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Research on optimization technology of NC machining of aluminum alloy single-sided frame parts

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Abstract

Aluminum alloy single-sided frame parts are a common type of parts for civilian passenger aircraft. These parts have large outer dimensions, small wall thickness, and a large number of holes. In the NC machining process, the problem of excessive deformation is prone to occur. This article analyzes the causes of the problem, and elaborates the technological process and deformation control technology of the single-sided frame parts, and evaluates the implementation effect through the process test, which finally guarantees the processing quality of the single-sided frame parts.

Keywords

Aluminum alloy; single-sided frame parts; deformation control; technological process.

1. Introduction

With the rapid development of aviation technology, in order to reduce the weight of the aircraft, more and more integral aluminum alloy structural parts are used for aircraft parts. Large aluminum alloy single-sided frame parts are one of the typical parts. This kind of parts are prone to overall warpage deformation during machining process [1], which directly leads to out-of-poor part size and flatness that cannot meet the assembly requirements.

Part deformation control has always been a key issue in the development of aviation technology. There are five main factors that cause processing deformation: material properties, cutting force, cutting heat, clamping force and residual stress [2-3]. Because it is difficult to quantify the various aspects of part deformation information, it is impossible to establish an effective mathematical model, and thus an effective process optimization plan cannot be derived through theory. Therefore, none of the current technological solutions for eliminating deformation through numerical control machining can guarantee complete elimination of deformation.

In the case that the deformation cannot be completely eliminated at present, correcting the part by fitter is an effective means to solve the final deformation of the part. For single-sided frame parts, the commonly used method of correction is the roll correction method. The prerequisite for adopting this correction method is that the single-sided frame parts need to be deformed in the positive direction after processing. However, due to the difference in the material and structure of the part, the final deformation trend of the part after processing is also different. For the parts whose parts are finally deformed in the reverse direction, the rolling correction cannot be used, and the parts cannot meet the flatness requirements in the end.

This article carried out research on the processing deformation control technology for aluminum alloy single-sided frame parts, and formulated the overall processing deformation control process flow of single-sided frame parts, and verified the feasibility and effectiveness of

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the process flow through experimental results, and the deformation of the parts was obtained Effective control.

2. Deformation characteristics of single-sided frame parts and deformation control process

2.1. Deformation characteristics of single-sided frame parts

Take a project's siding as an example, as shown in Figure 1, the siding part is a large single-sided frame type part. This type of part is difficult to process. The main reason is that the middle part of the part is easy to be deformed after processing, that is, reverse to deformation.

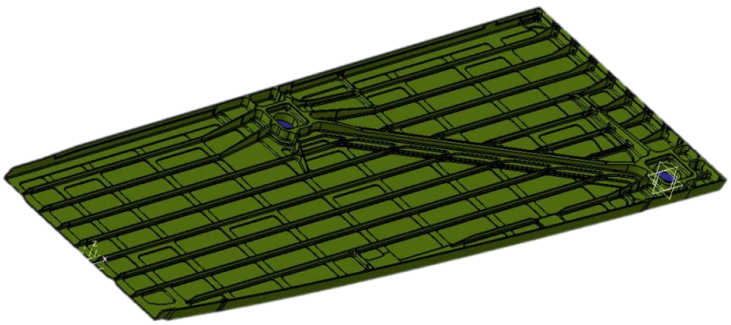

Figure 1 Three-dimensional structure diagram of a single-sided frame part of a project

Figure 2 Positive deformation of single-sided frame parts after processing

Figure 3 Reverse deformation of single-sided frame after processing

See Figure 2 and Figure 3 above. After the parts are finished, the positive deformation is manifested as the two ends of the parts are warped and deformed when the frame is facing upwards. Reverse deformation is manifested as arching and deformation of the middle part of the part when the frame is facing upwards. Among them, the reverse deformation cannot be corrected for roll bending. In order to change the direction of deformation and make the processed state of the part become a positive deformation that is easy to roll and correct, this article analyzes and studies the deformation control technology of single-sided frame parts.

Developed a complete processing deformation control process, adopted pre-deformation compensation technology and finishing deformation control technology in the process, and verified these technologies in actual processing, which can effectively change the deformation direction of the part, thereby controlling the part The deformation.

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2.2. Process flow of processing deformation control for single-sided frame parts

For aluminum alloy single-sided frame parts, the blanks are generally pre-stretched aluminum alloy plates. With the advancement of the processing process, the residual stress of the plate is continuously released, and finally deformation of the part is formed. The aerospace parts themselves are complex in structure, and the stress concentration positions are diversified, which leads to different structural parts with different deformations. For the parts that eventually form reverse deformation after processing, we adopt the following process and deformation control methods.

As shown in the figure above, for aluminum alloy single-sided frame parts that are prone to reverse deformation, the process flow includes: finishing the upper and lower sides of the sheet, finishing of the positioning surface, natural aging, vacuum clamping, finishing, roll correction .

Among them, the main function of finishing the upper and lower sides of the sheet is to mill both sides of the sheet to avoid the deformation caused by the sheet itself and affect the subsequent processing.

Positioning surface finishing: It is different from the positioning surface finishing that we usually know. The finishing here mainly uses the pre-deformation compensation method that has not been used before. Its purpose is to force the sheet metal to form a positive deformation before the overall finishing, which is used to offset the reverse deformation after the overall finishing of the part.

Natural aging: Fully release the residual stress of the sheet material to facilitate subsequent control of the deformation of the parts.

Vacuum clamping: Due to the pre-deformation compensation method used before finishing, the sheet has formed a positive deformation and the positioning surface is curved. Therefore, the positioning surface is flattened by vacuum suction clamping.

Finishing: In the vacuum adsorption state, the overall processing adopts the layer drop method, that is, the layer priority processing method to remove the large margin of the part, and the excess material is uniformly removed from the part Z upward to avoid stress concentration affecting the deformation of the part. The partial area adopts the reciprocating machining method, which can also reduce the residual stress of the parts.

Rolling correction: Because the pre-deformation compensation method is used in the early stage to cause the sheet to deform in the positive direction, it offsets the reverse deformation caused by the finishing. In the end, the part still has a small amount of positive deformation. The positive deformation is conducive to the roll correction, and the positive deformation of the part can be eliminated through the roll correction.

3. Deformation control technology

3.1. Pre-deformation compensation method

Considering that there is a certain probability that the deformation control method used in the subsequent finishing process cannot completely eliminate the deformation, the pre-deformation compensation method is used before the finishing process to force the aluminum alloy sheet to form a forward deformation in advance to offset the reverse deformation caused by the finishing process. The parts are still positively deformed after finishing, which is conducive to the subsequent roll correction and completely eliminates the deformation of the parts.

The principle of the pre-deformation compensation method is as follows:

(1) Mill the polished surface to the light state, eliminate the deformation of the sheet itself, and add a pressure plate slot in the middle of the sheet;

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(2) Milling the frame surface to the light state, eliminating the deformation of the sheet material itself, and milling steps at both ends of the sheet material, which is used to raise the two ends of the part during the next second milling of the smooth surface.

(3) With the smooth surface facing up, use the steps at both ends of the frame to padded the two ends of the blank, and use the pressing plate at the middle pressing plate groove to bend the blank, and in this clamping state, the smooth surface is milled flat.

(4) When the pressure plate is loosened, the sheet material rebounds into a bent state due to elastic deformation. At this time, with the frame face up and the smooth face down, the sheet will be deformed in a positive direction.

The process route is shown in Figure 5, the position of the platen groove is shown in Figure 6, and the schematic diagram of the blank bending is shown in Figure 7. The pre-deformation compensation method changes the direction of deformation of the sheet material in advance, so that the sheet material is deformed in a positive direction. To prepare for the subsequent offsetting of the reverse deformation and the roll correction caused by the finishing of the parts.

3.2. Finishing deformation control process method

Finishing is the key process to form the final size of the part, so it is very important for the process to control the deformation of the part. For single-sided frame parts, the smooth surface is used as the positioning surface, and the parts are clamped by vacuum adsorption. The following deformation control methods are used in finishing.

3.2.1 Layer drop method

In the finishing process, the large-diameter milling cutter is used to remove the large margin of the part first, and the layer drop method, that is, the layer-first processing method, is used to remove the material according to the Z-direction of the part and layer by layer, which is beneficial to the release of residual stress. As shown in the figure below, the step-down method is adopted for processing, and the processing surface of each layer maintains the same height.

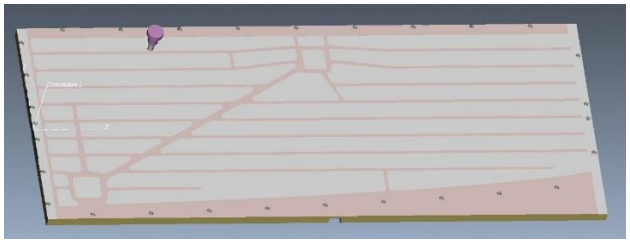

Figure 8 Early stage of processing

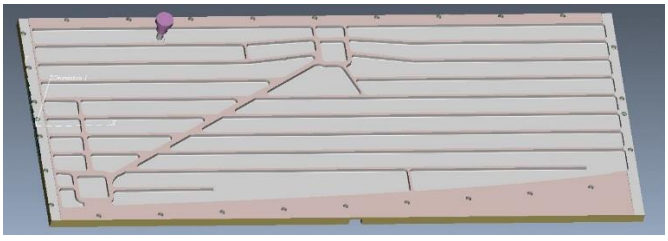

Figure 9 Late processing stage: the processing surface maintains the same height in the Z direction

3.2.1 Tool path planning for finishing

When finishing a local area (such as a single frame area), the tool adopts a reciprocating machining method along the long direction of the part, which can well uniform the stress and reduce the deformation of the part.

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Fig. 10 Way of reciprocating machining

4. Processing verification

4.1. Improvement of part deformation

Figure 11 and Figure 12 show the deformation of parts after finishing. The positioning surface (smooth surface) is precision milled by pressing and bending of the blank. After finishing milling the positioning surface, loosen the pressing plate, the material will automatically rebound due to the elastic deformation of the material; the two ends of the part have been slightly tilted before finishing with the smooth surface positioning. After processing, the reverse deformation is offset. In the finishing process, the layer drop method and the reciprocating machining method are adopted to eliminate residual stress and release deformation as much as possible. Finally, the smooth surface of some parts is combined with the worktable, and the flatness is good; the ends of some parts are deformed in the positive direction, which is easy for roll correction.

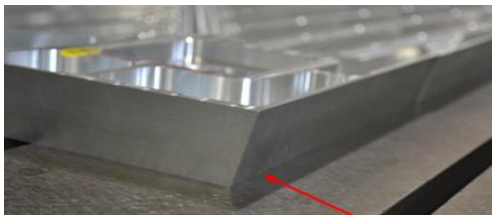

Figure 11 Schematic diagram of the end of the single-sided frame close to the worktable

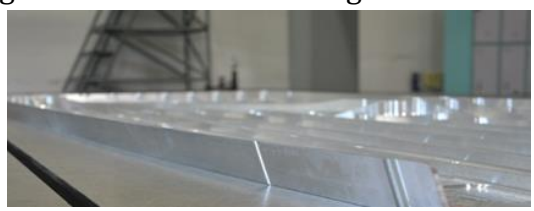

Figure 12 Schematic diagram of slight warping at the end of a single-sided frame part

4.2. Improvement of surface quality

Figure 13 and Figure 14 respectively show the surface quality of the siding frame surface and smooth surface. It can be seen from the figure that the blank is in a stressed state during processing, with high clamping rigidity, stable processing state and high surface quality.

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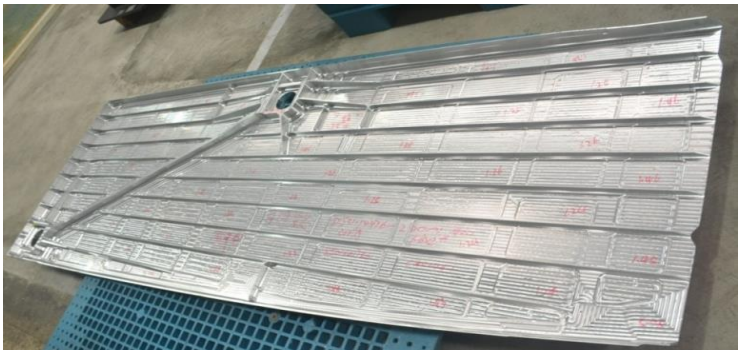

Figure 13 The actual surface of the part frame

Figure 14 The surface of the part smooth

5. Conclusion

This paper studies the processing deformation control technology of single-sided frame parts, and considers the deformation control of the parts from the entire process flow. The pre-deformation compensation method is used in the early stage of finishing to ensure that the parts will not be deformed in the reverse direction. In the finishing process, through the finishing deformation control method, the processing deformation is greatly eliminated, and then the final positive deformation is eliminated through the roll correction, and finally the purpose of controlling the deformation of the part is achieved. The processing deformation control method has very good promotion and application value, and is of great significance to the development of my country's aviation field.

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