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An Automated Design Framework for Assembly Task Simulation

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Abstract

This paper presents an automated design framework for the development of individual part forming tools for a composite stiffener. The framework uses parametrically developed design geometries for both the part and its layup tool. The framework has been developed with a functioning user interface where part / tool combinations are passed to a virtual environment for utility based assessment of their features and assemblability characteristics. The work demonstrates clear benefits in process design methods with conventional design timelines reduced from hours and days to minutes and seconds. The methods developed here were able to produce a digital mock up of a component with its associated layup tool in less than 3 minutes. The virtual environment presenting the design to the designer for interactive assembly planning was generated in 20 seconds. Challenges still exist in determining the level of reality required to provide an effective learning environment in the virtual world. Full representation of physical phenomena such as gravity, part clashes and the representation of standard build functions require further work to represent real physical phenomena more accurately.

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1. Introduction

Digital methods such as computer aided design (CAD), finite element analysis (FEA), computational fluid dynamics (CFD) and product lifecycle management (PLM) have now matured to the extent that they have become ubiquitous across all engineering design disciplines. Multidisciplinary interaction has also become routine as interface methods and codes have been developed which allow the seamless interchange of data between platforms and disciplines for the purpose of developing optimal engineering systems. Opportunities still exist to enhance and exploit automated design methods through better use of tacit design knowledge in concept development and broader use of virtual methods for design evaluation as a product and its manufacturing requirements evolve. If these opportunities can be exploited then OEMs would be in a better position to overcome the perennial problems of time and cost overruns on major product development programs [1, 2].

Previous work has demonstrated the need for automated design methods and has shown how an aircraft fuselage section can be transformed from a simple 1D structural representation to a full blown 3D CAD model [3], see Figure 1. Methods have also been developed to develop assembly fixtures automatically based on rules derived from the geometric properties of the product itself [4], see Figure 2.

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This work focuses on the development of an automated design framework for the development of tools suitable for forming a carbon fibre reinforced stiffener. In the context of this paper, automated design is defined as: *'the generation of 3D CAD geometry automatically through a custom coded user interface without direct designer interaction with the traditional CAD interface'*. Similar components differing only on key dimensions are used for the work. Part details, manufacturing procedures and tooling features are captured and embodied in the automated design code. The approach includes the use of the required geometrical relationships between the tool and part as well as the peripheral design rules required to form the tool geometry beyond the part / tool contact surfaces. These are used in turn to generate and articulate design options. The work includes the transfer of the resulting component and tool geometry to a VR environment enabling the virtual assessment of tooling functions. By providing an interactive and immersive human-computer interface this work creates an efficient framework for designing, planning and assessing composite part manufacture including tooling functionality with respect to the human user.

2. Method

2.1. Automated Design Framework

Figure 1 maps the framework used for the development of the composite layup tool required to form the stiffener. The process includes component inspection and definition of the data required to drive mould tool design.

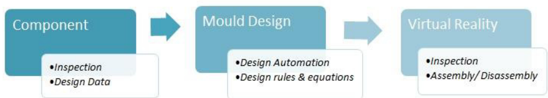

Fig. 1. Automated Design Framework for Virtual Development of Composite Layup Tool.

This was then used to develop tool forms based on critical features and dimensions as well as integrating the tacit knowledge of the tool designer i.e. 'in house' design rules and mould tool functions. These include the elements required for ease of handling by the user and how the tool integrates with the curing environment. The stiffener and its associated mould tool were then transferred to the virtual environment for functional assessment where the designer could interact with all elements of the system.

2.2. Structural Stiffener

Fig 2 shows the basic stiffener with the main dimensions highlighted. This component currently exists in two forms and the dimensions highlighted in Fig 2 vary for each case. Both versions of the stiffener have the same Thickness, Length, Width 1 and Width 2 (see Figure 2). All other dimensions differ for the two variants. The aim of this work was to create a third variant of the stiffener based on the design rules and key dimensions derived from the existing components. During the inspection phase a subtle change in the profile shape along the surface defined by Widths 2 & 3 and Depths 2 & 3 was identified (see figure 3). A decreasing gradient along this surface meant that there was a variation between the two stiffener versions as the parts have to fit in with different structural profiles during final assembly.

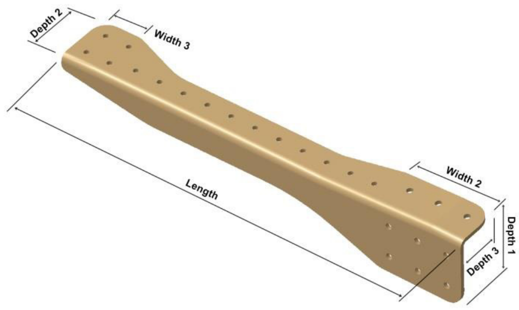

Fig. 2. Composite Stiffener.

2.3. Layup Tool

Fig 3 shows the composite layup tool with the main features highlighted, these are: The Mould Block which is a shelled feature with two underlying ribs, three holes required on upper surface as well as a further 18 holes for the periphery bar.

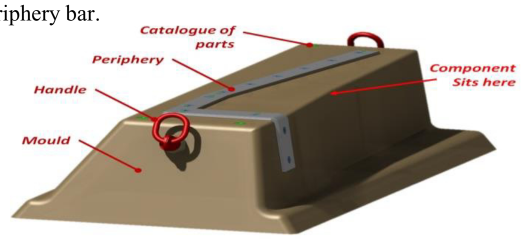

Fig. 3. Composite Layup Tool.

The Periphery Bar – which consists of three separate components and a total of 18 holes required for fixing component. Two Handles on the ends of the block and the Catalogue of Parts (Nuts, bolts and screws). The process for automated mould design started by assessing the features of the existing mould tools. This identified key features and dimensions. The moulds include multiple holes which vary in size, however despite the dimensional differences between the parts and mould for the two existing stiffeners, the hole properties on the tools remain identical for both.

The tool inspection process also included the comparison of the hole positions and part locations relative to a datum point located at the corner of the upper tool surface. See Figure 4. The mould tool also reflected the decreasing gradient along top surface of the stiffener. This feature is an important aspect of the layup tool as it forms a critical feature which interfaces with a higher profile on the aircraft. The automated development of this feature is critical to the overall success of the work as it influences assembly accuracy.