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Conception of a mobile climate simulation chamber for the investigation of the influences of harsh shop floor conditions on in-process measurement systems in machine tools

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ABSTRACT

In-process measurements by machine tools offer high product quality, lower manufacturing costs, high productivity and a real-life assessment of product quality. Measurement errors of machine tools are influenced by complex environmental factors on the shop floor (e.g. temperature). The project "Traceable In-Process Dimensional Measurement" (TIM) aims for the ability to measure fabricated parts accurately in-process under the influence of the previously named factors. The development of a mobile climate simulation chamber is one of the work packages in this project and has the objective to simulate shop floor conditions to which a machine tool is exposed in its daily use. Based on the analysis of the variety of influencing factors, different concepts for the design of the mobile simulation chamber have been elaborated and the final concept was chosen. The validation of the final concept was supported by a computational fluid dynamics simulation and a modified temperature sensor distribution that is fit for the described purpose with regard to the mobility and thermal stability of the system.

1. Introduction

The machining accuracy of machine tools is connected to numerous influences such as the character of the machined work piece, the condition of used tools but also different environmental conditions that affect the operation. These possibly harsh conditions vary from shop floor to shop floor and therefore require special, reproducible conditions for measures of quality assurance. These measures are often related to additional paths that lie between themselves and the manufacturing location and are counterproductive for the demand for higher quality assurance rates. A possibility to avoid these additional distances is the integration of measurement systems in the machining area of machine tools. This is the reason why the project TIM (acronym for Traceable In-Process Dimensional Measurement) aims for the research on the traceability of measurement uncertainties under harsh environmental conditions due to the behavior related to environmental influences on machine tools [1]. One essential part of the project is the development of a mobile chamber that is able to house a typical machine tool and simulate climatic conditions in a reproducible and stable manner. The primary feature is the implementation of different temperatures. Thereby it is possible to imitate shop floor conditions in numerous locations with regionally different climatic influences. The mobility of the chamber allows its industrial use where machine tool operators themselves can investigate and optimize the running parameters of their machines and their integrated measurement systems (see Fig. 1).

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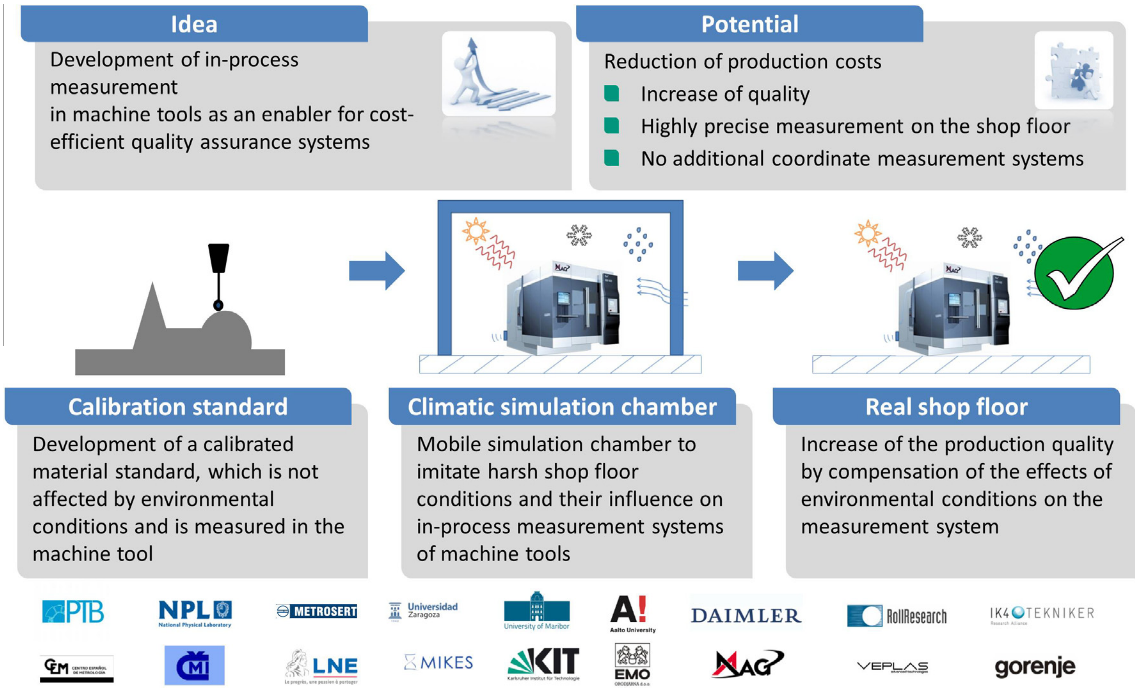

Fig. 1. Traceable in-process dimensional measurement.

2. Boundaries and requirements on climate simulations

The requirements for the development of a mobile climatic simulation chamber can be summarized in two main functions:

(1) Capability of the subsystems to create thermal states under the influence and possible interactions with both heat sources and sinks.
(2) Conservation of the climatic state, which can be expressed by both the sealing against material flows and the thermal conductivity in the surrounding housing.

The definition of the simulated temperature results from regionally measured conditions throughout different manufacturing locations. Expert surveys with the German company MAG IAS GmbH, which is a leading manufacturing technology group in milling and turning for manufacturing systems [2] resulted in the definition of a temperature range of 15–45 °C, in which machine tools find themselves during their application and a definition of different time-spans, which are characteristic for the operation of the climate simulation chamber. Long-term climatic simulations can be represented by temperature changes over several days and weeks and can be seen as regional boundary conditions in the application of machine tools. Medium-term time-spans are described in thermal changes with durations of several hours and represent heating or cooling of a shop floor environment due to the course of the sun or local air flows during the day. The simulation of both long-term and medium-term temperature profiles is the overarching goal that is discussed here. Highly dynamical simulations of temperature changes would allow a holistic perspective on the behavior of machine tools, which however can be characterized by weights of up to 25.000 kg and are expected not to have a significant reaction to the described influence. A targeted rate of temperature change of 3 °C per hour is sufficient to simulate both long-term and medium-term profiles without the necessity of specially designed air conditioning aggregates. A reliable conservation of the climatic state necessitates low thermal conductivity coefficients of the walls and a sufficient sealing to minimize the leakage of the conditioned air and thus to maintain the humidity in the air. The restricting factors in the definition of requirements for these components are the availability on the market and a reasonable price-performance ratio considering the targeted values of temperature and the surrounding environment conditions, which are shown in Table 1.

Another influencing factor in the specification of the chamber is the emitted heat of the machine tool. Expert surveys with machine tool manufacturers revealed values between 18 kW up to a maximum of 24 kW of heat that can be expected from a typical machine tool. The same expert survey revealed typical machine tool dimensions in the automotive industry that are used as a reference for the final housing dimensions, that will be dealt with further below in the section about the dimensioning of

Table 1
Surrounding conditions.

Outside temperature	Outside relative humidity
18–35 °C	30–60%