Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 55 (2016) 59 – 64

www.elsevier.com/locate/procedia

5th CIRP Global Web Conference Research and Innovation for Future Production

Unified approach in design and manufacturing optimization of hybrid metal-composites parts

Panagis Foteinopoulos[a] , Panagiotis Stavropoulos[a, b], Alexios Papacharalampopoulos[a], George Chryssolouris[a,] *

[a]*Laboratory for Manufacturing Systems and Automation, Department of Mechanical Engineering and Aeronautics, University of Patras, Patras 26500, Greece*
[b]*Department of Aeronautical Studies, Hellenic Air Force Academy, Dekelia Air-Force Base, TGA 1010 Athens, Greece*

* Corresponding author. Tel.: +30-2610997262; fax: +30-261 0997744. E-mail address: xrisol@mech.upatras.gr

Abstract

An optimization strategy is described herein for the design and manufacturing of parts, combining composites and metals. The design stages of such parts, as well as the modelling procedures, required in each stage, are presented. More specifically, the modelling steps that are essential for the optimization of the production processes are described. A sample analysis of three different parts is also included. Moreover, a strategy for the optimization of the process parameters is proposed. This is based on maximizing the Key Performance Indicators (KPIs) of each process, considering the difference in the importance of each factor, between the different industry sectors. Finally, issues such as humidity and size effects are also taken into account

Keywords: Composites manufacturing; Decision making; Simulation of processes; Design for manufacturing; Optimization; Hybrid parts

1. Introduction

The combination of metal parts with composites lead to hybrid parts with a lot of advantages: Such parts have better specific properties than those of the fully metal parts, due to their composite part, whereas, they minimize the common disadvantages of fully composite parts (anisotropy, compression-dominance), due to their metal component. Subsequently, the metal-composite hybrid parts combine the advantages of two material types, simultaneously minimizing their disadvantages.

Up to now, the problems that manufacturing was faced with, when dealing with this kind of parts, were both the dissimilar material joining and the manufacturing of the composite part, relatively fast and at a low cost. However, recent advances made in automated tape placement, have rendered possible the fully automated manufacturing of composites, with optimized mechanical properties [1], [2]. Moreover, such automated processes are characterized by fast production rates, since there is no need for autoclave curing. The use of thermoplastic-based composites has led to better mechanical properties than those of the previously used thermosets, as well to more environmentally friendly composites, due to the recycling capabilities of the thermoplastic matrix.

As far as dissimilar joining is concerned, there are numerous alternative options such as bolting, screwing, riveting, welding, adhesives joining, or a combination of the those [3], [4]. Each method has different advantages and disadvantages, however, in this approach, the joining with the use of a thermoplastic adhesive layer will be analyzed, because of its low price and weight and other advantages namely, the fact that it uniformly distributes the mechanical loads Furthermore, fewer components are required in order for the joining to take place than it does in other methods and it leads to rigid, sealed and isolated unions [5]. Such joining methods significantly contribute to increasing further the process automation, as it can be incorporated into the

doi:10.1016/j.procir.2016.09.035

automated tape placement procedure, which will also offer the thermal energy necessary for the potential curing. Finally, the use of thermoplastic adhesives enables the disassembly; whereas, the thermosets adhesives have rendered the connection permanent by making the disassembly process impossible.

Subsequently, both the problem of the production rates and the cost, as well as that of the joining between those two materials have been tackled with constituting the metal-composite hybrid parts as a viable choice, with many advantages.

The current study sets the boundaries of a methodology that has to be followed during the design of such hybrid parts. The decision making strategy, along with the three aspects of modelling (i.e. Part design, texturing/joining design and Lay-up optimization) necessary for the successful design of such a part, have been analyzed in depth.

2. Decision Making Strategy

In order to successfully design and manufacture a hybrid part, the steps to be followed can be seen in Figure 1. Initially, the determination of the geometry and functional specifications [6] has to be conducted. More specifically, the geometry specifications and the part's ability to properly work /withstand the loads of its excessive working conditions are the goals that the design process has to meet. Utilizing this information, and also taking cost and desired weight into account, the material selection will be conducted: the type of the metal and the composite to be used, as well as the percentages of both will be defined, taking the desired weight into account [7], as well as the cost and manufacturing time restrictions. This will lead to the important design decision, concerning the percentage of load the composite will receive, which will determine the necessary number of plies and their orientation. This procedure may well be carried out in a reversed way, depending on which goal is the most crucial-difficult to satisfy (weight, cost, specific material that has to be used). Other types of loads, such as thermal and humidity, except for the mechanical ones, have to be taken into account in the material's selection.

Moreover, the part, according to its use, may have to be tested both in normal repetitive working condition loads (fatigue test), as well as in emergency excessive loads (strength test) [6]. All the above selections will have to be tested via simulations. The joining between the materials can be considered ideal for this stage.

The second step, as it can be seen in Figure 1, for the optimization of the design of the hybrid metal-composite part, is the selection of the joining type of the two subparts (metal and composite). In order for this to be done, the operational environment conditions such as humidity, temperature and vibrations, have to be taken into account, since they play a major role in the deterioration of the joining [7]. This selection has to be tested through simulation, which will take into consideration the joining characteristics. The results of the simulation will help in the validation or rejection of the type of the joining selection.

The final step is the optimization of the lay-up process, for the manufacturing of a part with the best possible quality characteristics (manufacturing (MFG) related KPIs). The optimal process parameters of the lay-up process have to be chosen (velocity of the head, heating power, consolidation force). This selection will be made by creating a simulation of the lay-up process which will enable the part's quality assessment using different process parameters, as well as the calculation of the manufacturing time required.

3. Modelling

3.1. Part Design

In this step, a simulation of the part to be manufactured is required for the validation of the design's capability to bear the specified loads. The weight of the structure will be also calculated. In order for this to be achieved, three different designs have been analyzed. All parts have a cylindrical cross section and low thickness. The first, is a fully dense metal

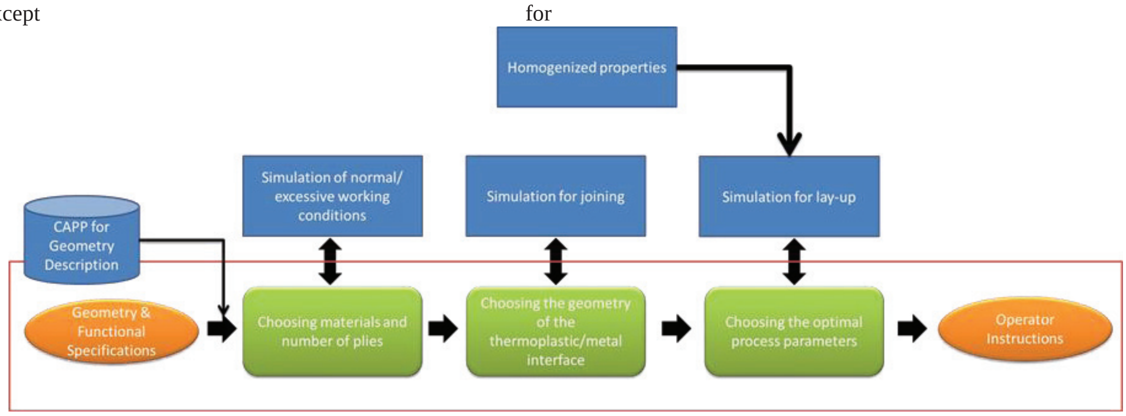

Figure 1 Design decision making strategy framework