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NEW APPROACH FOR THE CONJOINT OPTIMIZATION OF THE DESIGN AND MANUFACTURING BY INTEGRATION OF PRODUCTION COSTS

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ABSTRACT

This paper describes an iterative approach to modelling and optimizing production costs in the design phase. The objective is to provide a decision-support tool by providing designers with a projection of the cumulative production costs according to the technical solutions decided upon, in terms of product architecture, mechanical connections, materials or the geometric shape of the components. The aim is to converge towards technical solutions with lower production costs. The experiment was carried out in a smart factory installed in our organization. The proposed iterative approach is organized in two phases allowing the product to evolve, without compromising its functionalities, from its initial version to a version optimized at each iteration. The first phase consists of breaking down and evaluating the cost elements involved in the product production process, such as the cost of raw materials used or the costs of maintaining the facilities. This decomposition allows to highlight the most important cost elements. The second step provides designers with recommendations, in terms of solutions, to be integrated into design and production in order to optimize production costs.

Keywords: design, production costs, modelling, optimization, iterative approach, smart factory.

INTRODUCTION

Over the past few years, industrialised countries throughout the world have continued to invest heavily in new technologies, software programs and services to advance product design and manufacturing using cyber-physical systems, connected machines, data analysis and high performance computing systems (Karre et al., 2017).

For manufacturing companies, this represents a real industrial revolution, referred to as “Industry 4.0”, in which value creation depends on the use of these new technologies (Synnes and Welo, 2016). In this new digital ecosystem, controlling the production cost of a product is not only an advantage, but has become a requirement.

Evaluating production costs (machining cost, assembly cost, cutting cost, etc.) is a strategic advantage that is necessary for product optimisation in the design phase. This evaluation can lead the designer to suggest another technological solution that provides the same functional characteristics but at a lower cost. In addition, the design phase accounts for 70% to 80% of costs, while the project accounts for only 5% to 10% of the total cost (Manac’h et al., 2013). In

addition, as the project advances farther, the costs associated with making the changes needed to reduce the cost become greater. It is therefore important to control the cost parameter as early as possible in the lifecycle of a product or project.

Currently, cost specialists can provide overall estimates in the design phase, but they cannot establish specific links to the technical characteristics of the product (Kumar et al., 1999; Markeset and Kumar, 2005). Thus, the designers break down the overall cost into individual cost elements to understand or establish causal relationships between design choices and their impacts on production costs. From this succinct analysis, there arises a need to formalise a new method that allows designers to optimise products through the use of a dynamic cost estimation, thus meeting current needs in the industry.

In this article, a new design approach enabling a product to be modified from its original version toward a version that is optimised in terms of production costs (machining cost, assembly cost, cutting cost, etc.), without compromising its functionality, is proposed. This approach, in the form of an algorithm, enables improvements (technical solutions) in terms of design and manufacturing that will contribute to a reduction in the production costs to be identified at each iteration. The contribution of this research is that it dynamically evaluated and mapped the cost of a product manufactured using a smart factory during the design phase.

The goal of this research study is to develop an approach, in the form of an algorithm, to model and evaluation the production costs of a product in the design phase. The objective is to provide the design team with information on the behaviour of production costs as a function of predetermined technical solutions. Many factors can influence production costs, such as the architecture of the product, the production volume per year, the mechanical linkages, the materials or even the geometric shapes of the parts. This tool enables the identification of design and manufacturing improvements that will help reduce production costs.

RESULTS AND CONCLUSIONS

The proposed algorithm was tested on a smart factory 4.0 at the ENSAM. The smart factory consists of digitally controlled machining units, a laser cutter and two 6-axis robots. This smart factory, which is shown in Figure 1 is controlled by a manufacturing execution system; MES and a programmable logic controller; PLC.

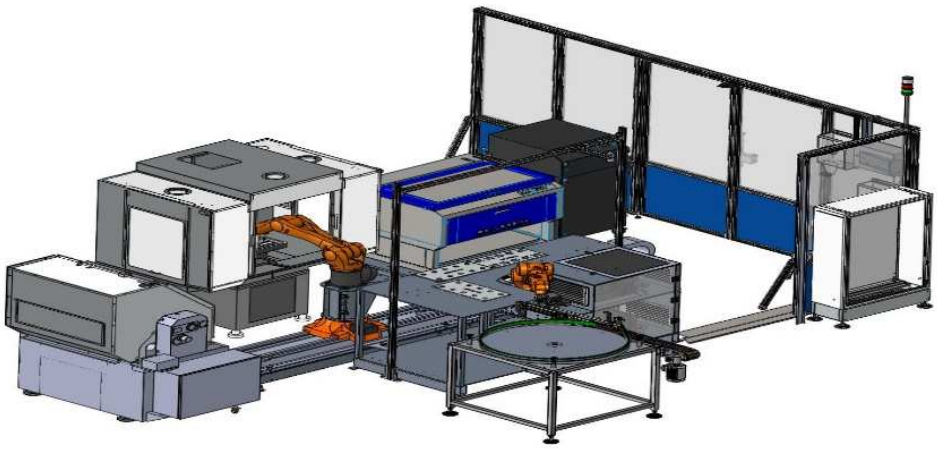

Fig. 1 – Smart factory used for the experiment.

The product used for the test is a geometrically simple shock absorber composed of a spring, a stem and a body (see Figure 2).

Fig. 2 – The product used for the experiment.

Here is an overview of the advantages of the proposed algorithm:

- Adapted to the industry 4.0 concept, notably data provision;
- Allows simultaneous optimisation of design and production processes;
- Allows comparison and optimisation of production costs in the design phase;
- Enables solutions to be adapted as a function of the desired economic model;
- Provides an optimal production plan;
- Allows relationships to be identified between the geometric characteristics of the product and the cost of production;
- Suggests recommended improvements based on recommendation mapping.

REFERENCES

[1] Karre H et al., (2017), Transition towards an Industry 4.0 state of the LeanLab at Graz University of Technology, Procedia Manufacturing, vol. 9, pp.206-213.

[2] Synnes EL, Welo T, (2016), Enhancing integrative capabilities through lean product and process development', Procedia CIRP, Vol. 54, pp.221-226.

[3] Manac'h Y-G, Khaled B, Améziane A, (2013), Life Cycle Cost through Reliability, New Results in Dependability and Computer Systems, Springer. pp.523-530.

[4] Kumar UD, Knezevic J, Crocker J, (1999), Maintenance free operating period–an alternative measure to MTBF and failure rate for specifying reliability', Reliability Engineering and System Safety, Vol. 64 No.1, pp.127-131.

[5] Markeset T, Kumar U, (2005), Product support strategy: conventional versus functional products, Journal of Quality in Maintenance Engineering, Vol. 11 No.1, pp.53-67.