euspen's 23rd International Conference & Exhibition, Copenhagen, DK, June 2023

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Injection mould measurement system for increasing manufacturing control and production quality

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Abstract

Tool and mould making is one of the most important sectors of industrial manufacturing. Currently, over a third of polymer products are manufactured by injection moulding or stamping. These processes are complex, as the melted or heated polymers are subject to thermomechanical changes. Since injection moulding and stamping are mostly used for mass production, process repeatability and quality of the final product are very important. Improper adjustments of process variables lead to various defects in the final product along with high amount of waste and rejects. The need for measurement and control of the process is mandatory.

Frequently, the tool is not operated by the owner of the mold or the end user of the plastic components, respectively, but by an injection molding service provider within the supply chain. Consequently, it is impossible for the tool owner to trace the quality of parts regarding the parameters applied for processing. This is crucial information to connect parts outside the tolerances to the respective process characteristics. The increase of quality in the production is achievable through correlating the processing parameters applied with the produced components. Therefore, the aim of the research herein is to develop an autonomous sensor system for monitoring injection moulding and stamping processes. The system comprises an external component of the tool in order to record and document the parameters applied such as tool temperature, pressure, number of machined parts and geolocation among others. In conjunction with a connected laser marking system for injection moulding, the unique identification of the components and the unchangeable connection of the production parameters with an individual component is enabled. The direct technological added value is given by the fact that the customer is able to monitor the production at any time, any place, comparing the actual production with the agreed and specified conditions. Furthermore, this information enables the creation of new business models for the tool owner. Even though this work is at initial stages, the preliminary results detailed herein are rather encouraging.

Injection moulding tools, stamping tools, smart systems, quality

1. State of the art / Introduction

In industry sectors with mass production like automotive, medical, consumer or electronics, process repeatability ensures a high quality of the final product. Improper deviations of process variables lead to various defects in the final product along with a high amount of waste and rejects [1, 2].

The need for measurement and control of the manufacturing process is high, so it is necessary to accurately design, measure and monitor the process in order to enable the key process variables to be supervised and controllable [3].

The injection moulding process, for example, provides high number of parts within three interlocked process loops, which are shown in Figure 1. These control loops are applicable for other processes as well. The first control loop, the machine control, comprises the machine parameters such as speed v and forces F. The process control, as the second loop, comprises the process parameters such as temperature ϑ and pressure p in the mould. The last control loop, called setpoint control, provides feedback on part quality.

The machine control loop is the most developed, as the these parameters are handled by the machine manufacturers. The second control loop is less developed, although there is a considerable research activity being carried out [4].

The third control loop is the least developed, as research in this area started the latest [3]. Further work on the three control loops is needed to improve the controllability of injection moulding process [5].

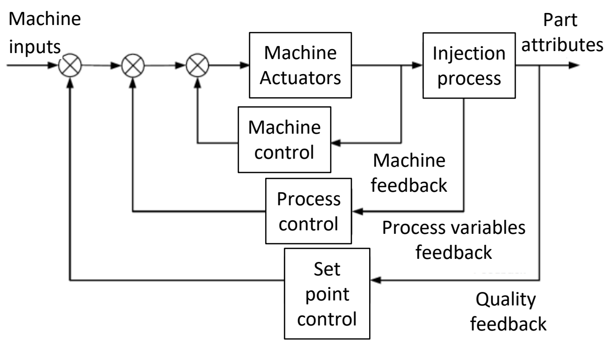

Figure 1. Block diagram of the process loops [3]

Besides injection moulding, the stamping process is also of greatest interest in this context. It is a process in which a sheet is forced in a more or less controlled way to flow by the action of a punch into a die. Three areas have high stress and are the subject of analysis: the punch, the die and the endplate. The last one is the area around the punch that limits the flow of the plate. In cold working tools occurs wear, metal transfer from the plates to the tool, breakage of the edges, plastic deformation and even a total breakage of the tool [6].

Some flaws in tools are visible, and others are only perceived by sensing. For some of them, it is even possible to follow their progress. Examples of sensors to detect tool breakage and failures in the parts being worked on are temperature ϑ, noise, ultrasonic and Eddy current sensors [7].

Frequently, the correct application of tools in injection moulding and stamping processes regarding the respective setup and processing parameters can not be supervised by the tool owner or the customer because a third party is subcontracted to operate the tools for the production of parts. Consequently, variation in product quality cannot be traced due to the lack of information concerning the current process characteristics.

Additionally, the planning and control of supply chain activities and logistics depend on precise estimatives of the volumes of products and services to be processed by the supply chain. Such estimates typically occur in the form of planning and forecasting [8]. There is a need for a real-time control of the production by the tool owner, which can ensure that important production information is reliable.

2. Autonomous process monitoring system

The aim is to develop an innovative real-time monitoring system for injection moulding and stamping tools, which is capable of transferring the relevant parameters to the customer or the tool owner, respectively. Another objective is to register the process characteristics in which the parts were produced, enabling their correlation with the quality of manufactured parts. Figure 2 shows the three groups of process characteristics for the collected data:

- The production signature, which allows, among others, the geolocation and the chronological registration of tool usage and number of produced parts;
- The processing conditions variables for stamping and plastic injection processes;
- The product traceability, which allows the assignemt of single parts to the corresponding process parameters.

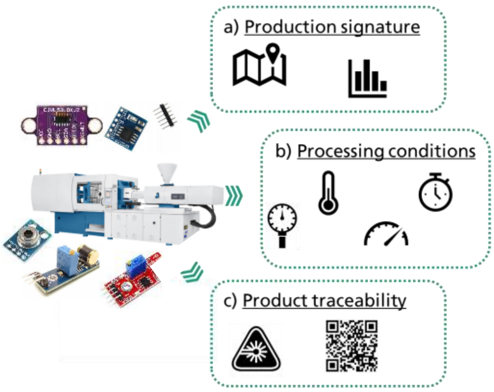

Figure 2. Three groups of process characteristics

For the production signature, a GPS sender or similar system provides information of the actual position of the tool in order to ensure its operation within adequate facilities. Acceleration sensors collect data about the tool dynamics, which is applied to monitor the time of use and numer of machined parts as well as the correct setup for individual components. The processing conditions are characterized by the most relevant processing parameters and variables for the respective process. This includes processing forces F_p, tool temperature ϑ, pressure p, cycle times t or tool vibrations.

The product traceability ensures that every single part produced in the injection moulding process can be connected to its production signature and processing conditions. Therefore, a laser marking system is integrated.

This monitoring system also includes an autonomous power supply, which guarantees that the energy for data acquistion and transfer is generated by the tool dynamics itself in the respective process. Since the monitoring cannot be disabled by the operator, this ensures that the tool owner has reliable data regarding the production signature and processing conditions.

Cloud solutions will be implemented in order to enable the access to relevant data. For visualizing the measured process conditions, a dashboard for the injection moulding and stamping process is being developed. Additionally, a digital twin of the moulding process will be applied in order to prevent inadequate adjustment and further optimize the production.

3. Expected results

In this context, the work addresses some of the main challenges for tooling companies in the medical and automotive industries, which are related to an increasing demand for cost efficiency in the serial production of injection moulded and stamped parts. The provision of the described monitoring system with traceability strategies for the produced parts is due to empower small and medium sized enterprises (SME) to reach a higher production quality and efficiency, achieving thereby the continuously increasing demands in this area.

The increase in quality and productivity is necessary for tooling companies to be competitive. The tool owner benefits from the knowledge generated by the sensing systems for monitoring the production processes and the improved management of production through the traceability and check of quality standards. The improved production control enhances the productivity and reduces the number of parts not attending the requirements.

The generated data may also be used for preventive maintenance. This has potential for opening new business models, which may also be unique selling propositions for project partners. For example, the companies may charge the end-user by the number of parts produced and simultaneously realize a quality check in the production, connecting the parts produced and the processing parameters applied.

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