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Reduction of Disassembly Forces for Detaching Components with Solidified Assembly Connections

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Abstract

The disassembly of components with solidified assembly connections is often difficult to plan. A typical example can be found in the aviation industry, where turbine blades solidify in the turbine disc due to operational loads. The solidification of the joining partners has several causes such as thermal stress or high centrifugal forces so that the disassembly forces cannot be estimated exactly. The forces in manual disassembly, e.g. when striking the assembled part with a hammer, are often too high and thus difficult to control. An automated approach is investigated, in which a piezo stack actuator induces vibrations to the joined components and force amplitudes are reduced based on a simplified model of the solidification. For this purpose, simulations are presented to determine forms of excitation for the piezo actuator and to control the disassembly process.

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1. Introduction

The disassembly of a product initiates its regeneration and the disassembly ability is a key indicator for the sustainability and a resource-efficient recycling of the product. The assembly connections strongly influence a product's sustainability and define the disassembly characteristics of the product.
Disassembly processes can be divided into either detachable connections, such as screws or guides, or non-detachable connections such as welded connections [1]. The last mentioned are generally separated by destructive processes [2]. Generally, a destructive process is counterproductive when attempting to regenerate a product through preliminary disassembly. For that reason, only detachable connections are part of the research in this paper.

A fundamental challenge in the disassembly of detachable connections is the change of the degree of freedom of the assembly connection due to product operation. Typical causes for changes in the degree of freedom include broken screw heads and worn or soiled guides. During disassembly, these changes can result in further damage to the connecting partners due to undefined reaction forces, acting inside the connections of the joining partners. The risk of damage decreases with an improved quality of a disassembly process. A quality process is worthwhile especially in the aviation industry, where the regeneration of quality goods is indispensable. The disassembly of turbine blades as a quality good which solidifies in a turbine disc is investigated in this topic. With regard to the aim obtaining a controlled process, the question is, whether unknown quantities such as a solidification parameter can be described to avoid oversized disassembly forces. A promising approach to control these forces is to induce vibrations with an adaptive application.

2. Related Work

In general, in assembly and disassembly technology oscillations are considered annoying and are avoided by rigid structures. However, there are also technologies where vibrations are deliberately brought e.g. in the instances of handling technology such as vibratory feeders. Further, also approaches are found that take advantage of oscillations in joining as primary assembly technology.

Vibrations are used for reducing assembly forces, for example in the field of geotechnical and mining technology such as sonic drilling. Sonic drilling is a soil penetration

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technique that strongly reduces friction on the drill string. This is used e.g. for insertion of pipes in the ground. This principle, so-called vibratory driving, bases on the harmonic excitation of a ram body, where a structure rearrangement of the soil occurs. The vibrations cause a temporary reduction of porosity of the soil and thus the friction between soil and ram body (shaft friction). The method is suitable for different types of soil, such as sand, silt, and clay with inhomogeneous formations. Also, hard rocks can be pierced within limits. In this technology, the tools press forward under a slight pressure into the ground with an overlapped axial vibration in the range of 100 to 200 Hz [3]. In these methods for drilling into the soil, vibrations are used to reduce assembly forces, but it remains questionable whether the same force reduction effects can be exploited for detaching components with solidified assembly connections.

In the case of solidified connections and necessary detaching tools, screw connections were primarily examined in the research of disassembly technology. One of the main causes that leads to a solidification of screw connections is corrosion. In [4], the influence of corrosion on disassembly forces was examined for screw connections. The higher the corrosion class, the higher is the torque required for loosening a screw connection. For electronic equipment, surface corrosion can increase the loosening torque up to 45% [4]. The effects of solidification on disassembly time are illustrated in another publication [5]. As shown there, the duration increases significantly due to solidification and deformation of a screw. To design a tool which can be used to loosen solidified screw connections, a mathematical model was created that determines the energy required for disassembly [6]. Based on the estimated energy that is required to loosen the assembly connection, the corresponding disassembly tool induces vibrations in the object to create an additional acting surface through plastic deformation. Given the plastic deformation caused in some of the components, the disassembly method is partially destructive. The priority is to reduce the force transmission to the user of the tool and not primarily a component protection [7].

In other publications, the positive effects of higher frequencies in the production are used for a component friendly manufacturing. Ultrasonic machining applies superimposed ultrasonic vibrations in classic manufacturing processes such as drilling, milling, grinding, turning, etc. and it has less negatives effects on tool wear, machining forces, machinability, and surface finish. In particular, coupled vibration can make the machining of brittle materials, such as ceramics and glass easier. Also for the machining of metals, ultrasonic machining could come with advantages such as lower machining forces, lesser tool wear, and thinner chips. Ultrasonic machining also reduces the breakage of the tool during the process. Piezoelectric actuators are often used to provide adjustable mechanical vibrations. The transducer, generally designated as a converter, converts electrical energy into mechanical oscillation energy [8] [9]. Aim of this research is to use oscillation energy for disassembly with the prospect of being able to control the force amplitudes well. In order to adjust oscillations, a description of the acting forces in a disassembly connection is required. This is shown by the example of a turbine blade disassembly.

3. Case Study - Turbine Blades Disassembly

After an engine operation, turbine blades in a turbine disk are typical examples for solidified connections (Figure 1). Due to the high quality of the components, there is a great demand for automated solutions that increase the reproducibility of the disassembly process.

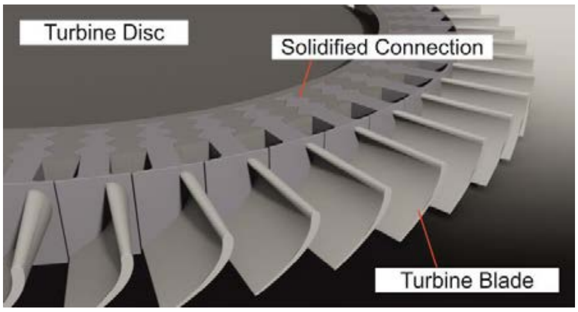

Figure 1: Turbine Blades with Turbine Disc

The last of many disassembly steps in a turbine disassembly is the manual separating of blade and disc. Depending on the type of turbine and turbine components, the removal processes distinguish to each other by the necessary detaching forces, which depend on the geometry of the connection profile. The high pressure turbine blades generally have a more jagged profile (fir tree profile - Figure 2 - left) connection to the turbine disc. The advantage of such a connection type is the distribution of the centrifugal forces onto several contact surfaces. In comparison, the low pressure turbine consists of a trapezoid prism connection (Figure 2-right).

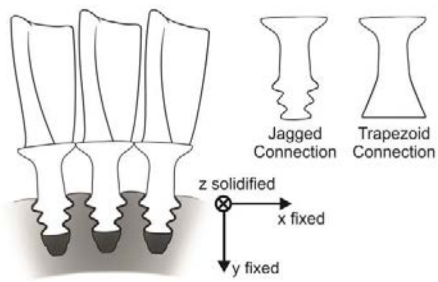

Figure 2: Connection geometry of Turbine Blades

The tight fit secures the turbine blades in radial and tangential directions, so that they only can be assembled and disassembled axially. The axial solidification between the foot of the turbine blade and disc blocks the axial degree of freedom and it may be the result of various causes. One possibility is that the high forces and temperatures occurring during engine operation stress the materials nearly to their resistance limits. Another possibility includes external forces such as weather conditions and other extraneous matters (for example sand), which entered in the turbine.

The degree of solidification, or the resulting forces acting in the connection, is typically unknown because the reasons are not obvious. Therefore, a targeted initiation of a force cannot be accurately planned for disassembly and the current