Concept design of a manually adjustable intuitive toolholder

Design of a manually adjustable intuitive toolholder for Philips' Lifrel

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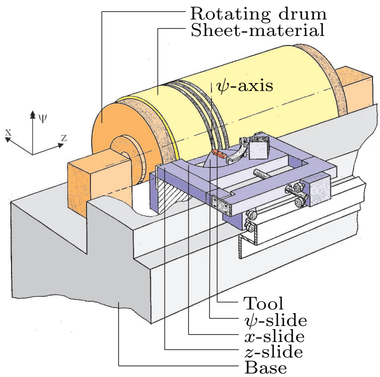
Abstract

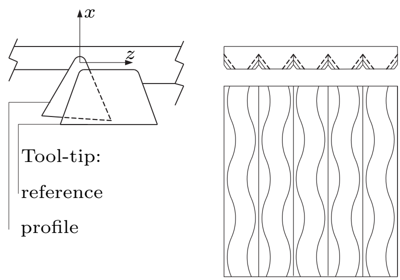
The toolholder design reduces the current adjustment time from a two day maximum to a two hour maximum. The toolholder has a stroke of $\pm 0.5mm$ in x- and z- and $\pm 1°$ in ψ-direction with an accuracy of respectively $0.25\mu m$ and $0.1°$. Groove structures can be applied with a $10\mu m$ depth variation at a $50Hz$ machining frequency.

Introduction

The Philips Applied Technologies Lifrel optical diamond turning machine (Figure 1(a)) can produce masters (of $1200mm$ x $1500mm$) in copper or plastic sheets for optical groove structures (for example backlights) using one or two tools. A profile structure is made with two tools, the profile tooltip is placed $8mm$ underneath the reference tooltip's left corner (Figure 1(b)), so one groove is cut with both tools at the same time. A depth variation (amplitude $10\mu m$) in or in between grooves could be part of the profile, but is currently not possible. The master's production time can amount up to a couple of days, this is justified by uv-curing a 2p-lacquer covering the master structure to make replicas.



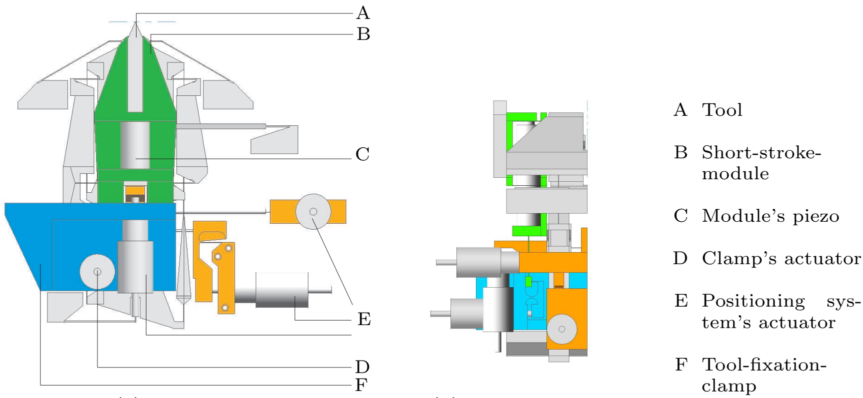
(a) Scheme of the Lifrel (optical diamond turning machine) machining a sheet (l $1200mm$, w $1500mm$). The toolslides move in x-, z- and ψ-direction.



(b) Profile-master structures with a depth variation. One groove is realized with two tools at once.

Figure 1: Lifrel and an example of an optical groove master structure

The operator influences the accuracy with which the groove master structure is made by manually adjusting the initial tool position in x-, z- and ψ-direction with respect to the mentioned reference. This iterative process can take up to two days for two tools and this had to be reduced.
This paper describes the design of a toolholder and its positioning system with which the x-, z- and ψ-position of the tooltip can be adjusted. Using this positioning system reduces the current maximum adjustment time to two hours when used in combination with a converging adjustment procedure. When machining, the tool position is taken over by a clamp (Figure 2), enhancing the stiffness in x-direction. A closed-loop piezo-driven small-stroke-module (Figure 2) enables the depth variation by moving the profile tool with respect to the reference tool.



(a) Top-view (b) Right-view

Figure 2: Toolholder for intuitive manual tool position adjustment of the profile tool. Using this toolholder reduces the maximum position adjustment time

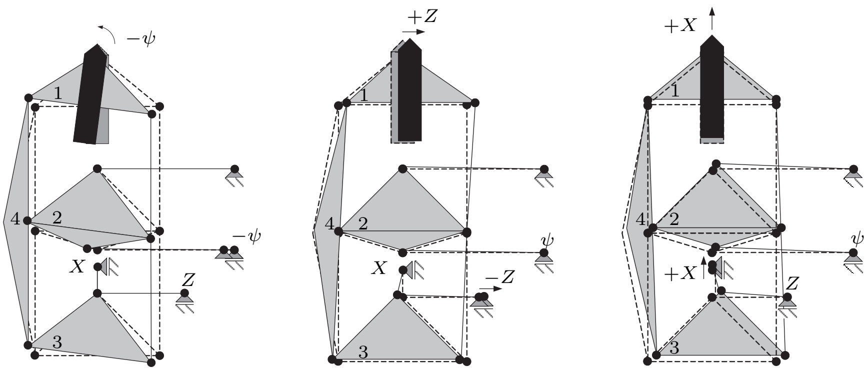
Toolholder's requirements

The toolholder has to perform a stroke of $\pm 0.5mm$ in x and z and $\pm 1^\circ$ in ψ-direction, because the tool is manually clamped within this range of the reference. Its accuracy is determined by the groove structure's replica requirements being $0.25\mu m$ in x and z and 0.1° in ψ when applied on the Lifrel. When the toolholder is used on more accurate machines this becomes respectively $0.05\mu m$ and 0.001°. Additionally the depth variation dx of $\pm 10\mu m$ should be provided with a machining frequency of $50Hz$.

Toolholder's positioning system

The initial tool position is currently manually adjusted in an iterative procedure of successively trying to move the tool over small distances, machining part of a try-out master, measuring a replica and finally comparing these results with the replica's requirements. When the replica requirements are met, the final master structure can be manufactured else another iteration loop has to be carried out. Currently, friction (causing stick-slip and hysteresis) makes accurate positioning difficult resulting in an unpredictable number of iteration loops. These iteration loops are made predictable by using flexures as a toolclamp suspension, because this eliminates friction, wear and play. A flexure guidance prevents relative movement of two bodies

in its stiff directions and allows relative movement in its unconstrained directions. Usually the ratio: $c_{stiff}/c_{low-stiffness} \approx 1000$ can be obtained, sometimes 300000 is possible [3].
Executing one iteration loop takes about half an hour. Manual tool position adjustments usually take less than 10% of this half hour. Automating this positioning part does not reduce the time required to make and measure the replica. Therefore the toolholder's positioning system consists of an intuitive mechanism, which can be manually adjusted. The reader is encouraged to look at Figure 3 to see the input effect on the tool position. The mechanism contains a virtual point of rotation, providing translation-free tooltip rotation (on condition that the tooltip is placed above body 1's rotation axis). The translations are coupled, since translation in one direction causes parasitic movements in the other direction. Adjustment of the rod lengths that are attached to the x- and z-actuator (respectively x- and z-rod) partly compensate for these parasitic movements. Applying a converging adjustment procedure in combination with the positioning system makes position adjustments easy. The input is provided by actuators (differential micrometer drives [5]) combined with transmissions to result in intuitive usage of the positioning system (Figure 2). For x and z, reducing transmissions 1:5 are used.



(a) ψ-movement (b) z-movement (c) x-movement

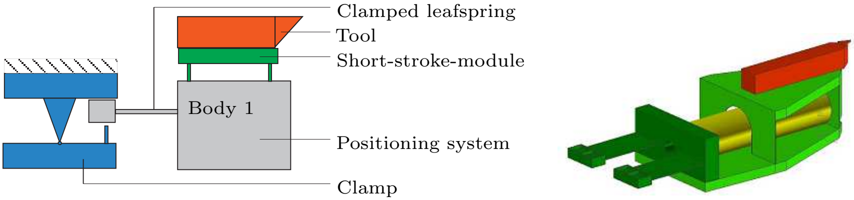
Figure 3: Positioning system's mechanism in 2d, with the tool on body 1

The tool on the toolholder's positioning system experiences stiffness $c_x = 0.2N/\mu m$ and $c_z = 0.7N/\mu m$. The positioning system has been modelled in pro-engineer, which is succeeded by an analysis in pro-mechanica, giving a first eigen-frequency of $390Hz$ and a second of $490Hz$.

Toolholder's lay-out

The tool position in x, z and ψ is fixed with a clamp during machining, because the positioning system's stiffness does not resemble the original toolholder's stiffness, a stiffness that seems to function properly. The clamp should fix a leafspring in the xz-plane mounted to body 1, after manipulating the tool to the desired position (Figure 2(a) and 4(a)). It will enhance the x-stiffness up to $c_x = 3.5N/\mu m$.

The profile tool's small-stroke module provides the depth-variation with respect to the reference tool reference surface (Figure 2(a)). The module is driven by a closed-loop piezo [5] underneath the tool (Figure 4(b)). This actuator provides the system with indirect position information.



(a) Toolposition fixation by clamp during machining

(b) Small-stroke-module for depth variation

Figure 4: Toolholder's fixation clamp and short-stroke-module

The positioning system on its own functions properly. But by introducing it on the ψ-slide and using it as part of the toolholder, it reduces the stiffness the tool experiences. It should be tested whether this stiffness is sufficient else a different toolholder composition will have to be considered.

Conclusions

A toolholder has been designed, which gives the possibility to manually position a clamped tool in x-, z- and ψ-direction. The intuitive positioning system is provided with a virtual rotation point and three differential micrometers. In x- and z-direction the toolholder's range covers $\pm 0.5mm$. In ψ-direction this is $\pm 1°$. Maximum initial tool position adjustment time is reduced from two days to two hours. Groove structures with a groove-depth variation of $\pm 10\mu m$ can be realized at an operating frequency of $50Hz$ due to the small-stroke-module driven by a closed-loop piezo actuator.

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