Development of Know-How Based Automatic Design System for Automobile Lamp Inspection Jigs

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***Abstract*—The purpose of this research is to develop an automatic design system for automobile lamp inspection jig based on know-how. The inspection jig consists of a sub-gauge, which is a measuring block, and inspects the height and outer peripheral shape of the design surface. The sub-gauge usually comprises two surfaces: a surface with a step difference of 0 mm from the design surface and a surface with a gap of 2 mm from the design surface. In this report, the former is called the step surface and the latter is known as the gap surface. In this research, we utilize the design knowledge and know-how acquired from the interview with an expert to automate the inspection jig design. The step surface is created using straight lines obtained from the intersection of the design surface and planes arranged at equal intervals. The gap surface is created from the offset surface of the side adjacent to the design surface. The sub-gauge is constructed as a solid with these two faces. Finally, the presence of an interference between the product and sub-gauge is determined and removed. The proposed system executes the processes, including step creation, gap creation, sub gauge creation, and interference cancellation using the SolidWorks API.**

***Index Terms*—quality control, design knowledge, automatic design system, inspection jig**

I. Introduction

CAD-CAM systems are widely employed for design and manufacturing processes in manufacturing industries, and contributes significantly to efficiency improvement [1], [2]. In particular, in the automobile industry, complex design and manufacture are required, because the products in this industry comprise several parts and free-form surfaces [3]. A precision inspection of automotive parts is performed using inspection jigs to control the quality of the parts that require high accuracy. However, designing an inspection jig according to the customer requirements (inspection specifications), requires a high level of design knowledge and know-how, as well as a considerable amount of time [4], [5].

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In this research, certain parts of headlights and rear lamps, which are automobile lamps, are targeted as the ones requiring high efficiency during the design of the inspection jig. To improve the efficiency of the design, the required design knowledge and know-how were acquired from interviews with skilled designers, and the design rules were constructed out of the information acquired. Based on these design rules, we developed a system to realize the inspection jig design automation and verified its effectiveness.

II. Inspection and Design of Inspection Jig

A. Inspection Method of the Inspection Jig

An inspection jig is used to inspect the accuracy of the parts during product quality control. The exterior surface that forms the surface of the final product is called the design surface [6]. During the inspection by the inspection jig, the product is fixed to the inspection jig, and the height and perimeter shape of the design surface are inspected using measuring blocks, called sub-gauges. Usually, the sub-gauges are designed with a step difference of 0 mm and a gap of 2 mm from the design surface. The height of the design surface is inspected by setting a step caliper on the sub-gauge and checking the height difference from the design surface. The schematic diagram of measurement of step is shown in Fig. 1. The perimeter shape of the design surface is inspected by inserting and removing a pin gauge between the sub-gauge and product. The schematic diagram of the measurement of gap is shown in Fig. 2.

B. Design Method of the Inspection Jig

Inspection Jig consists of sub-gauges that are measurement blocks. The shape of the sub-gauge depends on that of the design surface of the product. Therefore, the design data of the base product is necessary for devising the design of sub-gauges. As mentioned in the previous section, a sub-gauge is designed to inspect the height and peripheral shape of the design surface. Therefore, it usually comprises two surfaces, including a surface with a step difference of 0 mm from the design

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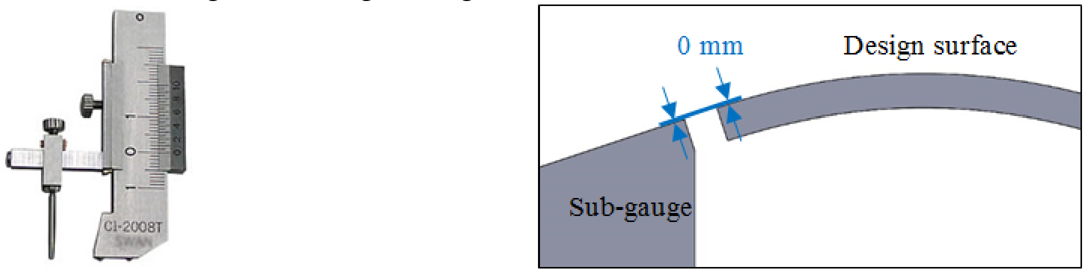
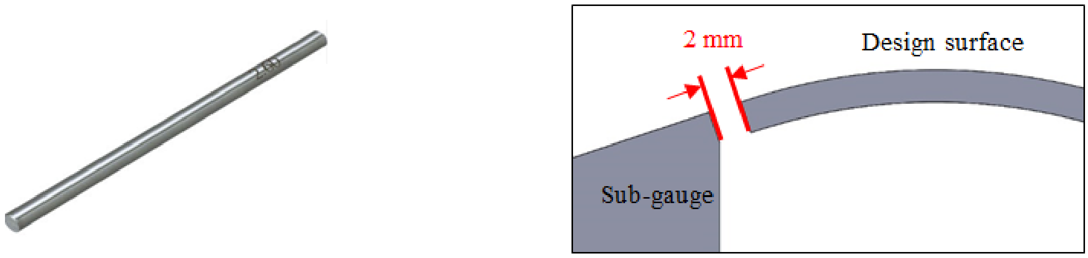
surface and a surface with a gap of 2 mm from the design surface. In this report, the former is called the step surface and the latter is known as the gap surface. The step surface extends the design surface tangent along the perimeter. The gap surface is 2 mm offset to the side surface, which is adjacent to the design surface. The sub-gauge is designed as a solid with these two surfaces.



(a) (b)

Figure 1. Measurement of step on the design surface [7].



(a) (b)

Figure 2. Measurement of gap on the design surface [8].

III. Automatic Design System for Inspection Jig

A. Overview

The proposed system was built by SolidWorks API based on the design knowledge of skilled designers and the methods followed by them. The system inputs the 3D CAD model of the product and outputs the 3D CAD model of the inspection jig. Currently, only automatic design of sub-gauges is supported.

Before executing the system, it is necessary to add surface information to the 3D CAD model of the input product. As shown in Fig. 3, the surface information correspond to the design surface, fillet surface, and side surface are provided. The design surface is the surface to be inspected, and the fillet surface is the surface that is rounded and chamfered, and the side surface is the surface adjacent to the design surface via the fillet surface. This surface information is provided by specifying the surface name.

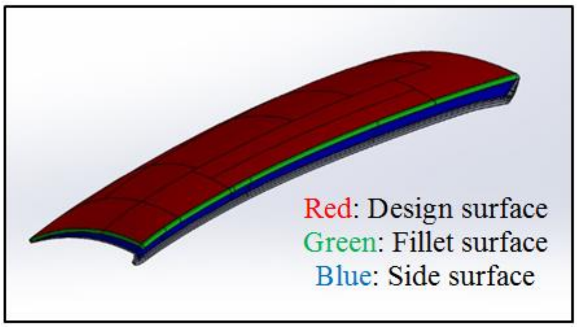


Figure 3. Types of surface information.

Furthermore, the values of the following four parameters related to the automatic design of the sub-gauge are specified: (a) step, (b) gap, (c) construction direction, and (d) bottom coordinates. Sub-gauges are automatically designed according to these design parameters.

B. Create a Step Surface

The step surface is defined as the one that extends the design surface tangent along the perimeter. In the proposed system, the straight lines that will form the section of the stepped surface later are created at equal intervals, and the step surface is created by creating a loft surface from them. Specifically, the following process is performed:

(1) Define planes orthogonal to the perimeter of the design surface at equal intervals, and create a line of intersection between the planes and design surface.

(2) Create a straight line, which the direction vector is the tangent vector of the intersection line created in (1).

(3) Create a loft surface, for which the section is the straight line created in (2), and create an offset surface according to the "step" parameter.

Fig. 4 shows the creation principle of the straight line.

C. Create a Gap Surface

After creating the step surface, create the gap surface. In the proposed system, the gap surface is created by offsetting the side surface by a fixed width. Specifically, the following process is performed:

(1) Untrim the side surface, and create an offset surface according to the "gap" parameter.

(2) Linearly extend the offset surface created in (1), and create a line of intersection with the step surface.
(3) *The* unnecessary part of the gap surface is trimmed using the intersection line created in (2).

As mentioned in (3), trim the gap surface so that its width becomes 10 mm. This width is considered for the inspection process. Fig. 5 shows an example of the aforementioned process of creating a step surface and a gap surface. Fig. 5(a) shows a 3D CAD model corresponding to this process, and Fig. 5(b) shows the A-A cross section demonstrated in Fig. 5(a).

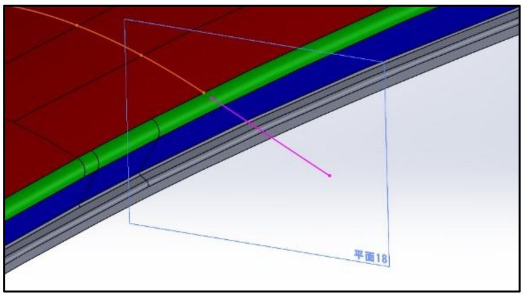
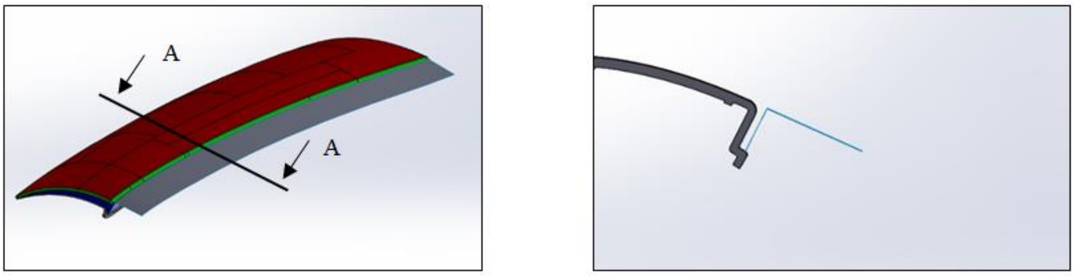
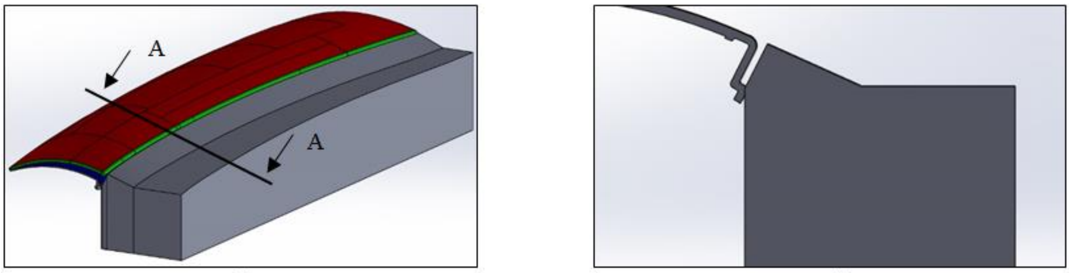


Figure 4. Creation of a section line.



(a) (b)

Figure 5. Creation of a step surface and a gap surface.



(a) (b)

Figure 6. Construction of a sub-gauge model.

D. Construction of the Sub-gauge Model

A sub-gauge model is constructed based on the step surface and gap surface. In the proposed system, a solid is created by pushing out the step and gap surfaces in the coordinate axis direction. The following process is

performed to achieve the construction of the sub-gauge model:

(1) Create a solid by extruding the step and gap surfaces according to the "construction direction" parameter and "bottom coordinate" parameter.
(2) Extrude the solid created in (1) in the direction orthogonal to the "construction direction" parameter.

The process defined in (2) is performed to deliver sufficient strength to the sub-gauge. Fig. 6 shows an example of constructing the sub-gauge with the aforementioned process. Fig. 6(a) shows a 3D CAD model of this process, and Fig. 6(b) shows the A-A cross section demonstrated in Fig. 6(a). At this stage, there may be some interference present between the product and sub-gauge. Therefore, in the proposed system, after constructing the sub-gauge, interference judgment is performed to determine if interference is present. If the existence of an interference is confirmed, the process of interference cancellation is performed, as described in the next section.

E. Interference Cancellation

If there is an interference between the product and sub-gauge, it is necessary to cancel the interference. In the proposed system, interference cancellation is realized by the subtraction of solids. Specifically, the following process is performed to achieve the interference cancellation:

(1) The step surface is offset by 7 mm, and a line of intersection with the gap surface is created.
(2) Using the intersection line created in (1), trim the offset surface so that its width is 10 mm.
(3) Extrude the surface created in (2) according to the "construction direction" parameter to create a solid.
(4) Subtract the solid created in (3) from the sub-gauge model.
(5) Interference judgment is performed again, and the width mentioned in (2) is extended by 2 mm until the interference cancellation process is completed.

The 7 mm offset width mentioned in (2) is the minimum required length for performing the inspection process. By repeating the process mentioned in (5), it is possible to reliably cancel the interference between the product and sub-gauge. Fig. 7 shows an example of performing the aforementioned process and cancelling the processing and cancelling the interference. Fig. 7(a) shows a 3D CAD model of this process, and Fig. 7(b) shows the A-A cross section demonstrated in Fig. 7(a).

F. Execution of the Proposed System

A 3D CAD model of automobile lamp parts is input to the proposed system, and a 3D CAD model of sub-gauges is constructed. The execution results are shown in Fig. 8. Fig. 8(a) shows the input CAD model, and Fig. 8(b) shows the output CAD model. Fig. 8(c) shows A-A cross section demonstrated in Fig. 8(b). From this figure, it is confirmed that the sub-gauges are constructed with the step and gap surfaces, and interference cancellation is appropriately performed, Therefore, the effectiveness of the proposed system is evaluated.

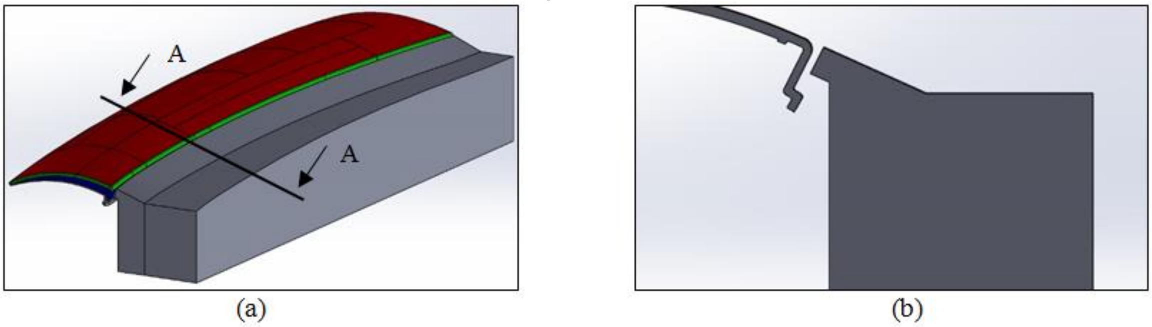


Figure 7. Interference cancellation process.

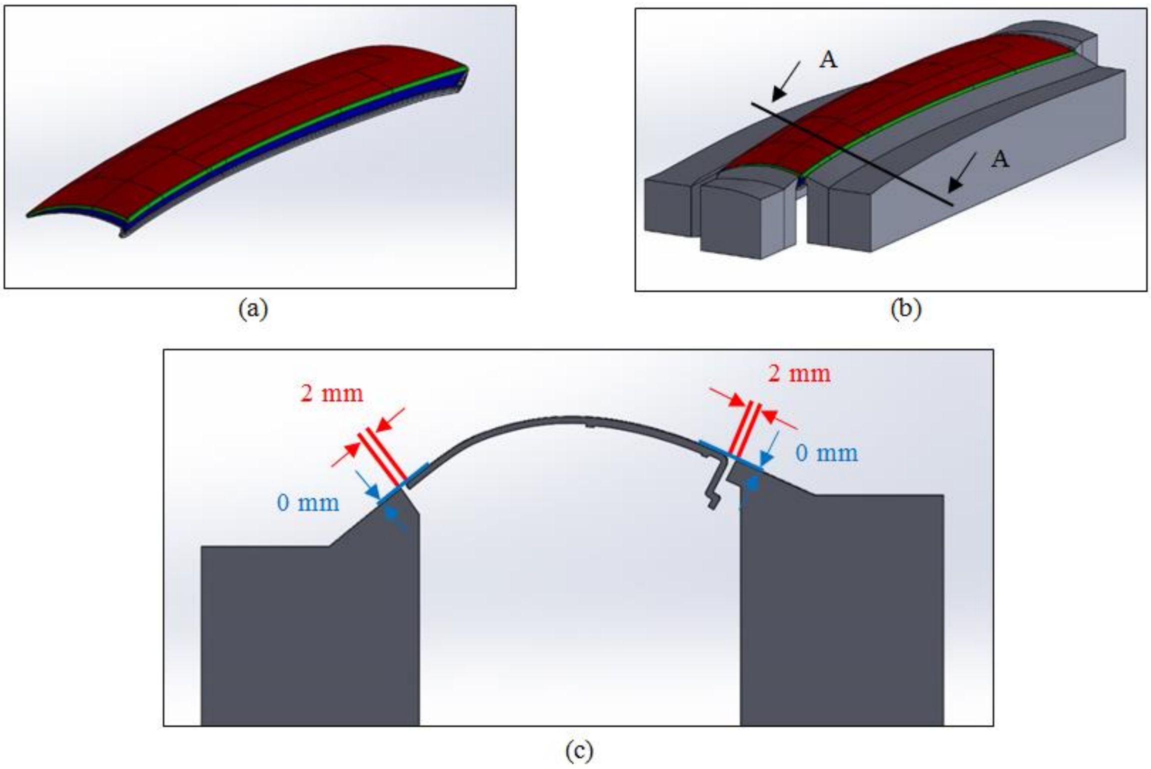


Figure 8. Execution results of the proposed system.

IV. Conclusion

In this research, to improve the efficiency of the inspection jig design, we proposed an automatic design system for the inspection jig, and the following results were obtained.

(1) The sub-gauge model was constructed using the intersection of the design surface and planes that were created at equal intervals on the perimeter of the design surface.

(2) For the interference existing between the constructed sub-gauge and product models, the interference cancellation process was performed by the subtraction of solid.

(3) The proposed system was executed, and its effectiveness was evaluated and confirmed.

Future research is to design automatically for inspection jigs of automobile lamp parts of various shapes.

References

[1] K. Asahina, "How to use 3D-CAD practice," *Japan Society for Design Engineering*, pp. 191-193, 2006.

[2] H. Aoyama, "State of the art and future trend of 3D-CAD/CAM" *Journal of the Japan Society for Precision Engineering*, vol. 81, no. 3, pp. 206-210, 2015.
[3] L. Yadong and P. Gu, "Inspection of free-form shaped parts," *Robotics and Computer-Integrated Manufacturing*, vol. 21, no. 4-5, pp. 421-430, 2005.
[4] Y. Sato, "Jig application techniques in the IT age," *The Nikkan Kogyo Shinbun*, pp. 23-29, 2000.
[5] V. Sabri, S, Tahan, X. T. Pham, D. Moreau, and S. Galibois, "Fixtureless profile inspection of non-rigid parts using the numerical inspection fixture with improved definition of displacement boundary conditions," *The International Journal of Advanced Manufacturing Technology*, vol. 82, no. 5-8, pp. 1343-1352, 2016.
[6] Y. Shimizu, "The technique generating curves with monotonous curvatures for aesthetic surface creation," *Unisys Technology Review*, vol. 21, no. 3, pp. 423-442, 2001.
[7] Factory Tool.com. [Online]. Available: http://factory-tool.com/shopdetail/004000000008/
[8] Monotaro.com. [Online]. Available: https://www.monotaro.com/g/00210399/

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