Research on economical sawing equipment for auto roll-forming frame part adapted to fast switching of multiple varieties

Peng Li-ming\textsuperscript{1a}, Qian Hua-min\textsuperscript{2b}

\textsuperscript{1}Department of Mechanical and Electrical Engineering, Ningbo Polytechnic, Ningbo, Zhejiang Province, China
\textsuperscript{2}Ningbo Huina Machinery Co., Ltd., Ningbo, Zhejiang Province, China
\textsuperscript{a}email: 429161309@qq.com, 0400131@nbpt.edu.cn \textsuperscript{b}email: 13362473387@189.cn

Abstract. Precise angle sawing is an important process to ensure the auto roll-forming frame parts be assembled and welded accurately. Large enterprises can adopt special sawing machine and fixture to meet the requirements. However, this method is not suitable for small enterprises due to its large investment and insufficient flexibility of the manufacturing system. Considering the multi-varieties and small batches production characteristics, economical sawing equipment based on the general cutting machine platform equipped with quick change fixture is introduced. By changing the fixture position on the platform, and replacing a few necessary elements, this equipment can accomplish different angle precise sawing for various auto roll-forming frame parts. Finally the economical technology renovation purpose is realized.

1. Introduction
Auto roll-forming frame part is one of the important parts used in car doors, windows, door slides, and so on. In order to meet the needs of automobile body, most of the car window frames are designed in combined structure [1]. Firstly the high strength band steel is rolled into desired section. Then it is cut into a certain length and bent into the needed shape. After that the two ends of the auto roll-forming frame parts need to be sawed into a precision angle in order to ensure that a number of frame parts can be accurately assembled and welded into a whole door or windows frame. So precision angle sawing is an important process in auto roll-forming frame part production.

With the development of personalization and customization, there are more and more car models. Different models of the car, the roll-forming frame parts are different in structure. According to the different installation position, the roll-forming frame parts are different also, such as the door window frame, body side frame, front window eyebrow frame, rear window frame, corner window frame, skylight window frame and so on[2]. In the same car, the left door and the right door window frame parts are symmetrical. Therefore automobile window frame production has the typical characteristic of multi - variety, small batch and symmetrical parts.

Under the premise of large quantity orders, large enterprises can adopt special sawing machine and fixture to meet the precise angle sawing requirements. However, due to the large investment, this method is not suitable for small enterprises [3]. The production of small enterprises is characterized by multiple varieties, small batches, and rapid market response. Hence they pay special attention to the flexibility, generality and low cost of process equipment.
In this paper, one kind of sawing equipment based on the general cutting machine platform which equipped with quick change fixture is introduced. By changing the fixture position on the platform, and replacing a few elements which used for the part positioning and clamping, this equipment can fulfill the different angle precise sawing processing requirements of various auto roll-forming frame parts. This study is helpful to reduce the small enterprises manufacturing cost when facing the similar products featured with multiple varieties and small batches.

2. Production status

Table 1 shows the statistics of auto roll-forming frame parts produced by a small enterprise, including 6 categories of products, 24 cutting conditions, involving 12 angles. According to its actual production needs, if the special angle sawing machine shown in Figure 1 is chosen for this process, 2 special machines and 4 sets of fixtures should be equipped at least. Based on experience this customized sawing machine generally costs RMB 150 ~ 200 thousand per unit. And the fixture is about RMB 10 ~ 15 thousand per set. Therefore, this small enterprise needs to invest RMB 300 ~ 400 thousand for the sawing process. That's too much investment for a small business. If the configuration standard of the customized equipment is reduced for cost consideration, the machining accuracy and stability of the equipment will be significantly affected, and the cost of later maintenance will also be higher [4]. Therefore, it is urgent to develop a low cost angle sawing equipment which adapts to the rapid switching of many varieties of auto roll-forming frame parts.

Table 1. Auto roll-forming frame parts cutting conditions.

| Categories          | Part position | Cutting conditions |
|---------------------|---------------|--------------------|
|                     |               | Positive sawing    |
|                     |               | Opposite sawing    |
| Front B pillar      | Left door     | 5°                 |
|                     |               | 49°                |
|                     | Right door    | 5°                 |
|                     |               | 49°                |
| Rear B pillar       | Left door     | 13°                |
|                     |               | 42°                |
|                     | Right door    | 13°                |
|                     |               | 42°                |
| Rear C pillar       | Left door     | 19°                |
|                     |               | 16°                |
|                     | Right door    | 19°                |
|                     |               | 16°                |
| Front upper beam    | Left door     | 16.5°              |
|                     |               | 53.3°              |
|                     | Right door    | 16.5°              |
|                     |               | 53.3°              |
| Rear upper beam front section | Left door | 11°               |
|                      |               | 45.7°              |
|                      | Right door    | 11°               |
|                      |               | 45.7°              |
| Rear upper beam rear section | Left door | 8.4° | 18.4° |
|                        | Right door | 8.4° | 18.4° |
3. Renovation solution

3.1. Overall design

As shown in Figure 2 left image, the universal pipe cutting machine has been developed by many manufacturers. It has the advantages of low price, good cutting accuracy and high reliability [5]. The whole idea of the equipment reconstruction is based on the platform, and replaces its general fixture with the special fixture, and then the economical angle sawing equipment shown in figure 2 right image is obtained.

Considering that the hydraulic system available on the general saw machine, the special sawing fixture for auto roll-forming frame parts adopts the hydraulic clamping method. In order to meet the requirements of multi-variety, small batch and multi-angle sawing, the special fixture is separated by three main functional modules, i.e. fixture body assembly, part positioning assembly and angle adjusting assembly. The fixture structure modules are shown in Figure 3.
3.2. Working principle

Fixed plate 1 is mounted on the general cutting machine work table. Pin 11 is built in the middle of this plate. Semi-circular movable plate 2 can rotate around the Z axis with pin 11. Positioning holes and screw holes between the movable plate 2 and the fixed plate 1 are made in advance. Different sawing angles can obtain by switching different positioning holes. The fixture body is mainly composed of base plate 5, fixed clamping block 7, movable clamping block 8, guide slider 9 and hydraulic cylinder 10. The angle adjustment of the fixture body around X axis can be realized through assembly adjuster 6. By adjusting adjuster 12 to push base plate 5 and move along the guide plate 3, the fixture can adjust its position along the Y-axis. The oil cylinder 10 drives the movable clamping block 8 to move along the X-axis guide slider 9 and realize the workpiece clamping and loosening action. In order to meet the clamping requirements of multi-varieties roll-forming frame parts, the quick-change positioning parts were designed according to different product shapes. Because window frame parts are generally slender, auxiliary support should be set on the clamping and positioning assembly to prevent vibration during sawing.

4. Improve analysis

4.1. Renovation cost analysis

The cost of each set is about RMB 40 thousand. It mainly includes general cutting machine (RMB 10 thousand), hydraulic station (RMB 5 thousand), fixture body (RMB 5 thousand), and 6 sets of clamping and positioning components (RMB 20 thousand). For the same production demand, four sets of the equipment (shown in Figure 5) are needed in this small enterprise. A total investment of RMB160 thousand is enough. By comparison, the renovation costs only about 40% of the original investment. The production practice shows that the failure rate and the maintenance cost is very low.
4.2. Multiple varieties adaptability

Base on the different installation direction of the fixture, it can be divided into four quadrants application (shown in Figure 6). Fixture in different quadrant should be equipped with different semi-circular movable plate. Table 2 shows the symmetric relationship between quadrants, products and angles. As long as the fixture installation quadrant is simply changed, the processing of symmetric parts can be realized. Therefore, the device is easy to achieve rapid switching of multiple varieties.

| Categories     | Part position | Angle | Quadrant | Angle | Quadrant |
|----------------|---------------|-------|----------|-------|----------|
| Front B pillar | Left door     | 5°    | 1#       | 49°   | 4#       |
|                | Right door    | 5°    | 2#       | 49°   | 3#       |
| Rear B pillar  | Left door     | 13°   | 2#       | 42°   | 3#       |

Figure 5. Real equipment after renovation.

Figure 6. Four quadrants application of fixture.
5. Conclusion

According to the characteristics of multi-varieties, small batch production of small enterprises, a kind of economical sawing equipment is proposed. By replacing a few positioning elements, the different shape of auto roll-forming parts can be easily clamped. Through changing the quadrant position of the fixture on the table of the general sawing machine, the symmetrical parts can be rapidly machined. Based on general purpose cutting machine and special fixture, the investment of production cost is greatly reduced. This design has been verified by production practice and obtained the Chinese patent authorization (ZL 2019 2 0499114.3). It has reference value when a similar product needs to be machined through economical means.

Acknowledgments

The project is supported by Zhejiang Provincial Public Welfare Technology Application Research Foundation of China (GG21E050014).

References

[1] Han, F., Shi, L., Xiao, H., et al. (2013) Development and key technologies on roll-formed automobile profiles with AHSS. Journal of plasticity engineering, Vol.20 (3): 65–69.

[2] Yin, Y. T. Study on flexible transformation of GESX company earplugs production line: [D]. Shandong University of Technology, 2018.

[3] Song, Ch. X., Ji, W. X. (2018) Research on process quality control for multi-varieties and small-batch machining workshop. Journal of modular machine tool & automatic manufacturing technique, 6: 172-176.

[4] Jing, D. M., Xu, H. Y. (2017) Research on modular fixture design of torsional arm series structural parts. Journal of tool engineering, Vol.51 (04):115-117.

[5] Li, W. L., Yang, J. J., Zhou, L. M. (2016) Research on key techniques of flexible assembly tooling based on modular design. Journal of Machine tool & hydraulics, Vol.44 (04):14-17.