한국기계가공학회지, 제15권, 제2호, pp.22～30(2016.4) ISSN 1598-6721(Print)
Journal of the Korean Society of Manufacturing Process Engineers, Vol.15 No.2, pp.22~30(2016.4) ISSN 2288-0771(Online)

http://dx.doi.org/10.14775/ksmpe.2016.15.2.022

Study on the Manufacturing Technology of 2-Cavity Fine Blanking Seat Recliner Die with Minute Module of Accurate Gear

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초정밀 Gear 미세 모듈율을 가진 2 Cavity 파인 블랭킹 시트 리클라이너 금형 제조기술에 관한 연구

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(Received 30 June 2015; received in revised form 2 September 2015; accepted 8 January 2016)

ABSTRACT

It is very important to obtain the net shape of the product to maximize the shear cutting surface of fine blanking. In this paper, the fine blanking die was manufactured to achieve part characteristics, such as flatness and a fully sheared surface. The V-ring in the fine blanking die was designed to prevent lateral movement of the material. The fine blanking experiment was conducted with the fine blanking die. The material usage rate was increased by over 5.7% and that of the water-soluble lubricant was decreased by over 33% when the 2-cavity die technology was applied to fine blanking. The capacity of the existing press could lead to productivity improvement and cost reduction. Thus, 2-cavity die technology for fine blanking with a minute module of an accurate gear for producing seat recliner parts was developed.

Keywords : Fine Blanking(파인 블랭킹), Accurate Gear(초정밀 기어), Manufacturing Technology(제조기술), Minute Module(미세 모듈율), Seat Recliner(시트 리클라이너)

1. Introduction

The fine blanking process is a type of press processing for sufficient precision and fine shear surfaces to secure the required thickness of products in a blanking process. A common blanking process involves various defective factors such as burr, fracture surface, scratch, dent, etc. To prevent these from occurring, a fine blanking process is adopted. The fine blanking process involves the following steps: workpiece materials are pressurized by means of strippers, V-shaped tension plates around a punch; station pressure is applied by the counter punch, a station pressure plate under the punch; and as compressive stress is applied to the punch and die materials of clearance part, breaking-off due to crack is prevented through shear separation. In other words,

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materials are pressurized by tension plates around a punch while materials under the punch are pressurized by means of station pressure plates. This is a way of shear separation with materials of the shear deformation part in a condition of compressive stress and with no crack occurring.

A common blanking process involves burrs and fracture surfaces due to board shearing [1]. In general, clearance is limited to 10% of the material thickness to keep the occurrence of burrs in the proper level. Methods to minimize burrs include shaving processing, chambering processing, cutting or grinding through mechanical processing, etc. Since two or more processing steps are involved, the manufacturing costs inevitably increase. The fine blanking process is to address such problems.

Common blanking or trimming works have limitations in that shearing is partial and a large portion of the shear surface becomes rough and rupturing. In contrast, fine blanking utilizes various forms of projections around materials to apply compressive stress. As a result, the image of a general shear surface is clear and the thickness is even. Besides, precise parts are produced in a single process and thus a large amount of costs are saved. To apply this fine blanking process, researches have been conducted on the effect of machining factors [2], change in the size of die rolls [3], effect on the height of die rolls [4], change in shear surface size [5], effect of the die gap on a shear surface [6], and bridge minimization [7].

A automotive seat recliner helps passengers adjust the angle between the back frame and seat.

Once the adjustment is completed, it functions to fix the back frame to the seat. Besides, a recliner is closely linked to vehicle stability, fine blanking produces that secure accurate processing are commonly utilized. This study aims to develop 2 cavity fine blanking die technology in application of a seat recliner, which is a automotive backrest angle adjuster, to an accurate gear minute module.

2. Material Property Test

2.1 Tensile test

The material used in the test was SCM415H as thick as 4mm, and the tension test specimens went through the wire cutting process in the direction of rolling. In the tension test, the speed of a cross head was kept constant by means of a universal material tester, and tension continued being applied up to the point of breaking. The mechanical properties of resulting SCM415H are presented below. Fig. 1 shows the image of specimens used in the tension test. Table 1 shows the tension test results of SCM415H materials. The yield strength was 344.4MPa, the tensile strength 477.6MPa, and the elongation at break 31.4% on average respectively [8].

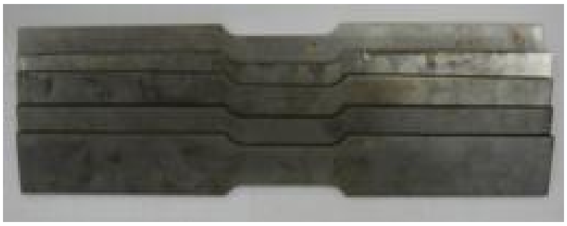

Fig. 1 Tensile test specimen(SCM415H)

Table 1 Mechanical properties of SCM415H(4t)

Direction		Yield strength [MPa]	Tensile strength [MPa]	Elongation [%]
0°	1	363	483	31
	2	357	486	31
	3	345	475	31
	4	320	485	31
	5	337	459	33
Average		344.4	477.6	31.4

3. Fine Blanking Forming Analysis

3.1 Forming analysis model

As for blank material properties in the forming analysis, the data acquired from the tensile test was referred. Table 2 shows forming analysis conditions, and Fig. 2 shows the forming mechanism of fine blanking dies. ① and ⑫ function to activate pressure pins by using insert rings. ② is a punch holder, ③ a stripper, ④ the main punch, ⑤ an ejector pin, ⑥ and ⑩ pressure pins, ⑦ a die, ⑧ a pad, ⑨ a piercing punch, and ⑪ the backing plate respectively. The friction coefficient between a die and materials was set to 0.05 on the assumption that water-soluble processing oil (lubrication oil) would be applied.

Fig. 3 shows a fine blanking product of a seat recliner with minute module of accurate gear. Fig. 4 shows the die moving up/down directions of a seat recliner. A fine blanking process involves the dedicated triple actions – shear force, V-Ring force, and counter force – and differentiates the forming steps from those of common blanking processes. As for the forming analysis of fine blanking dies, press die conditions and material properties were entered by means of Simufact Forming S/W. Since this fine blanking product was of symmetry, a 1/2 model was selected as an interpretation object.

Table 2 Simulation conditions

Plastic material	SCM415
Rigid die	STD11
Friction coefficient	0.05
Material thickness	4mm
Stamping velocity	25SPM
Blank holding force[tons]	Blanking force : 259.8 V-Ring force : 36.6 Counter force : 98.0

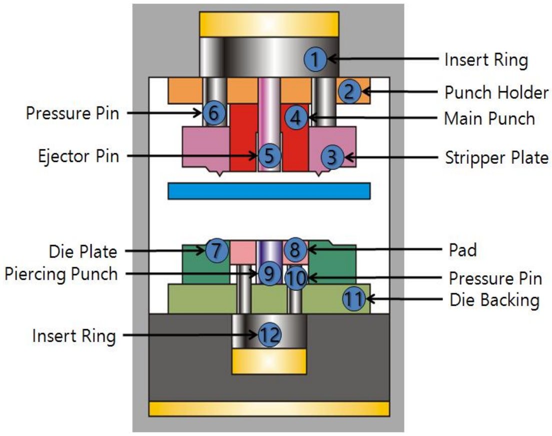

Fig. 2 Mechanism of fine blanking dies

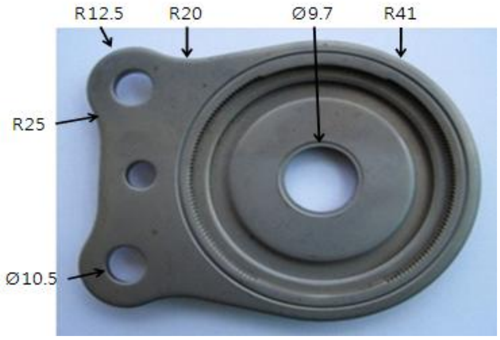

Fig. 3 Fine blanking product

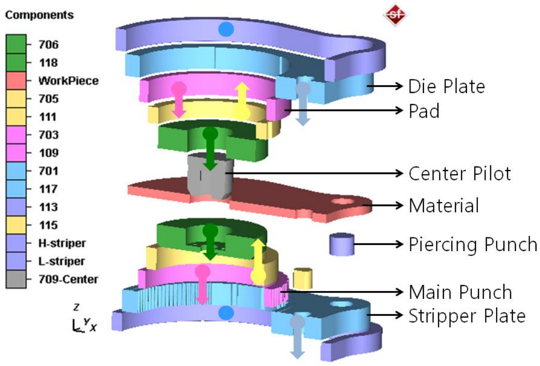

Fig. 4 Moving direction of a fine blanking die

3.2 Results of the fine blanking forming analysis

Fig. 5 shows the result of the 3D forming analysis of fine blanking dies to which an accurate gear was applied. As shown in the figure, the effective stress was high at the gear forming part, and as shown in Figure 6, the temperature was also high at the gear forming part. This is because the forming of a minute module gear required significant shear force and thus the gear forming part involved a high level of effective stress and temperature.

Sheet forming analysis S/W was utilized for the 2D forming analysis of fine blanking shear dies for the modeling of each die part. The general die modeling was conducted in the order of the designed mechanism. Fig. 7 and Fig. 8 show the distribution of yield stress and temperature around the material shear part before and after the forming process. The result of the 2D forming analysis of fine blanking shear dies shows that the yield stress and temperature were high around the material shear part before and after the forming process.

As workpiece materials (thickness: 4mm) were processed in the fine blanking die, the process required high surface pressure and thus the temperature increased up to 70℃. Hence, as shown in the result of forming analysis in the fine blanking die to which an accurate gear of minute module was applied, concentrated stress was applied

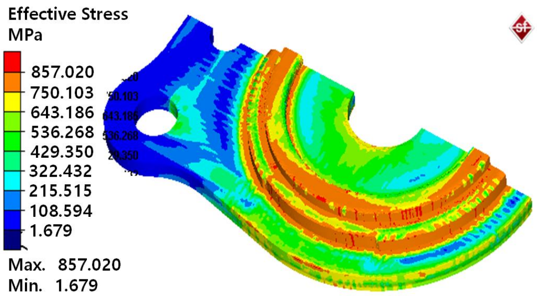

Fig. 5 Numerical simulation results of fine blanking for a seat recliner(effective stress)

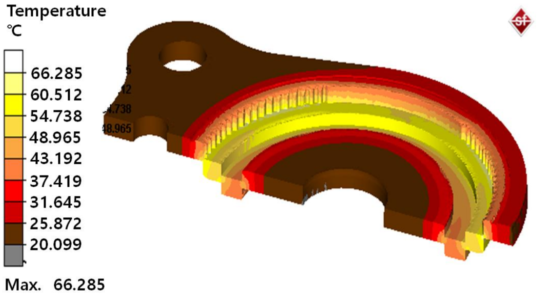

Fig. 6 Numerical simulation results of fine blanking for a seat recliner(temperature)

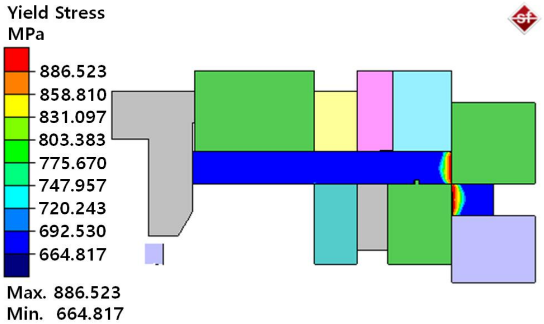

Fig. 7 Numerical simulation results of fine blanking for seat recliner(yield stress)

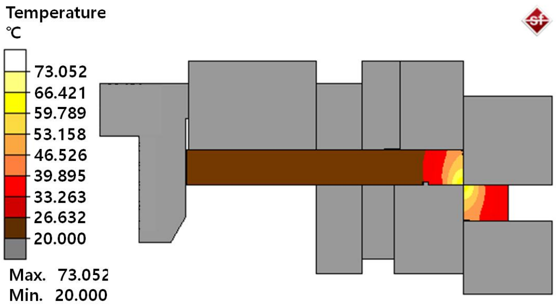

Fig. 8 Numerical simulation results of fine blanking for seat recliner(temperature)

to the gear forming part, which increased the effective stress and temperature. However, since fine blanking oil (water-soluble processing oil) continued to be supplied for lubrication, the cooling effect decreased the temperature and alleviated effective stress [9].

4. Fine Blanking Die Test Results and Investigation

4.1 Fine blanking die design and production

The structure of a fine blanking die is more complicated than that of common presses, and the mechanical processing of die parts requires precise as high as ±0.005mm. In particular, die insert parts require a high level of precision for wire processing, and thus a precise wire processing unit needs to be utilized. A high-precision fine blanking die requires a press dedicated for fine blanking that can deliver three different types of pressure simultaneously or each at a time, as required, in addition to the force necessary for thick plate shearing. In the fine blanking shear process, force in three axes is applied and the clearance of dies and punches are kept within 0.5% of the material thickness. The shear surface is as much as at least 95%. Fine blanking also requires fine blanking oil for lubrication depending on the materials. In other words, a plastic flow of materials on the product's shear surface results in a good-looking shear machined surface. Without lubrication, cold welding disturbs forming a good-looking shear surface and it is difficult to secure precise measurements. Furthermore, the punch and die are overloaded, which leads to pressure and temperature increase and excessive abrasion. As a result, the die lifespan is shortened and the quality deteriorates. In comparison with existing that of 1 Cavity, the progressive die technology of 2 Cavity contributed to saving water-soluble processing oil as much as 33% and improving the material utilization as much as 5.7%. In addition, as the production capacity of existing facilities was doubled, productivity was improved with expenses reduced.

To fix materials tightly in a fine blanking die, a guide plate with a v-ring is used to make a v-shaped groove along the shear outline. Thus, there is no lateral movement of materials upon shearing, and materials are sheared rather almost in a pure flow. Since the ejector at the bottom of a punch supports a product to be shorn with materials clamped, the resulting measurement and shear surface are satisfactory. If a measure of v-ring force is applied to materials prior to shear force during the material clamping, the die is opened and ejects a product. The force (F) required for fine blanking is the sum of shear force (F_S), V-Ring force (F_S), and counterforce (F_G). The fine blanking force 'F' is about 394.4 ton, which secures at least 30% of safety ratio. In this study, selected was a 700 ton fine blanking press.

$$F = (F_S + F_S + F_G) \times 2 \text{ (Cavity)}$$
$$= (129.9 + 18.3 + 49) \times 2 \text{ (Cavity)}$$
$$= 394.4 \text{ ton}$$

To form a minute module gear of automotive seat recliner parts, a fine blanking die was designed as a type of progressive die. To design a optimal layout and minimize the use of materials, the width was set to 174mm and the pitch 105mm respectively. Fig. 9 shows strip layout sketch of 2 cavity seat recliner. Strip layout design is an important step in the planning stage of sheet metal work on progressive die. The quality of 2 cavity strip layout is highly dependent on the knowledge and skill of die designers to improve material economy. In consideration of the balance to the press pressure, attention was paid to preventing eccentric load. The die was designed to exchange die parts promptly for high productivity and easy die maintenance. As for fine blanking die materials, alloy steel CPMM4 materials were chosen for the main punch and gear punch in consideration of the high surface pressure applied to workpiece materials. SKH51 was chosen

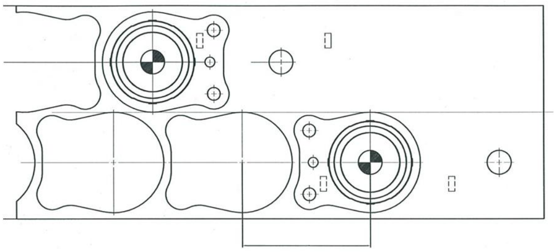

Fig. 9 Strip layout sketch of 2 cavity seat recliner

Fig. 10 Die assembly of a seat recliner

for die insert parts. For other parts, alloy tool steel STD11 was chosen. Fig. 10 shows the die assembly of the upper die and the lower die.

4.2 Fine blanking die test

In short, fine blanking technology is a combination of die technology and mass production technology. To determine the optimal layout in reference to a product drawing, the following factors need to be taken into account: Whether a compound die would be realizable, whether the progressive die engineering would be advantageous, raw material loss minimization, punch strength, die strength, estimated lifespan of the die, convenience of maintenance, minimization of imbalance, safe product ejecting, mass productivity, and cost reduction.

Mass production technology needs to optimize the maintenance condition of presses and dies. As for worker performance, the ability to cope with changes in working environments promptly is required for each item. In addition, it also needs to be possible to repair a defective die promptly in the given onsite condition. Since fine blanking presses and dies require a large amount of investment, it is the best way for each company to improve its unique technical power.

Fig. 11 shows a gear forming part of seat recliner parts, and Fig. 12 a strip layout. Fine blanking products are widely used for functional parts of vehicles and also for such areas as common mechanical elements where both product precision and high quality of the shear surface are required. In this study, designed and produced is 2 Cavity fine blanking die that can make two products simultaneously through a single press process of automotive seat recliner parts. Fig. 13 shows a seat recliner’s gear OD measurement appearance of parts, and Fig. 14 shows measurements of a shear surface. Since the 2 Cavity fine blanking process involved measurement reduction of the gear part, the test was repeated to examine the range of contraction. The gear punch was then re-processed in reflection of the range. Since the seat recliner product was not fully symmetric in the 2 Cavity fine blanking process, the production involved eccentricity and deformation of the inner diameter into an oval. The corrected punch was re-processed to make the final product.

Table 3 shows the measurement results of the seat recliner products and Table 4 shows the measurement results of gear diameter of the seat recliner products. A 3D precise measuring device was utilized, and the measurement tolerance is as follows: diameter 0.04mm, flatness 0.032mm, and

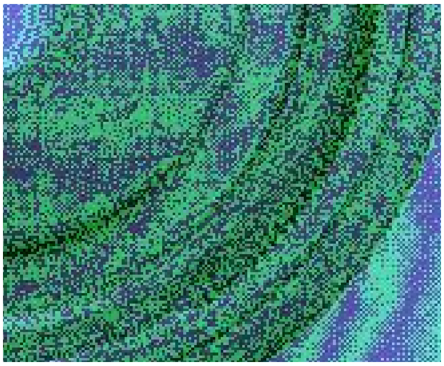

Fig. 11 Sector tooth of a seat recliner

Fig. 12 Strip layout of a 2 cavity seat recliner

concentricity 0.039mm. Thus, the condition for dimensional accuracy was satisfied. When the shear surface was measured by means of a tool microscope, the measurement was 98%. The module of the automotive seat recliner part used in this study was 0.22 and the material thickness 4mm. 2 Cavity tooth sector was produced as a type of fine blanking progressive die. The shear surface and quality of the product were proved to be satisfactory.

5. Conclusion

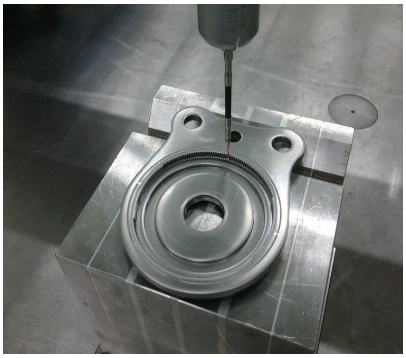

Fig. 13 Gear diameter measurement of the seat recliner product

Fig. 14 Sheared surface measurement of the seat recliner product

Table 3 Measurement results of seat recliner products

Classification	Dimensional tolerance	Measurement data
Gear diameter[mm]	0~0.05	0.04
Flatness[mm]	0.2	0.032
Concentricity[mm]	0~0.05	0.039
Sheared surface[%]	Over 95	98

Table 4 Gear diameter measurement results of seat recliner products

Classification	Gear diameter [mm]	Measurement tolerance [mm]
1	67.610	0.040
2	67.586	0.014
3	67.595	0.025

This study is to develop 2 Cavity fine blanking die technology in application of an accurate gear for parts of a recliner, a automotive backrest angle adjustor. In application of the forming analysis technology applied to the major processes including initial die design and production, 2 Cavity fine blanking die technology was successfully developed. The results of this study may be summarized as follows:

(1) Automotive seat recliner parts require complex processes for the precise forming of tooth shapes, forming images, etc. 2 Cavity fine blanking progressive die was utilized to produce a sector tooth of module 0.22 and material thickness 4mm. It was able to get a clean shear surface and premium products with productivity improvement and cost-savings.

(2) A prototype of 2 Cavity fine blanking die was produced in application of the accurate gear of minute module, and it was measured by means of a 3D precise measuring device. As a result, the allowance of the gear diameter was 0.04mm, flatness 0.032mm, and concentricity 0.039mm respectively, which all met the precision requirements.

(3) As a result of measuring the shear surface of the automotive seat recliner product, it turned out that the shear surface was as much as 98%, that the need for gear cutting was removed in the manufacturing process, that material utilization was enhanced, and that water-soluble processing oil was saved as much as 30%. This result demonstrates the possibility of wide distribution of this eco-friendly technology.

(4) As 2 Cavity fine blanking die technology for accurate minute module gear parts was successfully developed, the production capacity in utilization of existing devices was improved.

References

1. Bahn, G. S., Suh, E. K., Lee, G. H. and Mo, C. K., "A Study on the Characteristics for the Blanking of Lead Frame with the Nickel Alloy42," Transactions of the Korean Society of Manufacturing Technology Engineers, Vol. 13, No. 6, pp. 87-93, 2004.
2. Han, K. T., "A Study on the Forming of Parts for Automobile using Fine Blanking Process," Journal of the Korean Society of Machine Tool Engineers, Vol. 8, No. 2, pp. 56-61, 1999.
3. Kim, J. D. and Kim, H. K., "A Study on the Change of Die Roll Size by the Shape of Die Chamfer in Fine Blanking Die for Automobile Door Latch," Journal of the Korea Academia-Industrial Cooperation Society, Vol. 12, No. 2, pp. 565-570, 2011.
4. Kim, J. D., "An Experimental Study on the Effect of V-ring Position and Die Chamfer Shape on the Die Roll Height in Fine Blanking Tool," Journal of the Korea Academia-Industrial Cooperation Society, Vol. 13, No. 5, pp. 2009-2014, 2012.
5. Lee, C. K. and Kim, Y C., "A Study on the share Surface Size Deformation of Fine Blanking Process," Journal of the Korea Academia-Industrial Cooperation Society, Vol. 14, No. 8, pp. 3650-3655, 2013.
6. Kwak, T. S., Kim, Y. J. and Bae, W. B., "Finite Element Analysis on Effect of Die Clearance on Shear Planes in Fine Blanking," Journal of Materials Processing Technology, Vol. 130, pp.

462-468. 2002.
7. Kim, G. T., "A Study on Edge Bridge Minimization of Fine Blanking Process," Journal of the Korean Society of Manufacturing Process Engineers, Vol. 12, No. 4, pp. 108-113, 2013.
8. Park, D. H. and Kwon, H. H., "Development of the Compound Die Forming Technology United between Semi-Progressive and Transfer Die," Journal of the Korean Society of Manufacturing Process Engineers, Vol. 14, No. 4, pp. 126-133, 2015.
9. Yoon, I. C., Ko, T. J., Lee, C., Kim, H. S. and Park, D. H., "Small Electrode Ring Forming by Multi-Forming Process," Journal of the Korean Society of Manufacturing Process Engineers, Vol. 8, No. 3, pp. 38-45, 2009.