DEVELOPMENT OF A CYBER-PHYSICAL SIMULATION ASSISTANCE SYSTEM FOR PARTIALLY AUTOMATED OPTIMIZATION OF THE EXTRUSION PROCESS

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1. Introduction

Regarding the methods of processing polymeric materials, extrusion is one of the most popular methods to manufacture polymer-based products like tubes, pipes, sheets, films, or rods. The increasing number of technological use and the developing market from polymer engineering low-cost products to high-end products reinforces the requirement of quality control and quality assurance. Presently, it is state of the art to detect fluctuating material properties through process monitoring and inline control. The measurements accompany with various parameters during the extrusion process, like pressure, temperature, granules humidity, or cooling velocity. Furthermore, it has been shown that linear product quality control models are not capable to deal with process-related nonlinearities. At the moment, it is nearly impossible to seek out the connection between deviant quality and causal process parameters without years of work experience (Fig. 1).

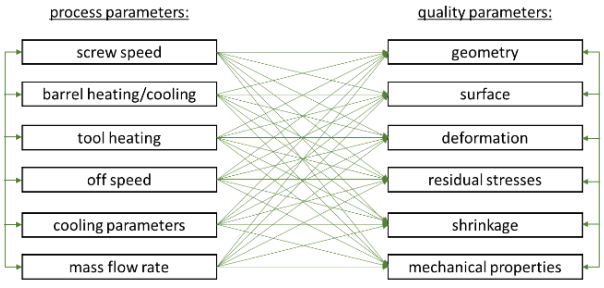

Fig. 1. Linkage between process and quality parameters [4].

In addition, the development of the assistance system provides a solution for the continuous shortage of skilled workforce and the fact that many companies more frequently have to employ untrained personnel as operators for extrusion processes and machines. Moreover, technological improvements should contribute to minimize the process related ubiquitous problems such as long machine downtimes, waste of material, labour and energy to offer multiple economic benefits [2]. In this regard, the development of a cyber-physical assistance system for partially automated optimization of the extrusion process and virtual assistance for unskilled labour force is necessary, to improve productivity, product quality, usability, diversity and working conditions.

2. System Development Process

To feed the cyber-physical assistance system with information from a database of sensor-based live data and an additional availability of expert knowledge regarding the linkage between process parameters and quality parameters, different development steps and information flows are necessary. First of all, the database requires live data from additionally installed sensors at the extruder screw, the assembled tool and the cooling section. Likewise, the data from the main plant control is transferred to the database. The real-time simulation also receives live data from additionally installed sensors and the main system control (Fig. 2). Meanwhile, the simulation software simulates the various process steps online, using the extruder simulation (*REX*), the tool simulation (*Extrude3DPro*) and the simulation of the cooling section (*chillWARE*).

The generated data is stored in a database and flows, combined with the extensive and integrated expert knowledge, into the cyber-physical

assistance system. In case of process deviations, the assistance system activates autonomously the corresponding actuators and supports the machine operator with visualized instructions or assistance for optimized process parameterization.

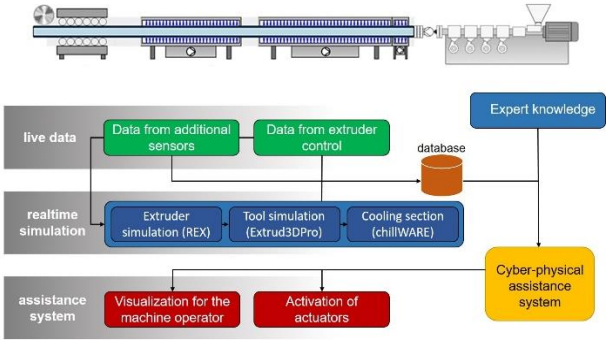

Fig. 2. Cyber-physical assistance system [3].

In order to be able to develop the assistance system in an application-oriented manner, the consideration and implementation of the knowledge of the machine operators and production setters is unavoidable [5]. During the development process, we will be evaluating various stages of the user interface by machine operators and other employees in the plastics industry. As an additional outlook, it is intended to integrate functions, beside the simulation overview, historical data and proposed solutions, as "Optimize" or "Virtual Laboratory". In order to implement the solutions in a user-oriented manner, special scientific methods are necessary.

3. Methodology

For the expertise analysis and the machine operators` requirements, qualitative and quantitative methods are applied. To identify and integrate expert knowledge into the interface between the database and the assistance system, qualitative interviews and observation in different extrusion plants are carried out and translated into social and technical system requirements [1]. These hands-on experiences facilitate to emphasize the actual problems and needs of people who work at the interface of human and machine on an everyday basis and are therefore of great value for a successful development of the assistance system. This approach is based on the fact that organizational work is always embedded in a so called sociotechnical system in which human and machine interact in a productive way. To include the broader expertize of organizations such as companies and works councils, we will complement our qualitative data with the results of a comprehensive survey study.

4. Conclusion

In order to evaluate occurring deviations in the process and in terms of component quality, the connection between process parameters and quality parameters plays the decisive role. The linkage between mechanical parameters and actual process values have to be linked to the online simulation and the expert database. The developed system and the underlying methods will be investigated further and published in the course of the project "ExtrA".

Acknowledgements

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5. References

[1] Holl, H. J., Cojocaru, E. C., Hehenberger, P., Ernst, W., and Horwath, I. Integration of gender in the design process of mechatronic products: an interdiciplinary approach. In *34th Danubia-Adria Symposium on Advances in Experimental Mechanics*.

[2] Kent, R. 2018. *Energy Management in Plastics Processing. Strategies, Targets, Techniques, and Tools*. Elsevier, San Diego.

[3] SHS plus GmbH. 2018. *How you can read data and process parameters from machine controls*. https://extrusion-training.de/en/wie-sie-daten-und-prozessparameter-aus-maschinensteuerungen-auslesen-koennen. Accessed 13 February 2019.

[4] SHS plus GmbH. 2018. *Virtual assistance systems for extrusion – sense or nonsense? | Extrusion Training*. http://extrusion-training.de/virtuelle-assistenzsysteme-fuer-die-extrusion-sinn-oder-unsinn. Accessed 6 September 2018.

[5] Wischmann, S. and Hartmann, E. A., Eds. 2018. *Zukunft der Arbeit - Eine praxisnahe Betrachtung*. Springer Vieweg, Berlin.