Development of fin forming machine with autonomous adjustment

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Abstract

For stably efficient manufacture of high quality products, we have developed a fin forming machine capable of autonomous adjustment. This newly developed machine measures "fin height" and "fin pitch" in line and gives feedbacks for autonomous adjustment of the forming conditions in real time. In process capabilities with the autonomous adjustment, means of the dimensional variations are closer to the specifications and the standard deviation is lower than conventional fin forming machines. The autonomous adjustment transcends the conventional model of human-dependent quality assurance and allows stably efficient manufacture of high quality products without needs of human intervention.

Key Words : Automation, monitoring / Quality assurance, In-line measurement, Autonomous adjustment

1. Introduction

In recent times, the manufacturing business is being exposed to increasingly severe competition in the globalized business environment. Under these circumstances, each company is promoting technological innovations including IoT (Internet of Things) and AI (Artificial Intelligence) in order to strengthen its business competitiveness.

Calsonic Kansei Corporation is also developing next-generation equipment in order to realize the processes that can stably and efficiently manufacture high quality products toward the strengthening of Monozukuri (manufacturing) competitiveness. Our representative development items are as follows:

- In-line measurement of products
- Monitoring of equipment operating state
- Autonomous adjustment of equipment
- Equipment state prediction and predictive maintenance by machine learning

This report introduces the development of a fin forming machine to which equipment autonomous adjustment is applied.

2. Background and new approaches of fin forming

2.1. About fins

Calsonic Kansei Corporation manufactures heat exchange products and air conditioning products (hereinafter collectively referred to as heat exchange products) that use aluminum alloy thin plate materials. A fin is a part that enlarges the heat radiation surface area of a heat exchange product to improve its heat exchange efficiency. Among the component parts of heat exchange products, a fin is one of important part that influence heat exchange performance.

Fig. 1 shows the model diagram of a radiator and a fin used for the radiator as an example of heat exchange products.

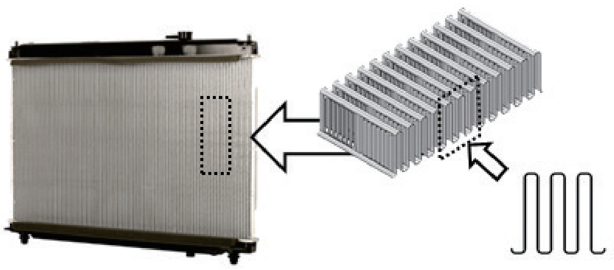

Fig. 1 Heat exchange product (Radiator & Fin)

Fins used for heat exchange products are generally produced by forming a rough shape by corrugate forming that runs a material through between nearly-gear-shaped molds that engages with each other to form the material into a corrugated shape and then making fine adjustments to be a specified height and pitch. Fig. 2 shows the process outline of fin forming.

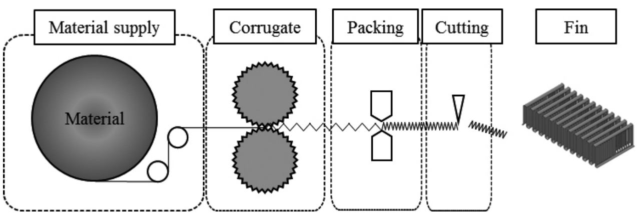

Fig. 2 Process outline of fin forming

2.2. Problems in fin forming

The important dimensions for fins are fin height and fin pitch as indicated in Fig. 3. This is because a change in

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fin height or fin pitch greatly affects the heat exchange performance of products, and moreover, causes a process defects in the assembling process and brazing process that follows the fin forming process.

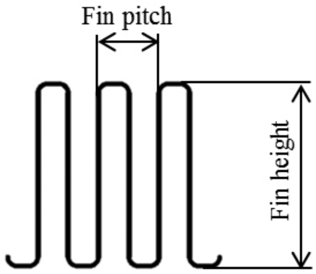

Fig. 3 Fin height and Fin pitch

However, fin height and fin pitch are subject to deviation from the target dimension and variation due to changes such as in the material lot. Under the current circumstances, we assure quality by maintaining fin height and fin pitch dimensions by frequent parts dimension checking and equipment adjustment by a maintainer and operator.

The quality assurance mentioned above depends on human work and has a problem of too many man-hours for measurement and adjustment.

In addition, quality dispersion is generated by differences in experience, skills, and know-how of the maintainers and operators in different factories and different countries.

Furthermore, another problem that arises is the fact that no one can adjust fin forming machine except some experts and experienced workers.

2.3. Approach for resolving problems

The problems in fin forming are the following three problems:

(1) Quality assurance depends on human work and requires a lot of man-hours.
(2) Due to the human-dependent work, quality dispersion is generated.
(3) Only highly-skilled workers can adjust the equipment.

In order to resolve the above problems, we sorted out the relationship between "fins" and "equipment" by first conducting the quality function deployment and basic experiment of fins. We sorted out the correlation between each shape of fin and each forming condition of equipment that were not clear before, and clarified the concealed equipment processes that should be adjusted. In conjunction with this, we quantified equipment adjustment know-how.

Next, as a method for transcending human-dependent quality assurance, we focused on autonomous adjustment of equipment. Autonomous adjustment of equipment means always giving feedback on measurement results and implementing a cycle of judgement and correction to make equipment itself perform equipment adjustment automatically without needing human intervention.

To make autonomous adjustments, a fin in-line measurement technique is essential. Prior to this development, we established an in-line measurement technique for fin height and fin pitch, which uses image processing, so that we can give feedback on the real-time measurement results of real-time fin height and fin pitch to related equipment conditions. Moreover, because the realization of the fin in-line measurement technique has enabled us to always check dimensions visually, we can expect a reduction in the periodical measurement workload of maintainers and operators.

3. System outline

Fig. 4 shows an outline of the autonomous adjustment system created by this development.

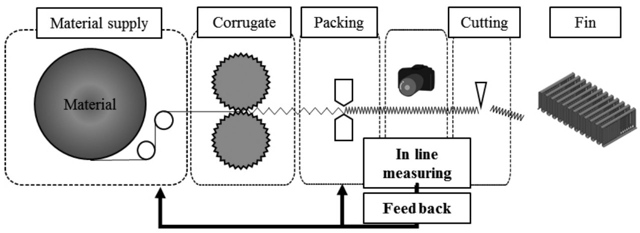

Fig. 4 System outline of autonomous adjustment

We decided on performing in-line measurement of fin height and fin pitch in the process just before the cutting process in which the final shape is formed. This is for using the in-line measurement results of fin height and fin pitch directly as quality data. We decided to set specified target ranges for fin height and fin pitch and perform feedback control to keep the fin height and fin pitch within those target ranges. The target ranges are parameters for making autonomous adjustments and they are different from dimensional tolerances described in drawings. Because the target ranges are set smaller than dimensional tolerances, if a fin height or fin pitch deviates from its target range, it will be automatically adjusted to be within the target range while the deviation amount is still small enough.

In addition, variation in dimension caused by factors such as disturbance and successive deterioration of equipment will be automatically restrained. This enables us to realize "human-independent quality assurance", "further stabilization of quality", and "equipment adjustment without needs of intervention of highly-skilled workers".

4. Verification results

In the course of continuous fin forming, we verified the effects of autonomous adjustment by switching the feedback control of the autonomous adjustment system from OFF to ON. Fig. 5 shows the movement of fin height before and after autonomous adjustment, and Fig. 6 shows the movement of fin pitch. The horizontal axis indicates the forming time in continuous forming, and the vertical axis indicates each dimension. USL and LSL indicate the upper limit value and lower limit value of dimensional tolerance, respectively, and Target USL and Target LSL indicate the upper limit value and lower limit value of the target range in autonomous adjustment, respectively.

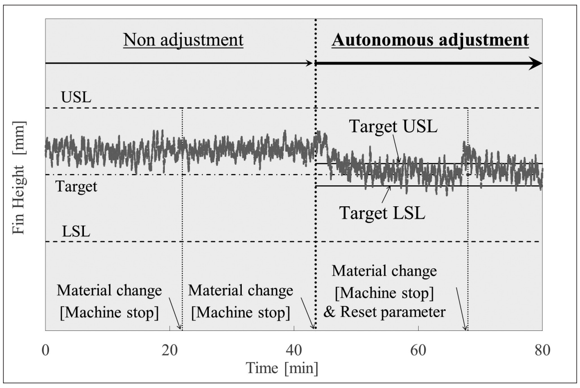

Fig. 5 Autonomous adjustment effect to fin height

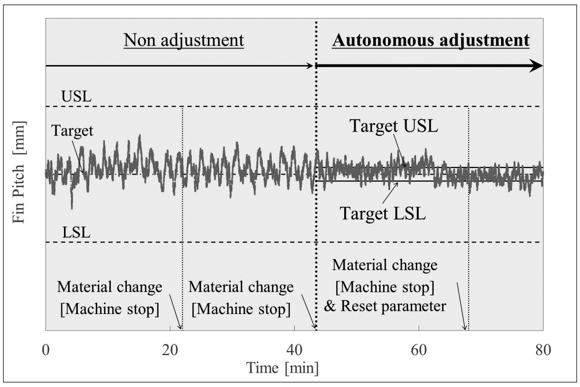

Fig. 6 Autonomous adjustment effect to fin pitch

First, we operated the equipment under standard equipment conditions without autonomous adjustment.

At this time, assuming disturbances in an actual production line, we changed the material in the middle of autonomous adjustment and intentionally changed the equipment conditions manually at near 68 min. A material change in an actual production line is a change point of quality. As there is a slight difference in the tendencies of fin height and fin pitch before and after the material change, a maintainer and an operator were required to perform measurement and equipment adjustment at every material change.

As a result of autonomous adjustment, we confirmed that, for the fin height, deviation from the target value was automatically corrected, and for the fin pitch, variation width was restrained. Furthermore, from the results of measurement before and after material change, we confirmed that the fin height and fin pitch were automatically corrected even when the forming conditions were changed.

Therefore, the quality assurance that has depended on human work can be achieved without the need of human intervention, and also further stabilization of quality can be achieved.

5. Conclusion

Through the development of the fin forming machine equipped with an autonomous adjustment function, we have successfully realized autonomous adjustment by implementing in-line measurements of fin height and fin pitch and giving real-time feedback of measurement results to forming conditions.

With this autonomous adjustment function, we have realized the benefit of bringing the median forming dimension much closer to the standard value compared to the previous machine and reduced the variation width. As a result, we found that it is possible to transcend human-dependent quality assurance and manufacture high quality products stably without the need of human intervention. As the employment of autonomous functions on equipment like this is a usable idea not only for fin forming machines but for other processing machines, we would like to implement similar developments in the future. Furthermore, we would like to realize more sophisticated functions, including predictive maintenance and the optimization of operating conditions, with a combination of IoT and AI technologies, such as machine learning, so that we can further improve the competitiveness of our Monozukuri.

Last but not least, I would like to take this opportunity to express my deepest appreciation to the many people involved who gave us support and cooperation for this technological development.

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