2), the high-pressure coolant supply has been emerging, especially for difficult-to-cut materials in the aerospace industry. By using the rake face sided high-pressure coolant supply, a focused and targeted coolant jet is directed into the wedge between chip bottom side and tool rake face. This coolant supply variant results in a deep penetration of the zone between the chip and the rake face of the tool. As a result, a liquid wedge is formed, which effectively cools and lubricates the cutting zone.

The potential of high-pressure coolant supply is highly promising with respect to reduced tool wear, lowered cutting temperatures and thus higher achievable productivity rates. Additionally, effective chip breaking and chip evacuation increase the process stability. However, this innovative coolant technology is mainly used in roughing operations. Industrial users report that chip-breaking potential of high-pressure coolant supply negatively affects the workpiece quality in finishing applications. Depending on the coolant parameters, broken chips are accelerated by the coolant jet towards the newly generated surface and cause surface anomalies through chip collision. The lack of understanding the physical interactions behind the cutting process with high-pressure coolant supply prevents this innovative cooling technology and leaves much of its potential unused.

Therefore, the goal of this thesis is to understand the underlying mechanisms for the occurrence of surface anomalies in turning of difficult-to-cut materials with high-pressure coolant supply. Based on empirical and analytical investigations of each type of surface anomaly, the cause-and-effect relationships between the relevant process parameters and the workpiece surface quality will be identified, translated into an explanation model for occurrence of surface anomalies and validated in a case study. In addition, an overview of different regions for each type of surface anomaly will be derived and possibilities for anomaly-free machining with high-pressure coolant supply will be shown. Finally, an innovative appraoch of pulsating high-pressure coolant supply will be presented in order to prevent surface anomaly occurrence.