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Adaptive restoration of complex geometry parts through reverse engineering application

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Abstract

After a certain number of hours of running, no two mechanical components are completely the same due to normal wear or foreign object damage. A nominal CAD model from a component designer is different from its corresponding worn one and therefore cannot be directly used for tool path generation for build up and machining repair processes. This is the main reason that most repair process used for complex geometry parts, such as gas turbine blades, is currently carried out manually and is called the "Black Art".

This paper proposes a defects-free model-based repair strategy to generate correct tool paths for build up process and machining process adaptive to each worn component through the reverse engineering application. Based on 3D scanning data, a polygonal modelling approach is introduced in this paper to rapidly restore worn parts for direct use of welding, machining and inspection processes. With this nominal model, this paper presents the procedure to accurately define and extract repair error, repair volume and repair patch geometry for the tool path generation, which is adaptive to each individual part. The tool paths are transferred to a CNC machine for the repairing trials. Further research work is performed on repair geometry extraction algorithm and repair module development within the reverse engineering environment.

Keywords: Repair; Defects; 3D digitising system; Polygonal modelling; Adaptive tool paths; Reverse engineering

1. Introduction

Due to the long hours of run in operation and harsh environments, complex components such as tools, dies and gas turbine components may suffer from various defects, such as distortion, wear, impact dents or under nominal dimensional limitations. As a result no part is completely the same as any other one. A nominal CAD model from a component designer is different from its corresponding "in service" one and therefore cannot be directly used for tool path generation for the build up process and machining process [1–4]. Fig. 1 shows the cross-section comparison between a blade CAD model and a used scanning model of this type. It is clear that the used blade cross-section is distorted from the original position, it will cause incorrect repairing if the CAD model is still used for tool path generation for additive and subtractive processes. Therefore, to generate correct tool paths for the repair process for each worn component a defects-free model needs to be created based on the component scan data. This model needs to have the same attitude or stance as the worn part and can work as a nominal model used for adaptive welding, machining and inspection.

For most conventional CAM systems a surface model can be input and used to generate a NC tool path for freeform geometries. Much research has been focused on finding a better approach to generate tool paths effectively and accurately for freeform surface machining [5–8]. At present, most reverse engineering (RE) software serves the function of creating NURBS (Non-uniform [knot sequence] rational B-splines) curves and surfaces. However, surface

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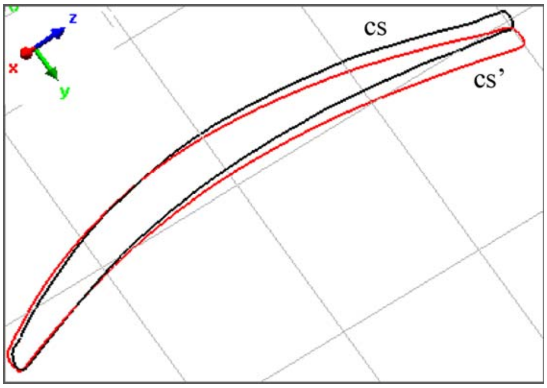

Fig. 1. The cross-section comparison of a CAD model and a scanned model of its used blade.

generation in a RE or a CAD system requires a major commitment in time, both in training and in operation for most real jobs [9]. When modelling complex shapes, the biggest problem for RE users is determining a reasonable surface patch boundary layout where the (u, v) surface parameterisations of each patch are in reasonable alignment with the underlying surface structure. Design options are improved but complexity is increased by the option of trimming off any portion of any surface using a trimming curve [9]. Mainly due to the complexity and time consumed in creating a high-quality NURBS surface model from scan data, the potential for a 3D digitising system is largely to date currently untapped in most manufacturing organisations even though high-performance scanners have been around since 1980.

This paper proposes a polygonal modelling approach to rapidly restore worn parts for direct use of the machining and inspection process. Compared with the complex procedures and difficulty in patch dividing in surface modelling, the polygon modelling can be both quicker and involve less complexity. A rapid repair process can be achieved through a commercial CAM system such as Tebis and Delcam Powermill for five-axis tool paths generation for machining.

With a defects-free polygonal model adaptive to its complex component geometry, it is possible to capture the maximum/minimum errors of worn components and to realise adaptive welding and machining.

In this paper, Section 2 presents the proposed repair system structure for complex geometry parts. Section 3 introduces the modelling approaches used in processing 3D scanning data and creating defects-free polygonal models through a RE tool. Based on the reference model created, the method of repair volume determination is discussed in Section 4, and the procedure for some repair patch extraction are presented in Section 5. Conclusions are given in Section 6.

2. Repair system structure

The structure of the proposal complex component repair system is illustrated in Fig. 2. In the acquisition phase, considering the factors of part size, accuracy, scanning speed, data processing speed, and restored part data quality for inspection, a GOM ATOS II non-contact digitising system is selected to scan the worn parts for repair and the

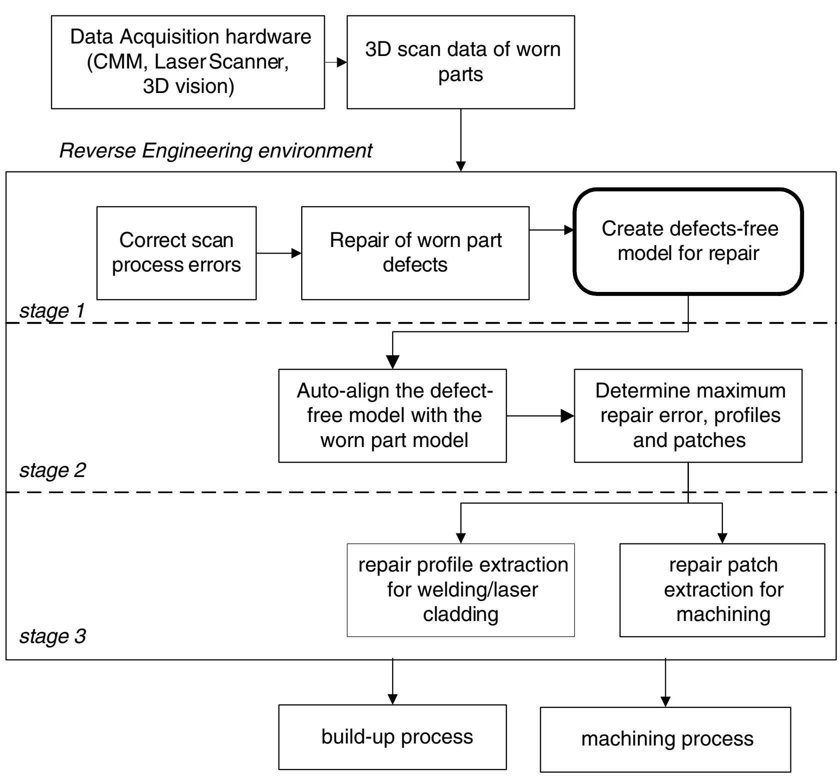

Fig. 2. Flowchart of the adaptive restoration for complex components.