ARTICLE

Precision engineering, an indispensable element to develop machine tools

- *Improving machine tool accuracy is one of the key goals for manufacturers and users (development and utilisation of machines and production systems) to ensure that the specifications of the products to be manufactured are fully met. On-machine measuring and zero-defect manufacturing are two of the concepts currently being developed in the area of research to be eventually incorporated to machine tools and enhance precision even in the case of larger parts.*

Precision engineering is geared towards developing and designing machines, equipment and products following a number of basic principles focused on prioritising precision over any other requirements.

Precision has commonly been associated with certain kinds of projects such as watches and even with countries like Switzerland, although it is a far more extensive concept. Generally speaking, an accurate system can be described as something that performs its tasks and functions free of errors in terms of the ultimate goal to be achieved and, should errors occur, they are always minor and quantifiable.

When addressing precision, there are three closely interrelated concepts that must be understood: **exactness, repeatability and resolution**. When described, people usually refer to a “storyteller”. Exactness is related to how true the story being told is, repeatability is the ability to always tell the same story and resolution addresses the details that explain the story.

For a system to be rated under the **“precision”** heading, it is obviously necessary to combine these three concepts. Reality has demonstrated, however, that many efforts made in the area of precision engineering have been focused on ensuring repeatability as, although exactness is the ultimate goal, it is important to know and understand the

repeatability of components and the system as a whole because repeatability represents the lower limit of precision.

Since its creation, **Tekniker** has included precision engineering as one of its lines of specialisation and has used it to develop an extensive range of equipment and systems in the form of special measuring machines, scientific instruments, testing equipment, optoelectronic components, measuring standards, etc.

In addition to designing systems based on the above mentioned concepts, another key element of precision engineering is **manufacturing processes** that require production resources to be conceived and used as precision elements.

Market demand is currently focused on manufacturing larger elements, although accuracy requirements must be maintained or even increased, a fact that explains why machine tools must be capable of performing functions with higher degrees of precision.

There is a rising demand in the machine tool sector that has to be addressed by delivering new developments featuring precision engineering principles from the very beginning to achieve a high degree of repeatability and limit **effects arising from thermal deformation, friction and clearance. Accurate drives incorporating systems to properly close loops must also be included.**

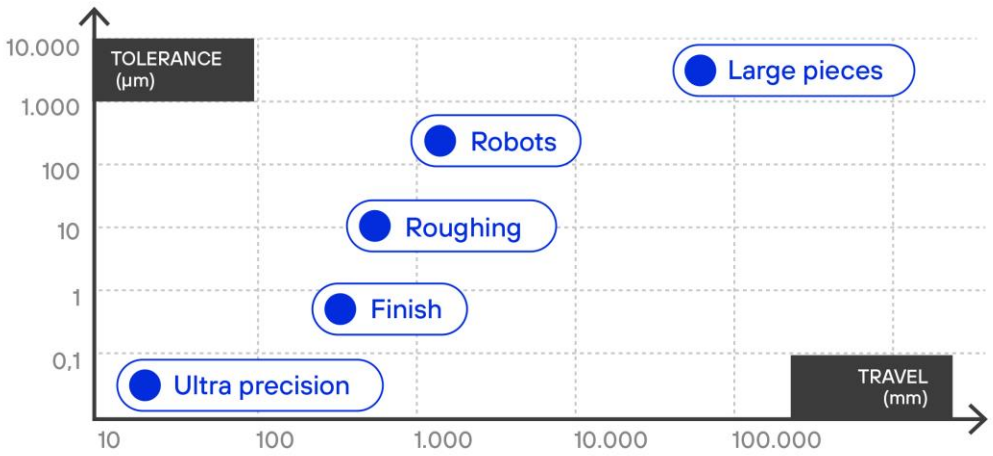

Figure 1: Precision of current production resources (Source: Tekniker)

On-machine measuring

Currently, and in order to properly address the challenge resulting from increasingly stringent manufacturing requirements, one of the trends consists in having the machine measuring itself during the production stage according to the targets set and the process phase. Thanks to on-machine measuring it is possible to ensure that workpieces are properly aligned once clamped and correct any deficiencies and validate a workpiece once fully processed.

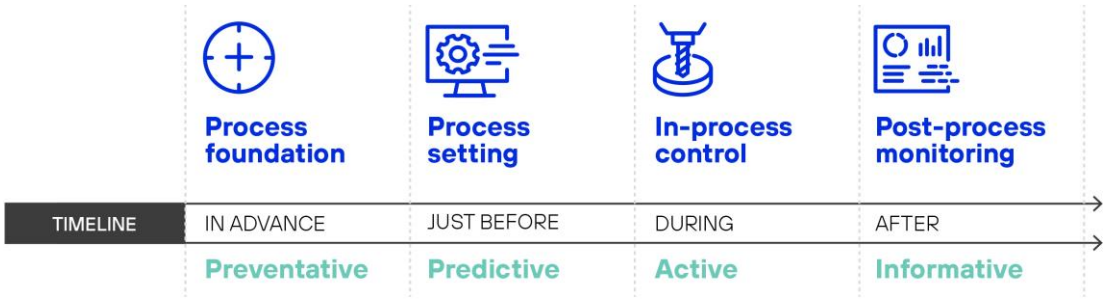

Figure 2: On-machine measurements in different stages during the manufacturing process (Source: Renishaw)

On-machine measuring is gradually getting closer to how it is applied under shopfloor conditions, although still in an early stage of development as research is still underway. Leading advanced manufacturing research centres such as Fraunhofer (Germany) and AMRC (United Kingdom) have already showcased their first machine tool demonstrators featuring on-machine measuring capabilities.

In the last five years, several research projects have been carried, especially at a European level, and attempts have been made to overcome problems associated with this technological challenge.

Listed hereunder are the challenges that most affect the capacity and quality of on-machine measuring in the case of machine tools:

- The degree of machine tool accuracy required to perform measurements and meet the dimensional requirements of components.
- Shortening machine shutdowns to perform machine calibrations by developing

simplified calibration patterns and procedures.

- Integrating on-machine measuring systems in terms of hardware and software.
- Allocating uncertainty to measurements performed with machine tools.
- Characterising machine tool thermal behaviour to lessen impacts on machine condition and, consequently, the results to be obtained by measuring.
- Modelling thermal behaviour subsequent to machining and the gravitational behaviour of the part to be measured.
- Software to run and process results obtained during on-machine measurements.
- Simulation tools applicable to machine tools to prepare measurement strategies (digital twins).

The “zero defect” strategy

As regards the line of research focused on advanced manufacturing, Tekniker has put its stakes on the “zero defect” strategy which, as the term itself suggests, consists in manufacturing defect-free products. The ultimate goal is that all end products must meet quality requirements in full and be designed to prevent waste associated with rejects.

This strategy has been specifically demanded by manufacturing processes used to produce large high-added value components such as those used in sectors dealing with wind power, aeronautics or science.

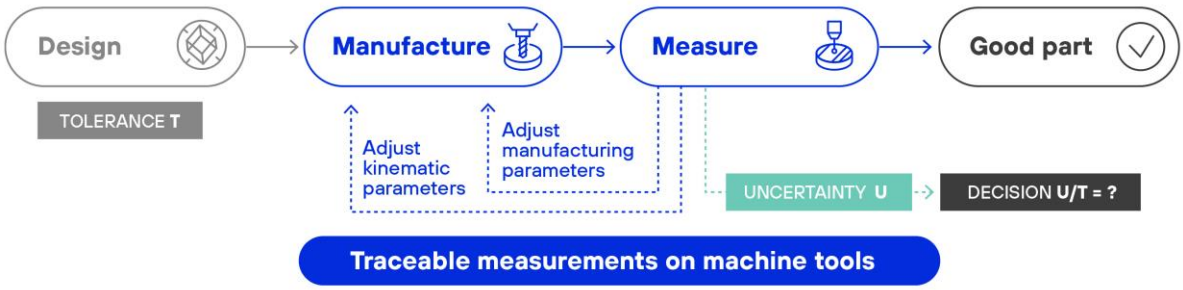

Figure 3: Zero-defect strategy based on machine tool coordinate measurements (Source: Tekniker)

These components must be manufactured correctly from the very beginning. Accurate and constant feedback must be provided during the different stages in order to minimise the number of faulty parts.

The different manufacturing stages, therefore, must implement the zero-defect approach from the moment raw materials arrive until the end product is obtained.1

To perform this strategy, the four steps listed hereunder must be carried out in the manufacturing process to implement this strategy:

- Aligning the workpiece on the machine tool: blanks must be placed in-line with the machine tool's axes to produce an end piece fully in accordance with the pre-set geometrical shape.
- Auto-calibrating machine tool geometry to characterise and compensate machine tool geometry automatically, without human intervention.
- In-process measuring to correct a manufacturing process: The aim is to perform in-process coordinate measuring of dimensions considered to be to assist the process and perform it correctly. In this instance, on-machine coordinate measurement traceability is essential to ensure a zero-defect manufacturing process.

[1]R. Schmitt et al., "*Advances in Large-Scale Metrology – Review and future trends*," CIRP Annals - Manufacturing Technology, 2016.

- Validating a workpiece on a machine tool: In this task, on-machine coordinate measurements are performed to make sure that critical dimensions of the component are correct and to also guarantee that the part can be removed from the machine and accepted with no reworking once quality control checks have been performed.

A multidisciplinary approach

Tekniker aims to improve manufacturing accuracy by applying a multidisciplinary approach and using the principles of precision engineering as a support to design and develop equipment within the scope of constant research actions focused on manufacturing processes (both conventional and non-conventional) to see how they react within the overall system by developing innovative control and compensation strategies supported by machine characterisation techniques and monitoring processes such as Tekniker Fingerprint and digital models at different levels.

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