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OPTIMIZATION OF PROCESSES TO MANUFACTURE COMPOSITE AIRCRAFT COMPONENTS WITH REGARD TO COMPONENTS QUALITY AND COST

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ABSTRACT

With the aim of manufacturing composite material products of a specified quality at minimum cost, a generic optimization methodology is developed and introduced. It involves a quality sensitivity analysis to derive material dependent Quality Functions (QFs) as well as a cost sensitivity analysis to derive process dependent Cost Estimation Relationships (CERs). The flow chart of process optimization concept is shown in Figure 1. For the application of the optimization process a novel software tool, namely the LTSM-OPT tool, is introduced.

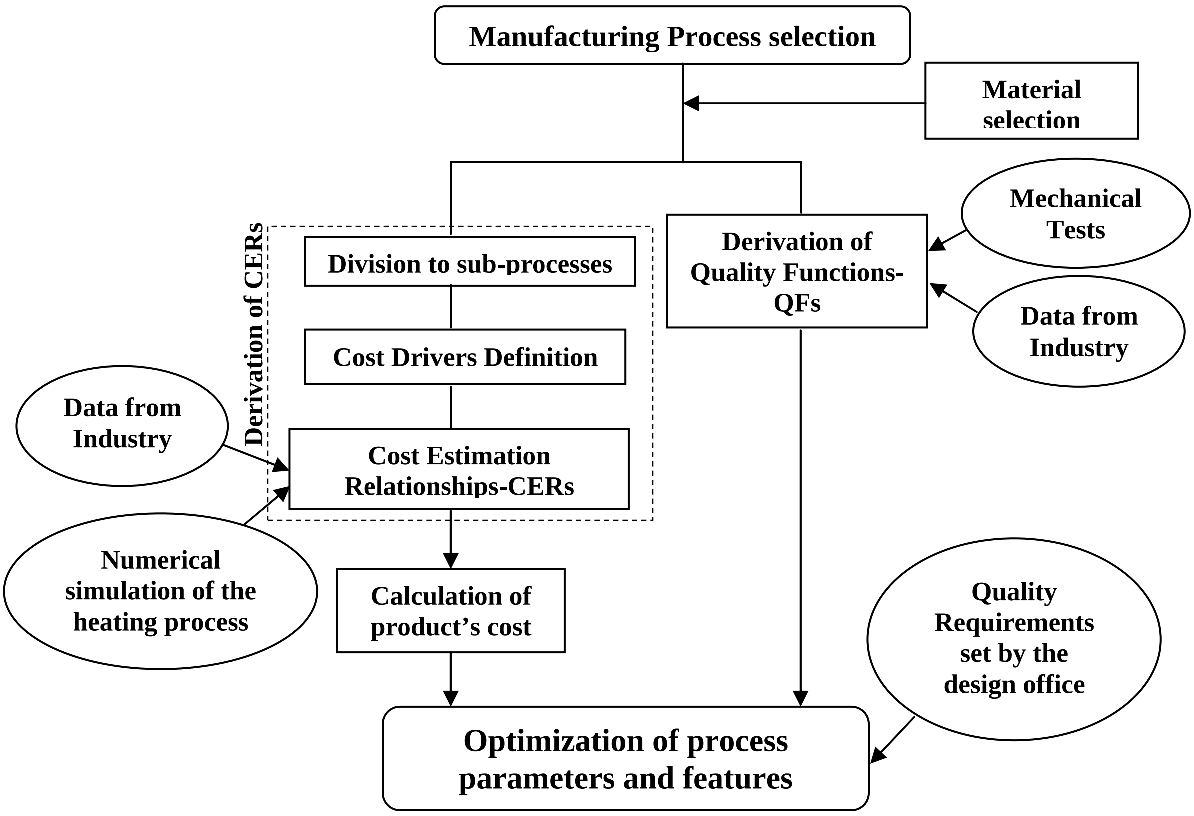

Figure 1: Optimization concept flow chart

The quality functions are derived experimentally and are material dependent. For deriving them certain quality features which are essential for the component under consideration are defined as representative for the product's quality. For the application of the present study, which is aeronautic structural components said quality features have defined to be certain mechanical properties. According to the requirements of the component's designer the selected mechanical properties should exceed certain limits for the safe in-service performance of the structural component. Then, the quality features defined are related to the parameters of the process's thermal cycle by deriving the dependency of each quality feature on the variation of each of the parameter of the thermal cycle. These thermal cycle parameters can be for example the temperature of the melt, the cooling rate, etc. The above dependencies are obtained by exploiting experimental data. The derived dependencies represent the QFs which will be processed by the developed software to derive a reference thermal cycle along with the windows which are allowable for the parameters of the thermal cycle in order to still meet the quality requirements.

For the cost sensitivity analysis the Activity Based Costing (ABC) methodology is used. It is a costing method that derives the product's cost as a sum of the costs of all activities involved to make the product. These activities may refer to a single process or to a production line. By using empirical data, available mainly by the industry, CERs are developed providing the dependency of the cost of the produced component on the variation of each of the parameters of the process cycle. While the dependencies of the quality features on the parameters of the thermal cycle are material dependent and, hence, may be exploited for any process, the cost dependency of the produced component on the thermal cycle parameters is process dependent.

Using the obtained QFs and CERs the derivation of the optimal thermal process cycle resulting to a product which satisfies all quality features set at the minimum cost can be made by means of an iterative optimization process. The variation of the thermal cycle parameters is made by assuming flexibility of the manufacturing unit. Furthermore, the thermal process under consideration is numerically simulated by means of FEM in order to avoid additional experiments and allow for the application of the optimal thermal cycle on the material. For processes offering flexibility in selecting the process features and parameters, implementing the derived optimal thermal process parameters which result to a product meeting all quality requirements at the minimum cost is then straight forward. On the other hand, for most of the forming processes already used for producing composite components technical modifications of the manufacturing facility itself would be required to enable the implementation of the optimized process features and parameters.

While the developed software can be exploited for the optimization of the majority of manufacturing – forming – joining processes of composite components, in the present work it is utilized for the optimization of the 'cold' Diaphragm Forming (CDF) process as well as the Laser Transmission Welding process (LTW), both used in thermoplastic composite components production. The developed software is used in order to obtain the CDF heating system and the Laser Transmission Welding unit configurations along with the optimal thermal cycle for producing a helicopter canopy and for welding stiffeners on aircraft fuselage skin, respectively. The results of the first study were successfully exploited by EUROCOPTER to install a new flexible CDF facility and produce helicopter canopies by applying the derived optimal thermal cycle. The results of the study for optimizing the LTW process were successfully exploited by AIRBUS to configure and adapt a laser diode source unit for welding stiffeners and riblets to aircraft fuselage skin.