DIGITAL PLANNING AND OPTIMISATION OF FLEXIBLE STRUCTURES FOR INDUSTRY 4.0

Julia Reisinger

E234-2 - Department for Integrated Planning and Industrial Building

INTRODUCTION

Industry 4.0 incorporates a highly networked, digitalized and therefore individualized production enabled through the Internet of Things (IoT), generating cost-effective production in batch size 1. The production cycles are extremely short and therefore the production systems are constantly changing. Due to the short product cycles and rapid product changes in industry, it is necessary for industrial buildings to be able to adapt quickly and easily to changing conditions [1],[2]. Thus, sustainable operation of industrial plants for Industry 4.0 require flexible and adaptable production, building, structural and building services equipment (BSE) systems.

FUNDAMENTAL OF THE PROBLEM

The sequential approach in building design where production, building and BSE planning are separated in time and run consecutively, the slow pace of digitization in the AEC (Architecture, Engineering, and Construction) industry and the rigid building systems in industrial buildings constitute the greatest constraints for the realization of Industry 4.0-compliant industrial construction plants. The bearing structure, as the element with the longest service life and the lowest level of flexibility in the building, plays the key role. The supporting system affects and limits the reusability of the whole production system the most. The non-flexible building systems cannot be adapted quickly and efficiently to support production changes, which usually results in cost-intensive modifications or in demolition and rebuilding of the plants, influencing the lifecycle costs and the environmental impact negatively.

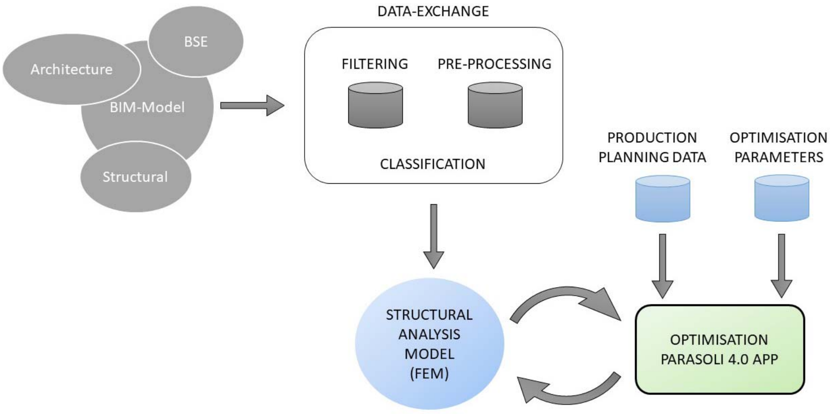
RESEARCH DESIGN AND METHODOLOGY

This study aims to enable the design of flexible, versatile production facilities, from the perspective of structural design, using integrated planning methodology and digital BIM (Building Information Modelling)-based parametric tools.

The main objective is to create a framework for an innovative parametric structural design application. The use of parametric design tools in the early planning stages enables the rapid expansion of potential solutions and the development of variant studies, which is difficult in BIM at the early planning stage. A Framework for an “Parametric Structural Design and Optimisation for Industry 4.0” (PARASOLI 4.0) App is developed and is intended to enable the analysis and calculation, as well as the optimisation and prediction of flexible structural systems, coupled to the BIM model. PARASOLI 4.0 aims to enable the planning, optimisation and prediction of flexible structural systems for Industry 4.0, taking into account the temporal changes of the production, building, energy and media systems through scenario formations in the early design stage, based on criteria such as cost, time and quality. It should serve as a decision-making tool via visual management - by linking to the BIM-model - and an evaluation tool.

Based on the generated workflow for the integrated planning process, the information necessary for the data exchange and specific data exchange requirements are prepared by classification, filtering and pre-processing of the geometric and non-geometric data. For a seamless import from the BIM model to the structural analysis software (FEM - Finite Element Method), a project-specific classification system is to be developed, which enables an optimal central data storage. By creating this seamless connection between BIM and FEM software PARASOLI 4.0 is optimally coupled with the structural analysis software. The various sub discipline information, requirements and data of production planning, BSE and architecture, which are dependent on the structural design in industrial construction 4.0, will be integrated (see picture 1).

To achieve these goals, the methods of process analysis and process definition from the management sciences, digital modelling and data analysis, as well as the embedding of FEM and other numerical calculation methods from the research field of structural analysis and mechanics in the digital models, by means of algorithm development, are applied.



Picture 1: Modelling of the data coupling including PARASOLI 4.0

EXPECTED RESULTS

PARASOLI 4.0 aims to achieve 20% more efficient design processes and 20% less emissions in the building's manufacturing and operating phases. The proposed framework serves for prediction, optimisation and decision support by means of scenarios formation and evaluation and should allow the determination of the optimal structural variant. This results in an increase in the overall service life of the building, as rescheduling or even demolition can be avoided. As a result, negative ecological effects and life cycle costs can be minimized.

CONCLUSION

The objectives in industrial design to meet the needs of industry 4.0 are the maximum flexibility of the horizontal structure (free floor plan and flexible layout design), as well as the flexible vertical building structure (reconfigurable structure). In order to allow the flexibility of the structure, the parametric structural design and its optimisation is proposed as part of the integrated design methodology, which couples the planning participants, their processes and partial models by means of BIM and parametric design tools. Due to the high information content in combination with real-time scenarios formation, the overall life cycle of industrial construction can be positively influenced and the information from architecture, engineering and production planning can be integrated and exchanged along the life cycle. Hence, the production systems should be quickly and efficiently adaptable to market requirements through the framework developed.

REFERENCES

[1] Bracht, U. (2018): *Digitale Fabrik. Methoden und Praxisbeispiele.* 2. Aufl. 2018. Berlin, Heidelberg: Springer Berlin Heidelberg (VDI-Buch).

[2] Wiendahl, H., Reichardt, J., Nyhuis, P., (2014): *Handbuch Fabrikplanung. Konzept, Gestaltung und Umsetzung wandlungsfähiger Produktionsstätten. 2*., überarb. und erw. Aufl., [elektronische Ressource]. München: Hanser. Online verfügbar unter http://dx.doi.org/10.3139/9783446437029.