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Modification of oscillation modes in low frequency vibration assisted drilling

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Abstract

Low frequency vibration assisted drilling (LFVAD) is applied to generate small chip sizes in order to avoid chip accumulation in drilling processes. In contrast to ultrasonic assisted drilling the oscillations are characterized by relatively high amplitudes of up to 200 µm at significantly lower maximum frequencies of around 300 Hz. This enables an interrupted cut which leads to a chip breakage, almost independent of the mechanical properties of the workpiece material. However, significantly higher cutting forces are generated in comparison to conventional drilling processes (at the same material removal rate). In the present study the shape of the vibration oscillations (which is usually sinusoidal) was modified in order to affect the uncut chip shapes. The geometrical cutting conditions have been visualized using a kinematic cutting model. Due to the modification of the oscillation mode the maximum cutting forces could be decreased by at least 13 %. Furthermore, the cutting force progression during the generation of each pair of chips (two fluted cutter) could be improved regarding a smoother slope of the forces. As a consequence, "shock loads" to the tools are avoided and higher values of the axial feed are enabled, which contributes to a raise of productivity in LFVAD.

Keywords: Drilling, Chip, Vibration, feed force

1. Introduction and target of research

In drilling of metallic lightweight materials like aluminium and titanium, widely used in the aircraft industry, the tendency of these materials to build long helical chips leads to reduced borehole qualities and high process

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temperatures. The high process temperatures are, inter alia, induced by friction of hot chips at the borehole surface and a disturbed chip removal [1, 2, 3]. A promising approach to avoid these problems is vibration assisted drilling at low frequencies. This kinematic leads to an interrupted cut, resulting in small chips and a sufficient chip removal followed by superior borehole qualities [4, 5]. Pecat et al. showed that the process temperatures can be reduced by 43% when applying low frequency vibration assisted drilling for Ti6Al4V compared to conventional drilling at the same material removal rate [6].

However, the axial osciallations in vibration assisted drilling temporarily lead to high chip thicknesses causing a significant increase of the maximum feed forces compared to conventional drilling [7, 8]. In consequence, the maximum feed forces are a limiting factor for the vibration assisted drilling process, especially when drilling parts with larger overhang or low structural stiffnesses. Another limiting factor is the maximum mechanical load the particular drilling tool can resist. Therefore, the target of the present study is to reduce the maximum feed force by applying modified oscillation shapes in vibration assisted drilling processes.

2. Experimental setup and procedure

For the planned modification of the usual sine curve, a system is needed, which allows an adjustment of the vibration parameters like frequency and amplitude independent of the rotational speed of the spindle. Together with oscillation shapes, divergent from a usual sine curve, this system allows to “design” chip shapes which are suitable for given process conditions. To realize these modifications a magnetic spindle, developed by LTI Motion, was used, which involves magnetic bearings and allows independent axial oscillations, superimposed to the axial feed movement. Position sensors allow to measure the actual position of the rotor within the magnetic bearing and therefore, enabling a comparison between the nominal and the effective generated curve. The feed force was measured by a Kistler Dynamometer 9272 (measurement frequency of 3000 Hz). Detailed information about the tool, workpiece and process parameters are given in Table 1. The experimental setup is given in Figure 1.

Table 1. process parameters, tool and workpiece

Cutting speed v_c	15 m/min
feed f	0.15 mm/rev.
amplitude A1	0.12 mm
frequency F1	1.5 oscillations/rev.
superimposed amplitude A2	0.03 mm
superimposed frequency F2	4.5 oscillations/rev.
phase shift φ	15°
coolant	internal MQL (AccuLube5000)
tool	carbide, point angle 120°, helix angle 30°, diameter 4.8 mm
workpiece	Al7075 (3.4365)