Proposal of a based-sustainable indicators Digital Twin Model for a green machining process

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Detailed Proposal

Today, machining process is subject to conflicting constraints, such as quality improvement versus cost, time and environmental impact reduction. To cope with these constraints, adopting digital technologies (DTs) is mandatory. Used, within I4.0, DTs open up new opportunities for most areas of engineering (Wang & Wang, 2019), especially sustainable engineering. They provide new means of connection, communication, and integration that chain together different resources and processes and then form a dynamic, up-to-date, and reliable cyber environment. The digital twin (DTw) is one of the leading technologies in the deployment of the industry of the future. Introduced at the beginning of the century by NASA, then taken up by (Grieves, 2014), the concept of digital twin is used to ensure digital continuity between different existing information systems (Boschert & Rosen, 2016), namely the management product life cycle (PLM) (Danjou et al., 2017), product data management, supervisory control and data acquisition.

Although, it has been applied in many industrial fields, since its proposal (Tao et al., 2017,2020), especially in product manufacturing (Liu et al., 2018, 2019), its application to the machining process has not attracted enough attention and still at a very early stage (Liu et al. 2018) Moreover, the environment aspect is not integrated in proposed DTws.

Mainly, DTws are applicated in the machining process modeling at different levels (Product modeling, Machine tool, Process data), in monitoring by including the shape of the machined part, the phases of machining in progress, generated by CAM systems, tool machining cost and time, etc (Zhao et al., 2019). However, applying DTws to improve the sustainability of the machining process has not been addressed until now (Gaha et al., 2021). This can be justified by the lack of eco-manufacturing work at the level of the digital model ((Gaha et al., 2016), (Slama et al., 2020)).

Accordingly, the main objective of this thesis is to develop and then experiment a digital twin model for CNC machining based on sustainability indicators, in order to meet environmental

challenges within the industry of the future, and then assist CAD/CAM/CIM user, non-environmental expert, to adopt the most environmentally conscious machining process.

Meeting the main objective involves addressing two challenges:

1- To support the geometric evolution (GE) and environmental evaluation (EE) of the product during machining, a first challenge of this thesis consists in defining, extracting and analyzing the dimensional /environmental necessary data and then determining what environmental indicators should be considered to assess the sustainability of the product being processed.

2. The second challenge is the development of DTw model incremented by collected data within a strategy aiming to simulate possible machining scenarios in real time process based on sustainability indicators and present possible environmental improvement actions.

On this basis, several scientific issues need to be addressed, namely: 1) The analysis of proposed digital twins-based solutions for intelligent CNC (ICNC) lacks covering the machining process parameters and levels. 2) The development of a machining life cycle assessment (LCA) model based on possible sequence machining planning scenarios (with consideration of cutting tools, fluid lubrification, etc.). This would allow the selection of the greenest one. 3) Development of sustainable DTw model. 4) Identification of an appropriate experimental strategy on the selected case study. Hence, the research methodology of this thesis can be summarized in the following tasks:

- T1: Definition of the DTw data model(s) to adopt in order to support the GE and EE of the product during machining.

- T2: Definition of environmental indicators to be considered when assess the sustainability of the product being processed.

- T3: Definition of required data to increment the sustainable digital twin

- T4: Definition of digital chain, hardware and software to use in the development of sustainable DTw model.

- T5: Development of a generic and reliable digital twin integrable into software.

- T6: Dissemination of the results. The proposed model will be applied on an industrial case study to prove the usefulness of digital twins in reducing the time of green machining operations based on real data of a product X.

Finally, these tasks should lead to a sustainable engineering model for the machining of manufactured products using digital twin technology. This model must be sufficiently generic to allow subsequent interfacing with certain tools used today in industry, and in particular

CAD/CAM/CIM software (e.g. parametric modeling), PLM/PDM systems (eg version/configuration management) and LCA (Life Cycle Analysis) tools.

The experiments carried out as part of the project will not include tests related to the implementation of this type of interface. The semantic data will be taken from simplified operating scenarios representative of industrial needs, and operated on systems available in the Roberval laboratory.

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