Potentials of Combining Different Manufacturing Techniques in one Machine for Ultra Precision Machining

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Abstract

This paper presents a theoretical analysis of work piece errors arising from the transfer between machines during the machining process. From this analysis the need for a machine that combines the characteristics of an UP-turning center and an UP-milling machine are derived. Finally a machine setup developed during a project of the Fraunhofer IPT is presented. The potentials of building this highly integrated machine combining the whole set of tasks needed during the process chain of UP-machining of complex parts is shown. Additionally, manual working steps are analyzed and the high degree of manual work is identified as a limiting factor for enhancing accuracy. The need for intelligent automation is presented and a clear distinction is drawn to automation that does not positively affect machining results.

1 Introduction

Ultra precision and micro machining is forced into new accuracy levels featuring more challenging geometries and shapes. Smaller structures and rising demands of surface roughness make the combination of different manufacturing methods more and more interesting. Since UP-machines are highly specialized, designed and optimized for exactly one manufacturing method, the combination of different machining in one work piece either leads to time consuming changes of the machine setup or to the transfer of work pieces between machines.[1]

1.1 Conventional manufacturing sequence of ultra precision machining

Rough machining and milling of reference marks combined with fast-tool-turning are used for manufacturing highly integrated parts. Furthermore, intermitten measuring takes place to achieve the high accuracies demanded for. Those machining sequences make the transfer between several highly specialized machines necessary.

Switching between machines with clamping and unclamping the work pieces leads to inaccuracies. Even though the fixtures generally used are very precise and machined to high accuracy, the repeatability of clamping is limited. To further enhance

accuracy the alignment is checked with the help of precise calipers, still providing limited accuracy.

Moreover, differences between the fixtures of different machines produce different states of induced stresses and thus work piece deformation and inaccuracies. To reduce those negative effects, time consuming premachining of fixtures and alignment procedures take place prior to transfers. Since ultra precision machining is still mainly done manually, these are challenging processes demanding for highly skilled workers and precise measuring equipment.

Alignment is most often enabled using reference marks or planes. Therefore, the alignment accuracy is also determined by the position accuracy of the marks and the accuracy of the measuring devices used to detect the references.[2]

To avoid the inaccuracies described, the number of transfers between machines has to be reduced.

2 Improvements

An approach of reducing the induced errors is the combination of the machining techniques UP-turning and micro milling, as well as the measuring equipment for quality control in one machine set-up. Another possibility to enhance reproducibility and reduce manufacturing time in UP-machining is the intelligent application of automation techniques into the machine tools.

2.1 Integration of turning, milling and measuring in one machine

To reduce machining time and enhance machining accuracy the aligning processes have to be reduced to a minimum. The new process chain has to be shorter with less transfers and thus less flawed manual woking steps. A possible solution is to include everything in one machine, so the rough part has to be aligned on the machining spindle only once at the beginning. Then the position is determined by the integrated measuring equipment and the machining process, consisting of milling, turning and intermittend control using the included measuring devices, can be started.

The only aligning procedure still necessary is the calibration of the machine and the determination of the position of the axes in relation to each other. This calibration is part of the machine characterization during machine setup and can be realized much more precisely than the alignment of work pieces inside the machining space.

The benefit of a machining center which combines the machining and measuring is obvious. Additionally, intermittent measuring between machining steps and correction machining is enabled.

2.2 Realized special machine design

The major goal of realizing the new machine design was to establish a shorter process chain by eliminating most of the aligning procedures and transfer operations. The combined machining center realized is shown in figure 1. The two parallel z-axes offer space for a milling spindle inside a y-axis and turning-tools or fast-tool-systems for UP-turning on a b-axis. Furthermore, the integration of tactile and optical measuring equipment is possible. A measuring microscope, an LVDT-caliper and a confocal sensor are to be inluded and connected to the machine control system. On-line and automatic work piece measurement and setting is going to be possible. The dimensions of the slides allow for the arrangement of the measuring equipment in a secure distance to the machining space. Contamination or damage can thus be prevented. Machining and aligning time is reduced by an optimal combination of machining processes and reduced machine transfer.

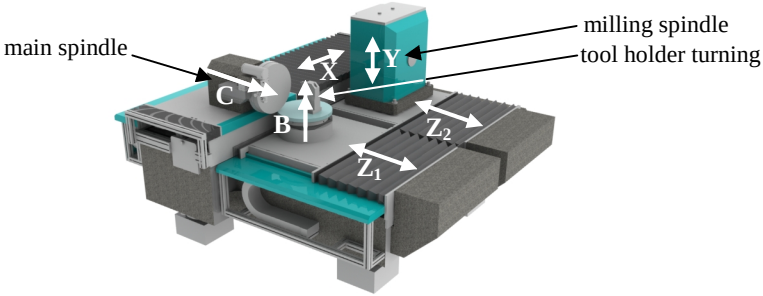

Figure 1: Combined ultra precision turning and milling center designed by LT-Ultra in close collaboration with Fraunhofer IPT

2.3 Automation

Besides the integration of as many tasks as possible into one machine, introducing “real” automation into the field of UP-machining offers the possibility of enhancing accuracy and speed. A careful distinction between automation really improving the performance and the one not being beneficial has to be drawn. Since UP-manufacturing is often single-piece production, automation of UP-machining primarily has to improve accuracy. The goals of improving speed or machining 24/7

do not necessarily have to be met. Most automation applied in conventional machining thus would not improve the performance in UP-machining.

The analysis carried out during this research addressed the processes of UP-turning, UP-milling and Fly-cutting. Therein the steps during machining were analyzed as to how long they take, whether they are automable and whether automation can improve accuracy. Figure 2 shows an excerpt of the results derived. It shows an example for the difference between automation that is benefitial (aligning and balancing), automation that is possible (starting of the machining process and measuring of the center artefact) and steps that are not reasonable to be automated (detaching of wp).

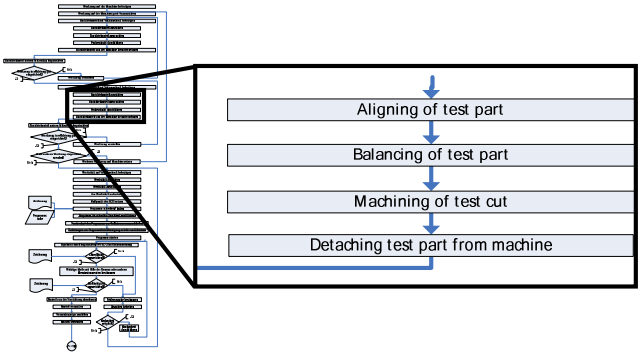

Figure 2: Manufacturing sequence of ultra precision turning. During this research project the manufacturing steps concerning tool changing and tool setting were detected to be most crucial to automate. The detailed results of the analysis and the realization of the specific automation inside the combined machine center are going to be presented later on.

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References:

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