Proceedings of the 11th International Conference on Manufacturing Research (ICMR2013), Cranfield University, UK, 19th – 20th September 2013, pp 121-126

A DIGITAL DEFINITION METHOD FOR MANUFACTURING MODEL OF AIRCRAFT INTEGRAL PANEL

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ABSTRACT

The manufacturing model of aircraft integral panel is presented based on the analysis of its structure and manufacturing process. The manufacturing model for each key process consists of model for processing and model for workpiece to bridge digital design and fabricating. Model for workpiece is used to express the target part information at the end of some operation. Model for processing is used to describe the intermediate state information, and it aims to attain but is different the workpiece because of process factors. The definition flow of the manufacturing model is given. The modeling approach of integral panel part blank from shot peen forming part model orienting to NC cutting is proposed and exemplified. It is analyzed that the approaches above can define the models accurately and totally to meet the needs of process planning , NC fabricating and inspecting.

Keywords: Digital definition, Manufacturing model, Aircraft integral panel.

1 INTRODUCTION

Aircraft integral panel has become the main force-bearing component of wing since the 1960's because of its high structure efficiency, smooth aerodynamic configuration, short process preparation cycle, less fabrication hours. Shot peen forming ranks as the one of the major processes for the manufacturing aircraft integral panels (Wang et al. 2002). It is well known that shot peening the surface of a metal sheet by small hard shot with sufficient kinetic energy can form a specific shape without need for forming die, and improve fatigue resistance of component significantly. It also has better adaptability to modern aircraft designs, for example, the capability to form tapered and sculptured integral structures, single and double curved shapes and virtually any size of parts (Wang et al. 2006).

The integral panel's manufacturing process starts at stock cutting and ends with finished part inspecting. The models that describe the information of intermediate parts at the different time in the fabrication process are crucial to forming the final shape. Nowadays, the component information needs to be described from s systematic view on the whole manufacturing process. First of all, the fabrication process consists of a sequence of working procedure, and the intermediate parts model must be defined accurately to drive the subsequent manufacturing activities, such as process parameters design, tooling design, NC Programming and so on. Furthermore, in order to take the three-dimensional (3D) model as the base in fabrication workshop, the geometric dimension and tolerance information, which was expressed in 2D drawing, needs to be defined, that is model-based definition (Quintana et al. 2010). The 3D model of manufacturing information contains geometric and non-geometric information. The composition, organization and definition of discrete intermediate part information are the key to integral panel manufacturing.

A variety of frameworks for the product information modeling in manufacturing process have been used, including information modeling for product lifecycle (Sudarsan et al. 2005), manufacturing information model (Wang et al. 2006), multiple viewpoint model for assembly (Demoly et al. 2010).The information content represented in the model arises diversely, which mainly classified into geometric and non-geometric information. The geometric information represents the shape in the manufacturing process such as blank model (Wang et al. 2002),intermediate part information (Park 2006) and so on. Non-geometric information describes the GD&T (geometric dimension and tolerance) (Quintana et al. 2010), quality data (Tang et al. 2008) and other engineering features. Feature-based model is a typical method for organizing the part's information. There are both individual and shared information in models with different perspectives on product information, and redundant information across models should be avoided. From single view or local extent of geometry, material and quality, the composition and organization of manufacturing information have been given. However, to the special structure and its peen forming process of aircraft integral panel, the structure of manufacturing model needs to be established further. Correspondingly, the definition process also needs to be taken into consideration from systematic view on the relation of multiple intermediate parts. The consistency across models should be ensured and the relations among the models should be built so that the related features are ensured to be updated when the design model are modified.

The current paper presents an alternate manufacturing model framework for aircraft integral panel that includes both geometric features and GD&T (Geometric Information and Tolerance) information so that the model can be used to digital manufacturing process. The content of the model are illustrated in detail and corresponding definition approach is presented as well.

2 MANUFACTURING MODEL OF INTEGRAL PANEL IN SHOT PEEN FORMING

The shape features of integral panel can be divided into base body and structure elements on it. Figure 1 illustrates the integral part's structure elements. The base body includes outer surface and inner surface modelled based on outer surface. The outer surface, as theoretical surface of aircraft, is the basis of integral panel design, which is classified into single curvature (ruled surface integral panel), double curvature (saddle-shape or variable hyperbolic supercritical wing), and the combination of them. The inner surface is stretched based on outer surface and the thickness of integral panel is different at various points. To meet the requirement of assembly strength, edge of integral panel should be strengthened by thickening.

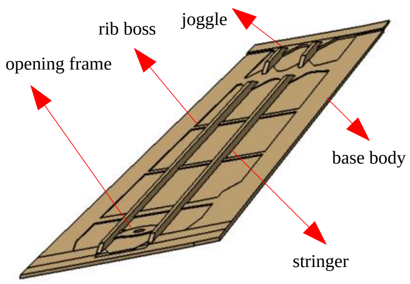

Figure 1: Example of integral panel structure

The structure elements, which is attached to integral panel base body, includes stringer, rib boss, joggle, opening frame, lug and so on. Stringer is often perpendicular to inner surface and reference of its modelling along the its axis on outer surface. In addition, the cross section of the stringer may be uniform and non-uniform. The lug can be added on the base body for assembly. Rib boss is modelled on the basis of outer surface and is used for strengthening structure, and often has equal thickness. Joggle is used for assembly and has constant deepness. Opening frame is used for the convenience of aircraft maintenance, and is a kind of combination of hole, groove, cover joggle and stiffener for improving structure strength and stiffness.

In digital manufacturing process, demand of manufacturing model is mainly original from the procedure of changing material shape and size. Orienting to the fabricating process, the manufacturing model is defined to bridge digital design and manufacturing on the basis of the part design model, which expresses the target shape. The fabricating process is composed of a sequence of working procedures, and consequently the manufacturing model is composed of several models of manufacturing state that expresses the feature on the different time in the process from the stock to the final part. The manufacturing model orienting to each key process is made up of two kinds of correlated model: model of workpiece and model for processing. The model of workpiece is used to express the target structure at the end of each working procedure and the model for processing is not same as the workpiece model of the process but for attaining it because of process factors.

The example part is fabricated by following the process chain. It is mainly composed of stock cutting, blank milling, material property inspecting, shot peen forming and shape inspecting. It is shown in Figure 2. NC milling of blank and shot peen forming of outer surface are two key working procedures. The blank of integral panel part is cut by NC milling from stock to flat outer surface with the structure elements and outer surface is formed by shot peen forming controlled by process parameters.

For the digital manufacturing of integral panel, the procedures of changing material shape and size include NC milling and shot peen forming. In order to support NC milling and shot peen forming, manufacturing model of blank and shot peen path should be defined. Blank model is used for generating NC code of milling and shot peen path model is used for designing the shot peen forming parameters.

Blank model is the direct data source for NC milling, and reflects shape and size of the structure after unfolding the design model of integral panel. While the plastic deformation is irreversible, there is not the only solution to the blank model.

Shot peening path model is critical to setting shot peen forming parameters of NC machine, which include peening flow, distance, angle etc. Shot peening path correlates with integral panel structure based on the lines of extreme curvature.

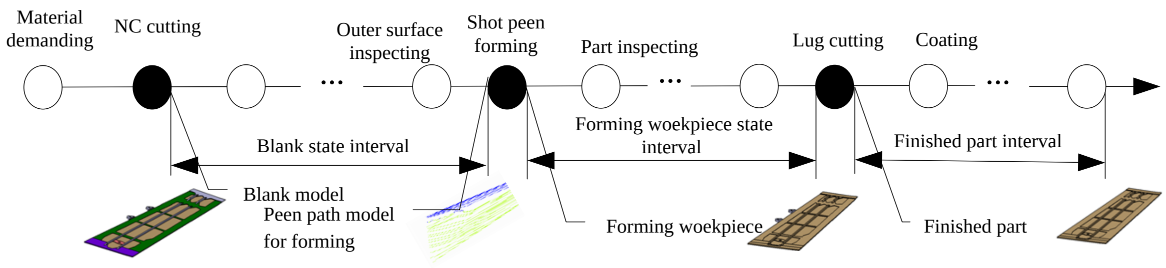

Figure 2: The process chain of integral panel fabrication and its manufacturing model

Manufacturing model is defined in three-dimensional CAD system, and each 3D model consists of geometric and non-geometric information. Geometric information describes the intermediate part shape, and non-geometric information describes the geometric dimension, tolerance, annotations (material feature, surface finishing etc.) and other features. The tolerances are defined in the models of blank and forming part for the inspecting working procedure after blank cutting and shot peen forming.

3 DEFINITION OF MANUFACTURING MODEL

The intermediate parts are correlated in the material flow of fabricating stock into final part, which is the basis of defining manufacturing state models. The order of defining manufacturing model is not from design model to blank model, that is to say it is not a reversible process of material flow, but decided by the dependent relations of the manufacturing state. The order of defining the manufacturing model of the example part is listed as follows:

- Defining the forming workpiece part by adding lugs on the design model;
- Defining the blank model by unfolding the forming workpiece;
- Defining the shot peening path on the blank model by computing the curvature of outer surface of forming workpiece.

The modeling flow of integral panel blank from design model orienting to NC milling process is shown in Figure 3. The blank part is transformed by the workpiece model for shot peen forming procedure. It is manifested by the changes of structure elements' shape and dimensions of forming workpiece model. The model definition of integral panel blank includes three steps: extracting geometric elements, calculating of unfolding geometric elements and blank modeling.

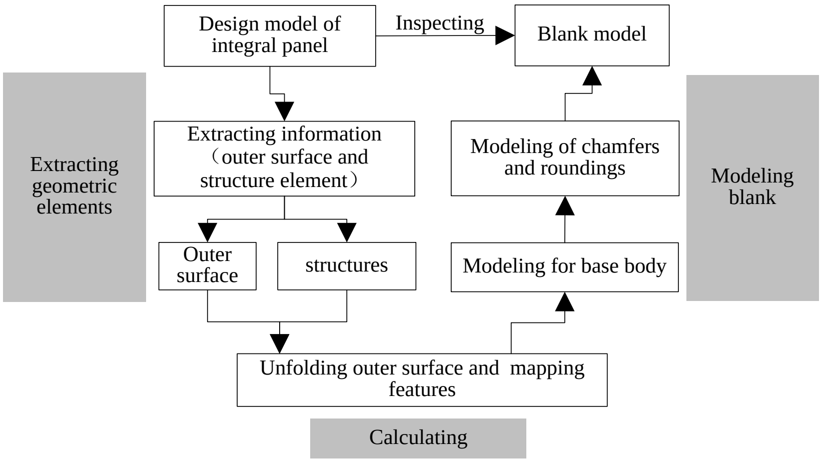

Figure 3: Definition flow of blank model

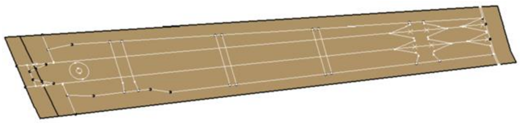

Figure 4: Extracting geometric elements

3.1 Extracting geometric elements

The geometric elements for unfolding are features that can be used to control the base body and other structure elements. As the deformation mainly occurs on the outer surface by shot peening, the structure elements attached to it are deformed at the same time, and the outer curved surface and the geometric elements, by which the structure elements are built, should be extracted. The extracted outer surface, points and lines of the example part are shown in Figure 4. When extracting geometric elements for unfolding, some rules should be followed.

- Pre-treat chamfers and rounding before extracting geometric elements;
- Ignore holes, grooves on outer surface;
- Extract the ultimate parent structural elements;
- Extract least elements for rebuilding structure elements;
- Do not extract a same geometric element twice.

3.2 Unfolding doubly curved surface into planar one

In the unfolding process, other extracted geometric elements are mapped onto unfolded planar surface panel by a mapping algorithm based on element deformation energy. The unfolding result is shown in Figure 5.

3.3 Modelling blank based on the unfolding result

Blank modelling is focused on rebuilding of inner surface of the base body and structure elements attached to it. In the modelling process, the inter surface of the base body is modelled by offsetting control points with a thickness value in direction of outer surface normal, based on the principle that the thickness of integral panel is invariable after unfolding outer surface. The structure elements are rebuilt by using the control lines and points to model sketch. Tolerances are defined by the requirements of inspection process after NC milling of blank. Blank model is shown in Figure 6.

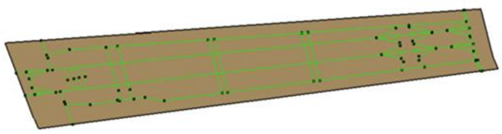

Figure 5: The unfolded geometric features

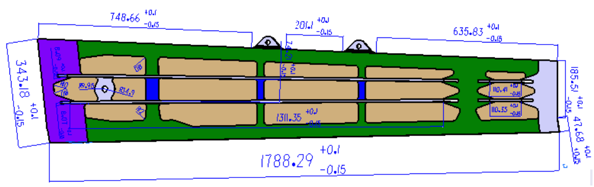

Figure 6: The blank model

4 CONCLUSION

Digital is the core of modern manufacturing technology development. For digital aircraft manufacturing, not only NC machine is used, but also the digital definition technology of product, process and resource in manufacturing needs developing. The manufacturing model is the key to integrate design information and material fabrication process. To support the digital manufacturing of integral panel, manufacturing model and its definition process is presented in this paper. Manufacturing model with model-based definition will change the current technology and make it possible the utilization of the digital information in fabrication process. With the contribution to some key technologies for its implementation, the tool of manufacturing model definition has been developed based on CATIA V5. Its applications, one of which is exemplified in the paper, have brought great benefits to the factories in terms of shortening production preparation cycle, manufacturing cost and operational efficiency.

ACKNOWLEDGMENTS

The research project is supported by the National Natural Science Foundation of China under Grant No.51275420.

REFERENCES

Wang, T., M.J. Platts. 2002.A computer-aided blank design method for the peen forming process. *Journal of Materials Processing Technology*.122:374-380.

Wang, T., M.J.Platts, A.Levers. 2006.A process model for shot peen forming. *Journal of Materials Processing Technology*. 172:159-162.

Quintana, V., L. Rivest, R. Pellerin, F. Venne, F. Kheddouci. 2010.Will Model-based Definition replace engineering drawings throughout the product lifecycle? A global perspective from aerospace industry. *Computers in Industry*. 61: 497-508.

Sudarsan, R., S.J. Fenves, R.D. Sriram, F. Wang. 2005.A product information modeling framework for product lifecycle management. *Computer-Aided Design*. 37: 1399-1411.

Wang, J.B., C. Liu, X.N. Han and B. Feng. 2006. Manufacturing oriented multi-state model for aircraft sheet metal parts. *Advances in materials manufacturing science and technology II, Material science forum*. 532-533:933-936.

Demoly, F., D. Monticolo, B. Eynard, L. Rivest, S. Gomes. 2010. Multiple viewpoint modelling framework enabling integrated product–process design. *International Journal of Interactive Design and Manufacturing*. 4:269-280.

Park, S. 2006. Generating intermediate models for process planning. *International Journal of Production Research*. 44:193-206.

Tang, X.Q., H. Yun. 2008. Data model for quality in product lifecycle. *Computers in Industry*. 59:167-179.