한국생산제조시스템학회지 Vol.20 No.1 2011. 2. pp. 67~73
Korean Society of Manufacturing Technology Engineers

A Study on the Manufacturing Technology of a Folding Blind Rivet

Hong-Seok Byun*, Young-Ho Kim+
(논문접수일 2010. 7. 7, 심사완료일 2010. 11. 5)

폴딩 블라인드 리벳의 제조기술에 관한 연구

변홍석*, 김영호+

Abstract

In this study, the manufacturing technology of a folding blind rivet was developed through finite element analysis(FEA). Numerical simulations of the folding blind rivet used to join two components have been performed with the finite element method for the forging process design. To minimize the process and manufacture the folding blind rivet without defects, a variety of design rules were proposed. From the results of FEA applied process design rules, an optimal six-stage process was proposed. The finite element simulation results such as shape of the forged rivet, strain distribution and forging load were investigated for the usefulness of the forging process of the blind rivet. In addition, the experiments have been implemented and their results were compared to the analytic results.

Key Words : Folding Blind Rivet(폴딩 블라인드 리벳), Finite Element Analysis(유한요소해석), Forging(단조), Process Design(공정설계)

1. Introduction

Recently, a rivet, a cylindrical piece of steel or aluminium with a forged head, that is used to fasten components on the section area of complex body has been widely used in a motor vehicle industry. Especially, it has contributed to cost reduction in production in the industry and has been spread in home appliance, furniture and housing and so on.

Nowadays, a rivet is substituted for welding to join aluminium, high tension steel and plastic used to decrease the weight of car body.

In particular, a folding blind rivet that is able to fasten plastic(or metal) to metal easily was used heavily in the construction of a car although it approaches only one side of the materials being joined.

It consists of two parts - the rivet body and, the setting mandrel within it. It works as follows.

- The rivet body is inserted in a hole in the materials to be joined.
- The tool(riveting machine) is actuated and the jaws of the power operated or manual rivet tool grips the mandrel of the rivet.

* Corresponding author, School of Mechanical Engineering, Ulsan College (hsbyun@uc.ac.kr)
Address: 148 Daehak-ro, Nam-gu, Ulsan, Korea, 680-749
\+ School of Mechanical Engineering, Pusan National University

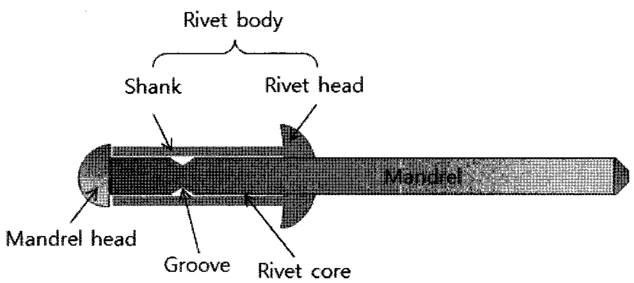


Fig. 1 Folding blind rivet

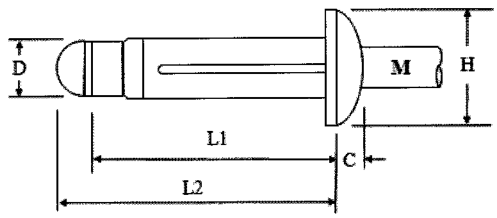
- The rivet is set by pulling the mandrel head into the rivet body, expanding it, and forming a strong, tight, reliable joint. At a predetermined setting force, the mandrel breaks and falls away.

The folding blind rivet has several advantages over other fastening methods. First, rivets are inexpensive. They can also be easy to assemble. The joined rivets don't work loose by the vibration since their joining area is large and they are strong, they can be used durably. Also, rivets can join many kinds of materials of different thicknesses. Especially, the riveting time is very short because the tool works on one side of material.

We have depended on metal forming expert's knowledge in manufacturing precision parts such as the folding blind rivet. However, there is the limit to design them through trial and error in order to reduce development time since the die is very expensive[1].

The aim of this study is to develop the manufacturing technology of the folding blind rivet with three legs which joins two separate materials strongly and resists the vibration well(Fig. 1). To achieve it, rigid-plastic FEM simulation is used to decrease the time required to the development of the rivet and reduce cost caused by trial and error.

Numerical simulations are performed based on the proposed design rules. They show the deformation, effective strain distribution and forging loads for each process. Finally, six processes are proposed. In addition, the experiments are performed and their results are compared to analytic results. The results demonstrate the validation of numerical simulation for the forging process design of the folding blind rivet with FEM.



unit:mm

D	L1	L2	C	M	H
φ4.0	18.0	22.1	1.2	2.3	φ8.0

Fig. 2 Blind Rivet and its dimension

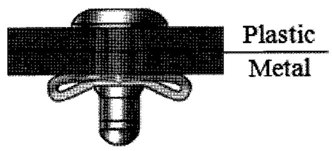


Fig. 3 Combined shape with plastic and metal

2. Forging process design

2.1 Shape of a folding blind rivet

A folding blind rivet can be used to join two materials easily on one side of the material in case of difficulty of access of the tool because its other side is narrow or there is an obstacle. A rivet consists of rivet body and mandrel. In general, rivet body is composed of shank and flange(rivet head).

Mandrel has a domed head and a groove to be fractured by predetermined setting load. It is also manufactured by upset forging, but its manufacturing process is simple.

This study deals with the manufacturing technology of rivet body that is more difficult to be fabricated than the mandrel.

Fig. 2 shows the folding blind rivet joined by the rivet body and the mandrel.

The folding blind rivet is made from aluminium, steel or stainless steel and used to join two materials such as steel and aluminium, or steel and plastic. Fig. 3 shows the deformed shape of the folding blind rivet joining metal and plastic.

2.2 Determination of initial length

The initial length(l) deformed to form the rivet head from initial billet is calculated from the volume constant[2,3]. Fig. 4 shows that the rivet head is formed by forging. The volume to be deformed will be equal to that of the final shape by

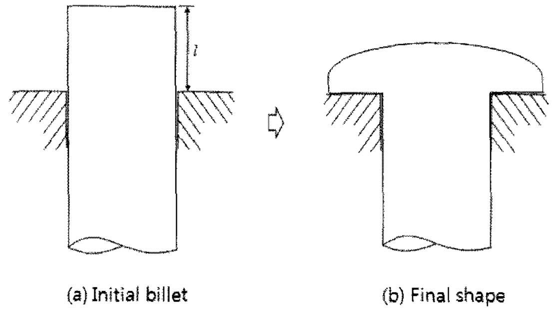


Fig. 4 Before and after deformation

the volume constant.

2.3 Process procedure and design rule

In this study, design rules for process design are proposed based on related works and researches, metal forming experts' experiences, plastic theory, etc(2~5) considering deformation, process parameters, die design and formability. Fig. 5 shows the process procedure of the folding blind rivet. Design rules are as follows.

(Rule 1) If the final product has a stepped shape, it is manufactured by sequential process and each process has a deformed area.

(Rule 2) If the process is required for the deformation of a product, it consists of a deformed shape and an undeformed shape.

(Rule 3) The dimension of preform in middle process is determined by volume constant.

(Rule 4) Initial shape of axisymmetrical product is wire rod.

(Rule 5) If solid strain(SS) of the smallest diameter for a solid product is bigger than limit solid trapped strainLSTS) 2×limit solid open strain(LSOS), the diameter should be decreased.

$SS = \ln(d_0^2/d_1^2)$

d_0 : diameter before deformation

d_1 : diameter after deformation

(Rule 6) Initial billet must be selected to satisfy the mechanical properties of the final product

(Rule 7) To manufacture the final product that has bigger diameter than initial billet, upsetting must be implemented

(Rule 8) upsetting and extrusion can not be done simultaneously.

(Rule 9) In upsetting, the distance between upper die and lower die is over 2.0mm.

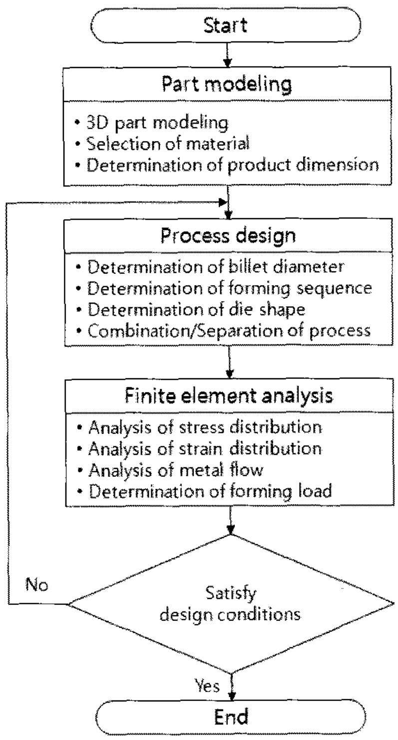


Fig. 5 A procedure of process design

(Rule 10) Upsetting length to diameter ratio(ULDR) must be smaller than limit upsetting length to diameter ratio(LULDR).

$ULDR = l_0/d_0$

(Rule 11) If initial billet is solid and the final product is hollow, upsetting is first and then extrusion is carried out.

(Rule 12) In case upsetting is fulfilled twice, a cone-shaped preform is made through first upsetting.

(Rule 13) When a hollow product is manufactured through extrusion, trapped dies are installed at the upper and the lower end of a product.

(Rule 14) If the upsetting ratio of length to diameter(l/d) for solid is smaller than 2.25, free upsetting is executed once.

(Rule 15) The diameter after upsetting is not 2.2 times larger than that before it.

(Rule 16) If extrusion ratio of the upper of a product is below 15%, forward extrusion and upsetting can be simultaneously carried out.

(Rule 17) Cylindrical upsetting and preliminary upsetting can not be combined.

(Rule 18) If the flow defect of the material and the damage of tool are predicted, a process should be added.

(Rule 19) The reasonable clearance between a die and a

Material	LSOS	LSTS	LULDR
Aluminum	0.287	3.912	1.8

punch is 3~10% of sheet thickness.

(Rule 20) LSOS, LSTS, and LULDR of aluminum are as follows.

2.4 Process design

2.4.1 Initial preform design

When the rivet head is manufactured through just one upsetting from initial billet, the folding defect at its lower end can take place as shown in Fig. 6. It is caused by the metal flow of the material, namely non-uniform grain flow.

To prevent it, a preform should be added. It can be created by using two stages process design method or multi-stages process design method. Two stages process design method in this study is utilized to remove the folding phenomena and minimize processes.

From the shape of material made from a given final die, the position of middle stage is selected. And the preform is designed through the modification of contact surface between the material and the die to deform its uniform shape at middle stage. Accordingly, one upsetting is divided into two upsettings and rule 7 is applied for this process.

2.4.2 Forging process design

The process of the rivet body forging is divided at the base of cold forging and design rules. Table 1 shows the applied rules according to the process. Fig. 7 shows the process sequences.

The first stage is to cut an initial billet considering the volume and the dimension of the final product as shown

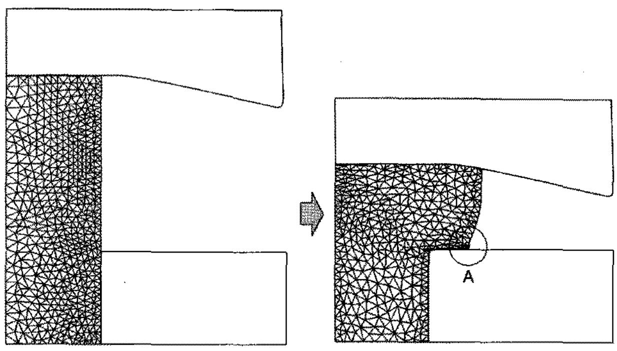


Fig. 6 A result of FEA without preform

process (a). The second process(b) is the early stage of the rivet body production and upsetting is implemented. The process(c) of the third stage is to manufacture the final rivet head. The process(d) of the fourth stage is to create the hollow to be inserted into a mandrel by backward extrusion. The fifth stage is the process(e) that creates a hole by piercing. The process(f) of the last stage is to create the shank with three legs by cutting.

3. Analysis

3.1 Rigid-plastic finite element analysis

DEFORM-3DTM, one of rigid-plastic finite element analysis tools, is used to analyze the forging process of the folding blind rivet.

The assumption for three-dimensional FEM simulation is as follows. (1) The friction on the punch and/or on the die

Table 1 The rules applied to each process for manufacturing the rivet body

Process	Applied rules
Billet Cutting	Rule 4, Rule 6
Upsetting	Rule 1, Rule 2, Rule 3, Rule 5, Rule 7, Rule 8, Rule 9, Rule 10, Rule 12, Rule 14, Rule 17, Rule 18
Head forming	Rule 2, Rule 5, Rule 8, Rule 9, Rule 10, Rule 11, Rule 13, Rule 14, Rule 15, Rule 16, Rule 18
Backward extrusion	Rule 2, Rule 5, Rule 8, Rule 11, Rule 13, Rule 18
Piercing	Rule 2, Rule 18, Rule 19
Shank cutting	Rule 2

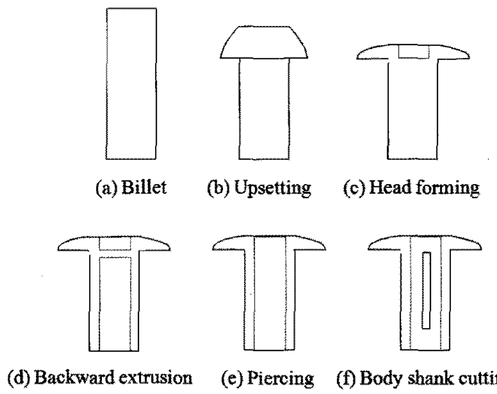


Fig. 7 Forging process sequence of a blind rivet body

is constant, (2) the die speed is the same for all processes, (3) the die is rigid and the elastic is ignored. The friction between the die surface and the material is regarded as constant shear friction, the friction factor is 0.12. Also, if the clearance between the die and material is smaller than 0.002mm, they are considered as each other. Since the rivet is axisymmetric, only a third of the rivet is analyzed. The material is Al5056.

3.2 Analytic results

3.2.1 Deformation and strain distribution

The folding blind rivet is manufactured through six processes. Fig. 8 shows the distribution of the effective strain for the folding blind rivet according to the deformed shape of each process.

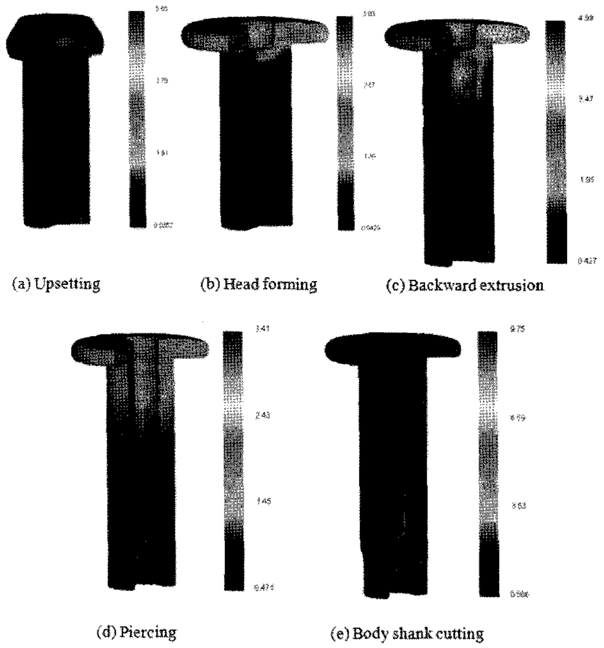


Fig. 8 Effective strain according to the stage

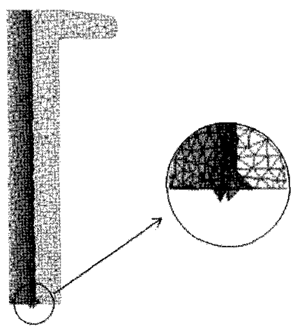


Fig. 9 Burr occurred in the end of shank

They don't include the folding defect caused by metal flow, crack or cold shut. The big effective strains at the rivet head, body, shank and the portion of three legs are shown.

Especially, it happens very much at upsetting that makes the rivet head. The reason is because the flow direction of material that is in touch with the upper die is perpendicular to that of a punch.

And, it is shown that the piercing of the rivet body makes the strain near thin web large considerably because it is cut. In case the hole of the rivet body is created by forward extrusion, burr can happen at the end of shank(Fig. 9)[3]. This causes the defective product. However, the piercing can remove a kind of defect.

3.2.2 Forging load

Forging load is one of the important factors that affect the manufacture of a product as well as the installation of equipment. The correct analytic results can help users save the money required to buy equipments and their installation cost, exact analysis and considerable judgment are required. Fig. 10~Fig. 14 show each of predicted forging loads

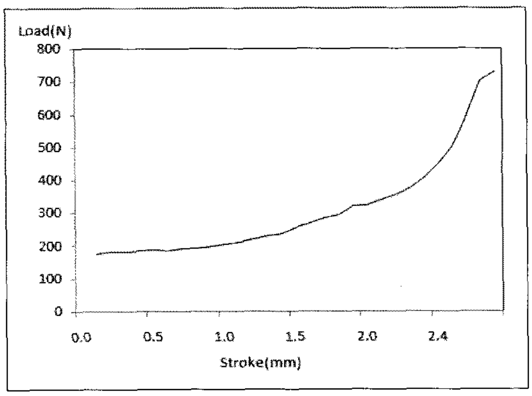


Fig. 10 Upsetting

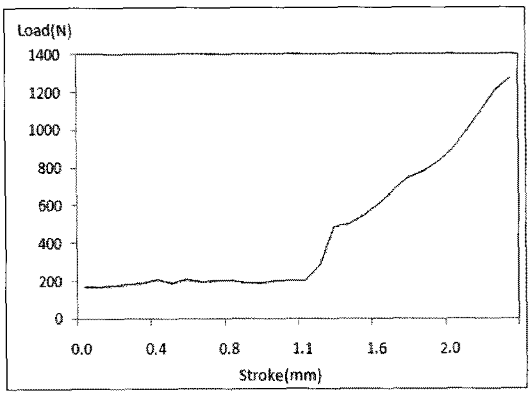


Fig. 11 Head forming

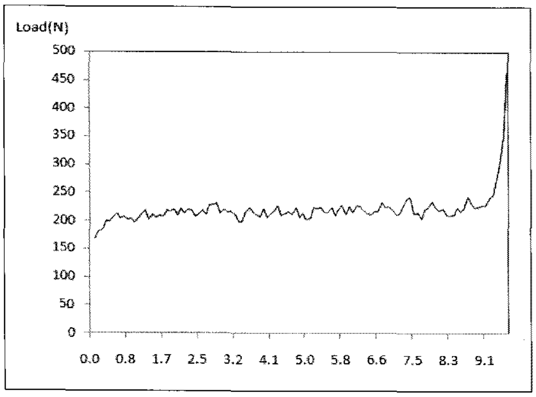


Fig. 12 Backward Extrusion

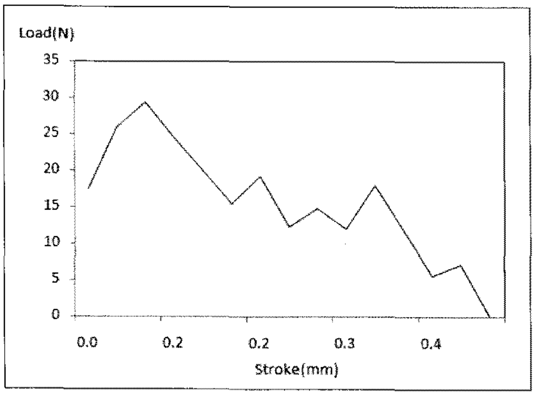


Fig. 13 Piercing

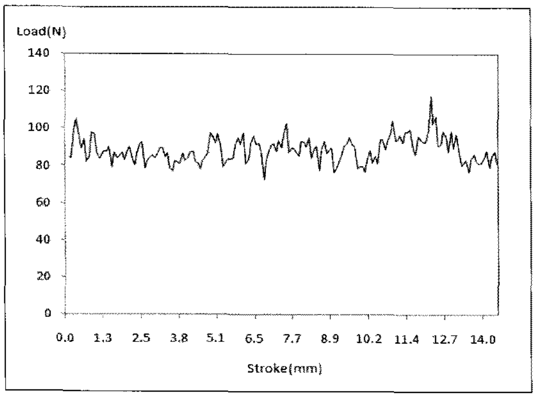


Fig. 14 Shank cutting

obtained by numerical simulations of FEM for the processes.

In manufacturing the rivet head, forging load is greatly changed according to reduction in area. It increases in proportion that the area of material that is in touch with the die increases. Also, it is proportional to deformation. Forging load increases rapidly with large deformation. The load doesn't vary largely according to the stroke in backward extrusion, but as thickness of web is thinner, forging load is bigger.

(a) Developed rivet

(b) Rivet combined with a mandrel

Fig. 15 A folding blind rivet developed by six-stage process

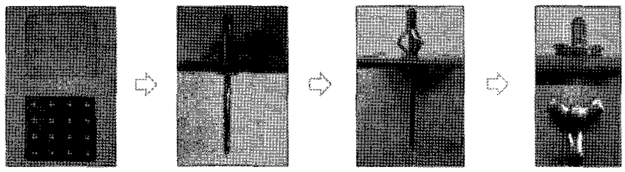


Fig. 16 Test joining two materials

4. Experiment

The experiment was implemented to compare and investigate the deformed shape for six processes simulated with FEM.

It was restricted to the examination of the deformation because it is difficult to construct instruments measuring forging load and punch movement due to the characteristic of the press.

The die of each process was manufactured and the experiment was carried out according to the proposed forging process that is created by finite element analysis and process design rules. Fig. 15 shows the folding blind rivet developed by forging process procedure.

Each of the deformed shapes for six stages was in agreement with those with simulation. And, the defects such as folding, crack and cold shut were not found.

Fig. 16 shows the test for joining two materials. It can be seen that the folding blind revet with three legs joins two separate material strongly.

5. Conclusions

The purpose of this study is to develop the manufacturing technology of the folding blind rivet with three legs which joins two separate materials strongly.

To do that, numerical simulations of the folding blind rivet used to join two components have been performed with the finite element method and the design rules were proposed for the forging process design.

From the analytic results, six processes to manufacture the folding blind rivet were proposed and the deformed shape, forging load and effective strain of each process were investigated and analyzed.

In addition, the experiments have been implemented to investigate the deformed shapes with FEM. Agreement between their shapes was good. The analytic results will be utilized as useful design data for the manufacturing of another rivet.

References

(1) Kim, Y. J., and Park, S. D., 2003, "Finite Element Analysis for Design of Closed Die Forging Process of a Bevel Gear", *Journal of the Korean Society of Manufacturing Process Engineers*, Vol. 2, No. 1, pp. 92~99.

(2) Park, C. W., 2009, "Finite Element Analysis and Process Planning about the auto Transmission Solenoid Valve using of Multi-Former", *Journal of the Korean Society of Marine Engineering*, Vol. 33, No. 1, pp. 97~103.

(3) Byun, H. S., 2009, "Finite Element Analysis for the Forging Process Design of a Blind Rivet", *Journal of the Korea Academia-Industrial Cooperation Society*, Vol. 10, No. 10, pp. 2577~2582.

(4) Park, C. W., Kang, J. H., Lee, J. H., Kim, C., Kim, M. S., and Choi, J. C., 2003, "A Study of Automated Process Planning and Die Design for Multi Former-Bolt Products", *Journal of the Korean Society of Precision Engineering*, Vol. 20, No. 4, pp. 29~38.

(5) Park, J. O., Lee, J. H., Jung, S. Y., Kim, C., and Kim, M. S., 2002, "An Automated Process Planning and Design System for Quasi-axisymmetric Cold Forging Product", *Journal of the Korean Society of Precision Engineering*, Vol. 1, No. 1, pp. 107~118.