工學碩士 學位 請求 論文

Effect of die dimensions on curvature extrusion of curved rectangular bar

指導敎授 金 允 海

2017年 07月

韓國海洋大學校 大學院

材 料 工 學 科

兪 政 吾

本 論文을 兪政吾의 工學碩士 學位

論文으로 認准함.

委員長 文慶萬 (인)

委 員 沈道植 (인)

委 員 金允海 (인)

2017年 07月

韓國海洋大學校 大學院

Contents

List of Tables

List of Figures

Effect of die dimensions on curvature extrusion of curved rectangular bar

Yu, jeong o

Department of Material Engineering

Graduate School of Korea Maritime and Ocean University

Abstract

The production of square bars with curvature requires additional processes such as bending press after extrusion, so the process is complex and uneconomical. Recently, many researches have been conducted to improve the production process of a curved square bar by using the cold extrusion method. However, these studies also had to build an additional process infrastructure such as the use of guide rolls, and they were limited in that the process could not be simplified based on a single platform. The curvature extrusion method proposed in this paper is a method to control the curvature by adjusting the shape of die to be extruded. Unlike the usual die shape, it creates a tilt angle on the die to induce a difference in speed between the upper and lower sides of the

extrudate by inducing the internal stress difference between the upper and lower sides of the billet to induce the curvature. This difference in internal stress is caused by the stress concentration effect occurring in the non-flow region near the edge of the die. In the past, the influence of the non-flow part was analyzed by the application of the upper bound method or the slab method, but the reliability tends to be lower because the material flow, stress and strain are not taken into consideration. Recently, finite element analysis has been applied to solve these problems. In order to use the curvature induction method by controlling the die shape, a systematic analysis process for the above effect was studied. The influence of non-flow region occurrence(DEAD METAL ZONE) was analyzed through Deform-3d analysis program. The billet is set as a tetrahedral element and the symmetry plane is set in the entire simulation model to save the computer memory and time required for the experiment. The friction coefficient condition was set to be Coulomb friction condition, and the same friction coefficient value was the same regardless of the area where the experiment was performed.

In the experiment, the simulation was performed under the tetrahedral element billet condition. Therefore, when there is no fillet of proper value in the extrusion design, the pull-out phenomenon is observed and the constituent elements of the non-flow region are erased. However, in the actual experiment, pull-out phenomenon was solved by giving a fillet in the simulation condition because there is a difference in friction coefficient depending on the place, unlike the Coulomb friction condition. However, since the lubricant was used in the experiment, it is difficult to measure the original friction coefficient . Therefore, in this experiment, By comparing and analyzing actual experimental results and simulation results, a simulation platform of a new curvature extrusion process was constructed by proving the effect of fillet in actual experiments and then studying the friction coefficient applied when setting experimental model to simulation condition.

Simulation results show that when the coefficient of friction is 0.4, the fillet is 0.4, the friction coefficient is 0.6, the fillet is 0.5, the friction coefficient is 0.6, the fillet is 0.8, and the friction coefficient is 0.8. When the fillet was 0.8mm, the result showed the same result as the experimental value. When the curvature value was numerically analyzed, the fit was best when the fillet was 0.4mm when the coefficient of friction was 0.4.

1. Introduction

Extrusion technology has been widely used as the primary production method for products such as bar, wire, and tube by utilizing high productivity and excellent mechanical properties. Among the extrusion techniques, cold extrusion research continued for nearly 200 years. The origins of cold extrusion originate from the French Revolution in the late 18th century when the French extruded lead into a narrow hole and made bullets. In Germany, the problems of the cold extrusion process were solved by using a phosphate coating as a lubricant. In recent years, as the application field of extrusion technology has widened, it has been demanded to develop an extrusion material production techniques having a small size and a complicated cross section.

The cold extrusion process is expected to improve the mechanical properties due to the work hardening, and it is possible to control the dimensional tolerance precisely, thereby minimizing additional processing and finishing work. Also, when a sufficient friction between the die and the billet is produced, the oxide film is less likely to be generated, and the surface characteristics are improved, and the production speed and cost are more competitive than the cutting process. However, the cost of the mold is very high as the size of the product that can be worked limited and the precision of the product is high. Also, it is necessary to pretreat such as lubrication to increase the flow of material surface such as coating. For this reason, cold working has a strength in mass production of products requiring the precision of small parts.

The application of this cold extrusion method to a curved square bar extrusion method is very suitable and economical, and therefore a lot of research is currently underway. In the case of the rectangular bar with curvature, Fig. 1, it is manufactured through additional processes such as cutting, pressing, cutting and bending after a simple extrusion process. In this case, additional processing cost and time are required for the basic cold extrusion process.

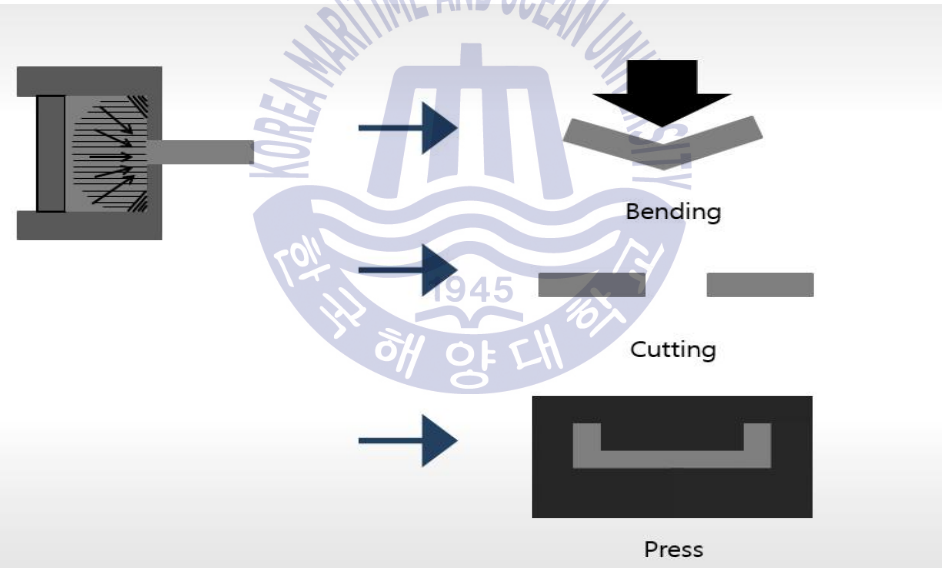


Fig. 2 Additional process of extrusion

As a countermeasure to reduce the additional cost and process steps, many types of research have been carried out. For example, in the process of extrusion, a guide roll is added to both sides of the billet to induce the difference in speed between the inner and outer guide rolls.

However, this is also effective when additional processing is indispensable, and the size of the extrudate is under the certain size. In curvature extrusion when the size is small, it is possible to simplify the process by directly controlling the curvature by controlling the shape of the die, but research on the way prediction of such an extrudate has been limited. In this study, a method of directly manufacturing a product with a complex cross-section by controlling the die shape has been proposed. Experiments were conducted to monitor the curvature of the extruded material produced by tilting the die. As the shape parameters of the die affecting the curvature of the extruded material, the inclination angle of the die, the height of the exit, and the width of the exit were taken into consideration.

In this study, the cause of the curvature in the extruded material was investigated through the finite element method, which is one of the simulation methods, and basic research was carried out to control the extruded curvature by using it. Experimental and analytical results show that the curvature in the curved method of tilting the die proposed in this study is due to the fact that the dead metal zone generated in the extrusion process causes internal stress change in the billet . There are various methods such as Upper bound method and slab method to obtain information about the non-inferred part in order to predict the change of curvature due to the internal stress change due to the non-inverse part. However, in the above method, only the machining force required for deformation can be known, and information such as the internal stress, strain rate, and strain rate of the workpiece generated during machining can not be known. Therefore, in order to clarify the influence of the non - inhomogeneous part, the finite element analysis method which is a rigorous analytical method for numerically solving the integral equations, which considers both equilibrium equations, constitutive equations, strain - displacement relations, incompressible conditions, respectively.

When simulating an extrusion process in the finite element method, the influence of various variables such as disappearance of elements, proper mesh shape selection, selection of basic properties, etc, should be considered. In this experiment, it is considered to set the proper value of the variables by comparing them with the values from the actual experiments. These parameters include friction factor, fillet size, mesh element selection, etc., and the effect on the influence of each parameter is considered and the material flow and the internal stress change were analyzed.

Through this research, it is expected to develop a standardized process method by commercialization of a new extrusion method analysis tool by comparing simulation values and experimental values.

2. Theoretical Background

2.1 Finite element method

The product and process development phases involve experience and trial and error. Experiential accumulation of experience requires a long time. Moreover, the process-specific design experience becomes less competitive as the utility value decreases when a rapid change occurs in the market. As a result, the need for simulation is attracting attention as a test that can be performed before the production of molds and prototypes. It has the advantage of being able to perform parts development time systematically, development cost reduction, lowest cost process and parts development, and development problem was solving systematically. The finite element method is a numerical method that is used to solve engineering problems such as stress analysis, heat transfer, electromagnetic and fluid flow. In general, engineering problems are mathematical models of physical phenomena. A differential equation gives the mathematical model with associated boundary conditions and initial conditions. Differential equations can be derived by applying basic laws and principles to systems or inspection volumes. The finite element method uses an integral process to obtain a complete solution through the combination of approximate continuous functions of each of these interpretation solutions. In this study, experiments were carried out through Deform-3d as follows.

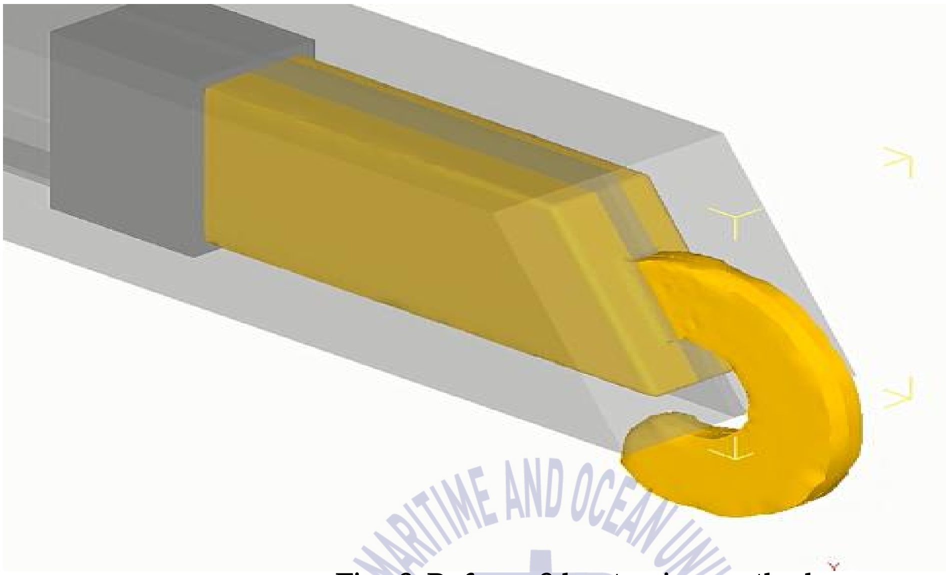


Fig. 2 Deform 3d extrusion method

2.2 Analysis extrusion process

2.2.1 Cold extrusion

In this experiment, the direction of extrusion was a director forward extrusion method in which the billets in the container were passed through the die by a ram moving at a constant speed. To prevent problems such as plastic deformation and heat recrystallization caused by friction, It was mainly used as lubrication. Soapy water was used by lubrication. The flow of the material is as follows, and the non-flow region called the dead metal zone (DMZ) is created by the frictional force between the billet and the die. This experiment was carried out by cold extrusion method at room temperature.

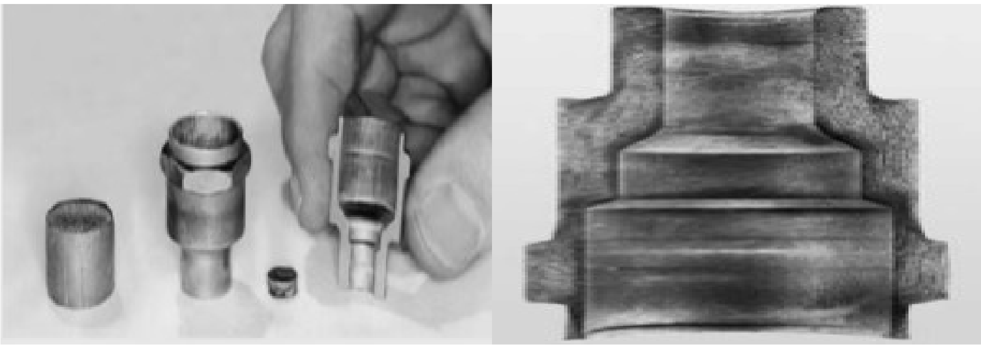


Fig. 3 Application of cold extrusion process to the production of small species

2.2.2 Principle of curvature extrusion

In general, when the curvature extrusion process material touches the front die, the deformation begins, and the stress applied to the material is as above. The vertical force of the die causes the material to undergo compressive stress around the y-axis, and at the outlet of the exit, the compressive stress in the -y direction becomes smaller before the deformation occurs, resulting in curvature in the extrudate as follows.

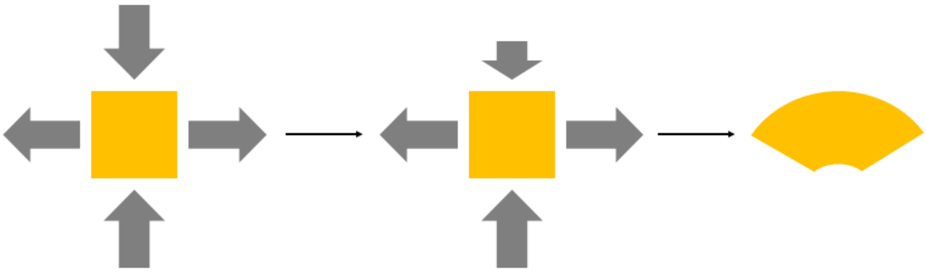


Fig. 4 Stress state of inner billet

2.3 Calculation Method

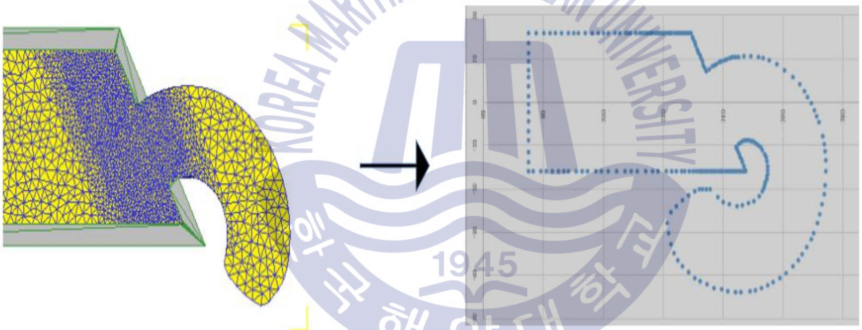


Fig. 5 Coordination result of extrusion result

The simulation results obtained in the post process of Deform 3D were sliced, and positional coordinates were given to calculate the curvature in the same way as shown in Fig. 4. Since the position coordinate also includes the position coordinates of the die, it is estimated by separately calculating the position coordinates of the billet as in Fig. 5.

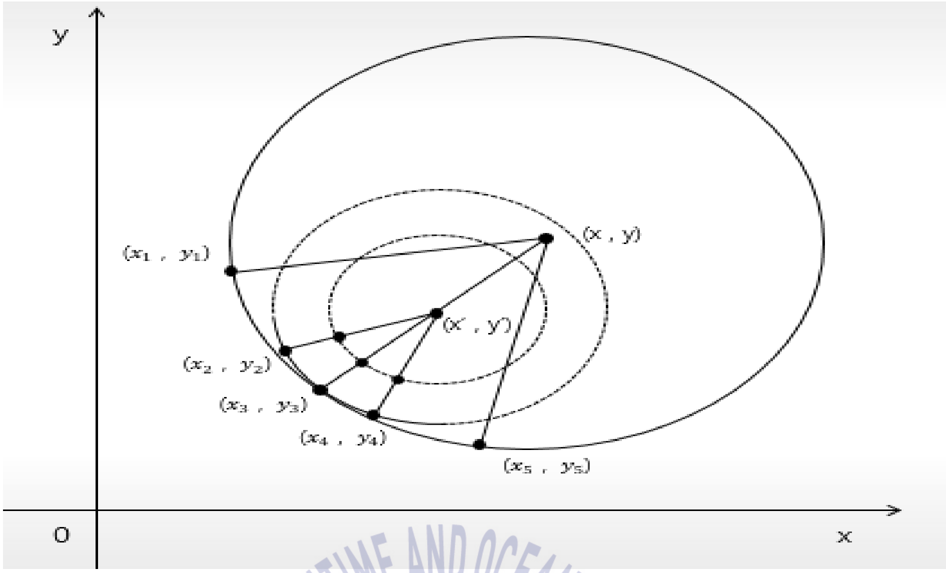


Fig. 6 Mathematical interpretation of extrusion results

The curvature was analyzed based on the position information of each element obtained from the simulation. To get the curvature, using the circle equation derive the formula for each coordinate value as shown in Fig. 5 for more than three element points.

In Fig. 5, the center points (a, b) of the curvature sources were obtained by assigning three element points to the standard form of the circle equation.

$$x^2 + y^2 + Ax + By + C = 0 \qquad (1)$$

Each element point is assigned as follows.

① $x_1^2+y_2^2+Ax_1+By_1+C=0$, ② $x_3^2+y_3^2+Ax_3+By_3+C=0$,

③ $x_5^2+y_5^2+Ax_5+By_5+C=0$ (2)

Eq. (2)-①과 Eq. (2)-③, Eq. (2)-② and Eq. (2)-③,

① $x_5^2-x_3^2+y_5^2-y_3^2=A(x_3-x_5)+B(y_3-y_5)$

② $x_5^2-x_1^2+y_5^2-y_1^2=A(x_1-x_5)+B(y_1-y_5)$ (3)

Eq. (3)-① and (3)-② simultaneous equation,

$$A=\frac{(y_1-y_5)(x_5^2-x_3^2+y_5^2-y_3^2)-(y_3-y_5)(x_5^2-x_1^2+y_5^2-y_1^2)}{(x_3-x_5)(y_1-y_5)-(x_1-x_5)(y_3-y_5)}$$

$$=\frac{(x_5^2-x_1^2)(y_5-y_3)+(x_3^2-x_5^2)(y_5-y_1)+(y_1-y_3)(y_5-y_1)(y_5-y_3)}{(x_3-x_5)(y_1-y_5)-(x_1-x_5)(y_3-y_5)} \quad (4)$$

From Eq. (4), the coordinates of the center of the curvature source can be known.

$$x=-\frac{A}{2}$$

$$=-\frac{(x_5^2-x_1^2)(y_5-y_3)+(x_3^2-x_5^2)(y_5-y_1)+(y_1-y_3)(y_5-y_1)(y_5-y_3)}{2(x_3-x_5)(y_1-y_5)-(x_1-x_5)(y_3-y_5)} \quad (5)$$

Eq. (6) can be obtained by calculating the coordinates of the center from the coordinates.

$$y=\frac{(x_1-x_5)x}{y_5-y_1}+\frac{x_5^2-x_1^2}{2(y_5-y_1)}+\frac{y_1+y_5}{2} \quad (6)$$

In x_2, x_3, x_4, (5) and (6) from the equation of the circle passing through

$$x' = -\frac{(x_4^2 - x_2^2)(y_4 - y_3) + (x_3^2 - x_4^2)(y_4 - y_2) + (y_2 - y_3)(y_4 - y_2)(y_4 - y_3)}{2(x_3 - x_4)(y_4 - y_2) - (x_4 - x_2)(y_4 - y_3)} \tag{7}$$

$$y' = \frac{(x_2 - x_3)x'}{y_4 - y_2} + \frac{x_4^2 - x_2^2}{2(y_4 - y_2)} + \frac{y_2 + y_4}{2} \tag{8}$$

Through this, the center coordinates of the circles passing through can be obtained, and the curvature of the circle can be achieved through this.

By using the above method, the curvature of the circle passing through and the curvature of the circle should be received, and the portion with significant deviation should be excluded as shown in the shaded portion in Fig. 6.

Fig. 7 Analysis method of curvature data deviation

3. Simulation modeling

3.1 Billet design

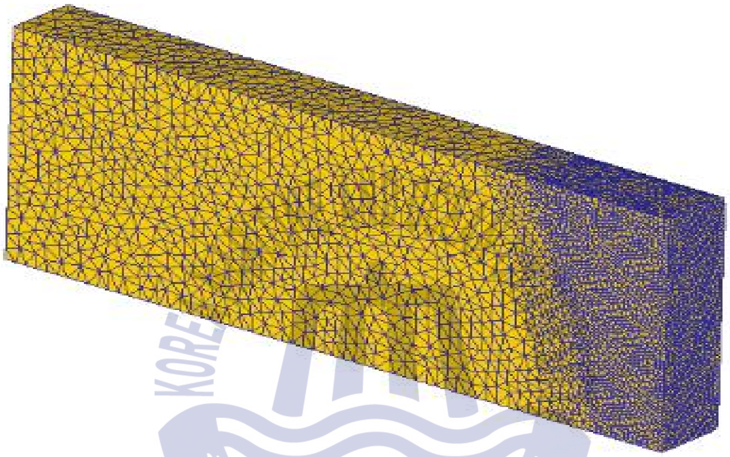


Fig. 8 Billet design

In the colored clay, the weight of the material itself is not taken into account, and it is assumed that it is an isotropic incompressible object. The friction between the billet and the die material was considered to follow Coulomb friction, and the coefficient of friction was made variable so as to determine the effect thereof. The flow stress of the material is given by Eq. (1).

$\sigma = 0.2\overline{\epsilon^{0.28}}$ --------------------------------(1)

Set the symmetry plane (1,0,0) on the billet and die to save computation time and memory. For symmetry plain setting, the billet was placed 1mm inward from die.

The time step was set at 600 seconds for 3 seconds with the time per one time set to 0.005 seconds.

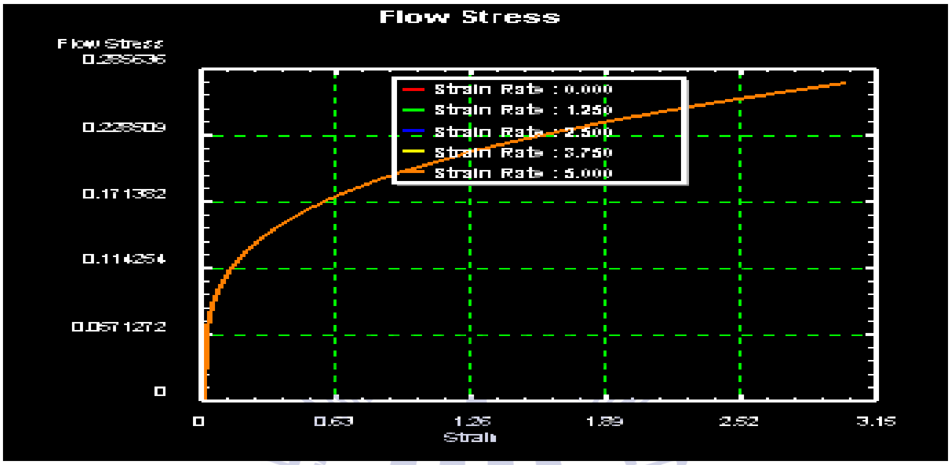


Fig. 9 Flow stress graph of material

3.1.1 mesh design

Billet model is created a grid by setting the size ratio 5 to 60000 elements. Simulation was not considered about weight factors, Boundary Curvature, Temperature distribution, strain distribution, strain rate distribution. Simulation set the mesh window to 1 to shorten the computation time and memory. Mesh window was 0.3 times in the 10 mm area from the die outlet to the die outlet, 0.5 times at the top to the die outlet, and 0.5 times at the bottom of the inside of the billet at an angle corresponding to the tilt angle of the die as shown in Fig. 10. Viewed from the side, the shape of the mesh is shown in Fig. 11, which is treatment for concrete interpretation of the part where deformation occurs.

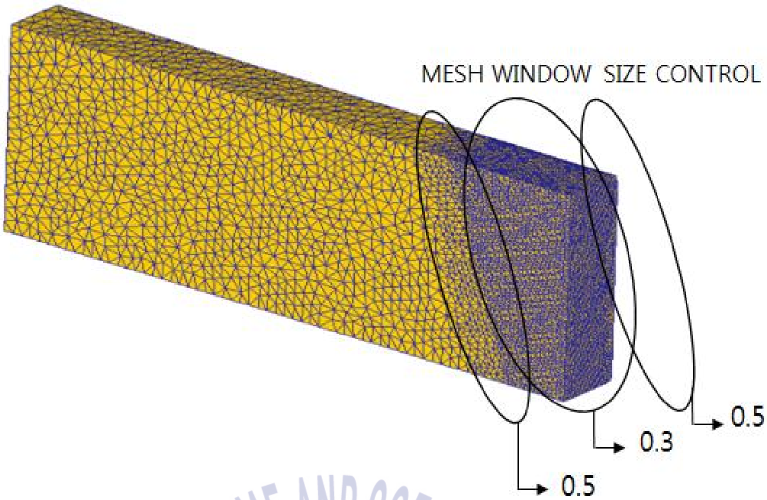


Fig. 10 Mesh window design of billet

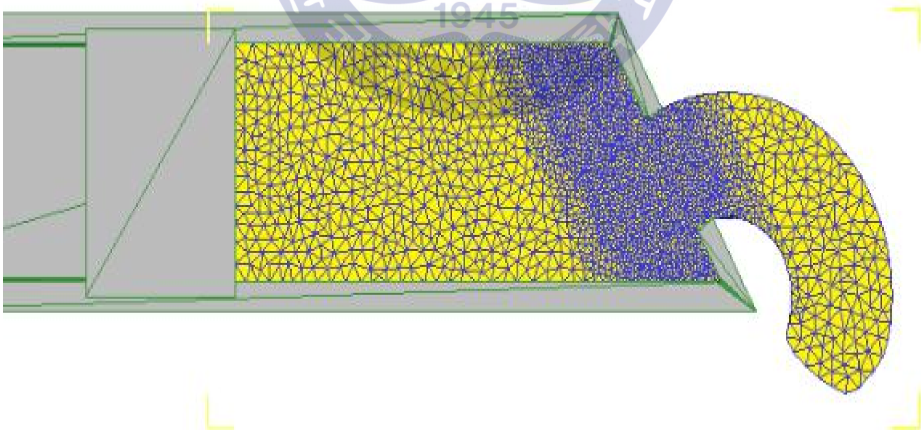


Fig. 11 Shape of the mesh from side view

3.1.2 Effect of remesh

The tetrahedral elements used in this simulation are suitable for large mechanical deformation of forged holes, but they are not as accurate as deformation such as bending as compared with hexahedral elements. Therefore, we need to use hexahedral elements in this study, but hexahedral elements do not correspond to remesh, so we needed to use tetrahedral elements. The difference between the two elements is illustrated in Fig. 12. Second, in the finite element method with the problem of remesh, the smaller the element size and the higher the number of elements, the better the accuracy. For example, if you calculate the entire workpiece as a minute element, the accuracy improves, but the arithmetic time and the memory used are so large that it is not practical.

Also, it is necessary to calculate the area near the exit hole with a minute factor and the other factor with a rough factor. In other words, it is necessary to implement a large element to approach the exit hole, to work as an element, and to work again as a large element when exiting the exit. Since the contact between the workpiece and the tool is determined by each contact point of the tetrahedral element, there arises a problem that the entire element is encapsulated in the tool as shown.

To remedy the encroachment regimes, the vacancy part disappears. This phenomenon is hard to avoid because it was a phenomenon that must occur even with a smoother mesh element. Although it is possible to reduce the number of remesh times, it is a problem that the accuracy is deteriorated by remesh. In the above three headings, the precision is worsened, and the curvature of each bar is considered to be smaller.

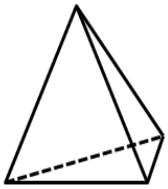
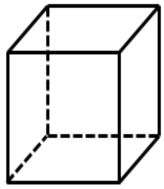
Shape of element	 Tetrahedral element	 Hexahedron element
Reliability of analyisis	Relatively low than other element which has more nodes	Relatively higher than other element which has less nodes
Speed of analysis	Analysize mesh using usual Personal computer ->60000, about 5hours	Analysize mesh using usual Personal computer->20000, about 24hours

Fig. 12 Differences of elements shape in FEM

3.2 Die dimension parameter set up

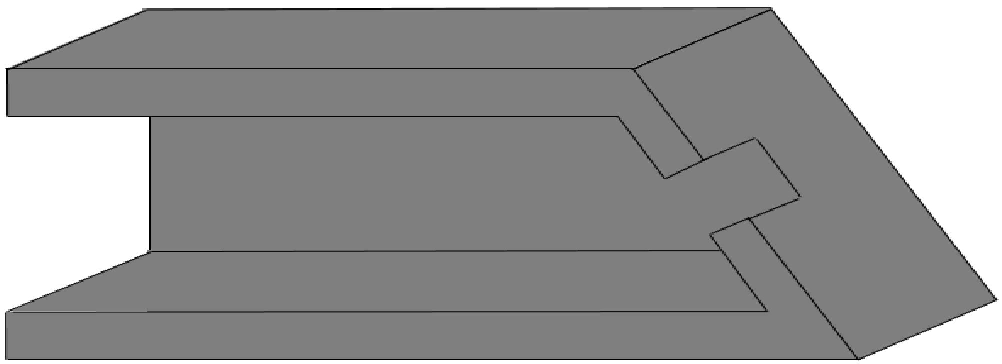


Fig. 13 Simulated die model

The variables of the die dimensions for constituting a general platform of a specific material are the height of the die outlet, the width of the die outlet, the die tilt angle, the friction coefficient of the billet and the die, and the fillet value of the die edge portion, and it is considered as like Fig. 13. Each of the above variables was evaluated, and the variables were determined by considering and considering the variables that affect the tendency of the die having curvature. Experiments were conducted according to the measured variables to focus on the design of the die optimized for the conditions of the billet.

Table 1 Die dimension parameters

Die dimension	Parameter					
h(mm)	13	15	17	20	25	
w(mm)	3.0					
α(˚)	30					
Friction	0.2	0.4	0.6	0.8		
Fillet(mm)	0.1	0.2	0.3	0.4	0.5	0.8

In the experimental graph, H is expressed as the ratio of the height of the billet to the height of the die outlet with respect to h. W is similarly shown as a ratio of the width of the billet to the width of the die outlet, expressed as W, and a change in curvature according to the extrusion ratio.

3.2.1. Die inclination angle

In the case of the die tilt angle, it was evaluated as a factor causing curvature extrusion at the beginning of the study. However, the experiment was conducted by adjusting the position of the die exit without giving the tilt angle. As a result, it was confirmed that the curvature was generated as shown in Fig. 14.

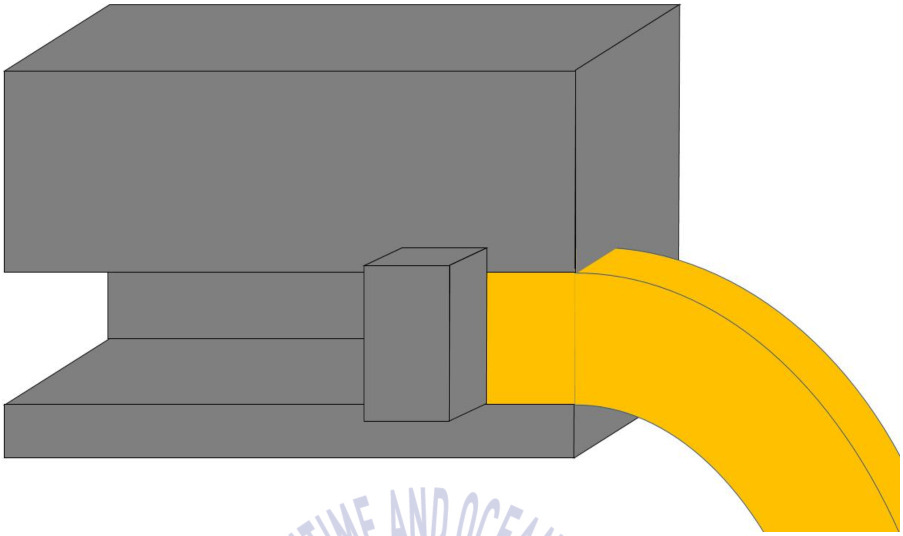


Fig. 14 Extrusion result of no tilting angle

It is easy to judge that the mechanism of the curvature extrusion is due to the inclination of the die when the die exit is located at the central portion of the front surface of the die without tilting angle. However, as a result of the experiment conducted by adjusting the position of the die outlet Proved. The driving force of curvature extrusion is the stress change inside the material. The stress change in the material is due to the size of the non-flow area inside the billet, so the die is inclined, or the die outlet is not at the center of the die. It is proved that curvature extrusion can be induced. In the die dimension design, the value of the die tilt angle was fixed because the die exit would be set to the center of the die front.

3.2.2. Friction coefficient

As mentioned earlier, the stress variation inside the billet is induced by the non-floating part generated at the edge of the die. The non-floating part needs to define the coefficient of friction between the material and the billet because the size of the area is determined by the friction between the die and the billet. When the coefficient of friction is too small or too large, it 's hard to make a proper analysis because an error occurs in the area difference between the upper and lower non-flow portions.

The variation of the curvature was observed while changing the coefficient of friction from 0.1 to 0.8. The type of friction was set as Coulomb friction condition because the frictional force between the billet and the die surface was independent of the contact area and was proportional to the vertical load and was not related to the friction speed. In this study, we assumed that the friction coefficient does not affect the curvature independently, but the curvature tends to vary with the fillet value. As a result of the experiment, if the fillet value has a value that smoothes the flow of the billet even if the coefficient of friction is low, the curvature tendency conforming to the actual experimental value is shown. From these results, it can be seen that the coefficient of friction and the fillet value affect each other without affecting the curvature independently. To investigate how the coefficient of friction and the fillet value interact with the curvature, the friction coefficient and the fillet value were used as the variables.

3.2.3. Fillet

When the material is pushed out during extrusion, the coefficient of friction of the die affects the stress acting in the direction of extrusion, resulting in various problems in the extrusion process. The peeling effect of the die is pulling the material and peeling off the surface of the material occurs, and it becomes difficult to accurately analyze the lubricating additive (soapy water) to alleviate stress concentration [2]. To solve this problem, a method was proposed to fillet the edges of the die and the billet. [5]

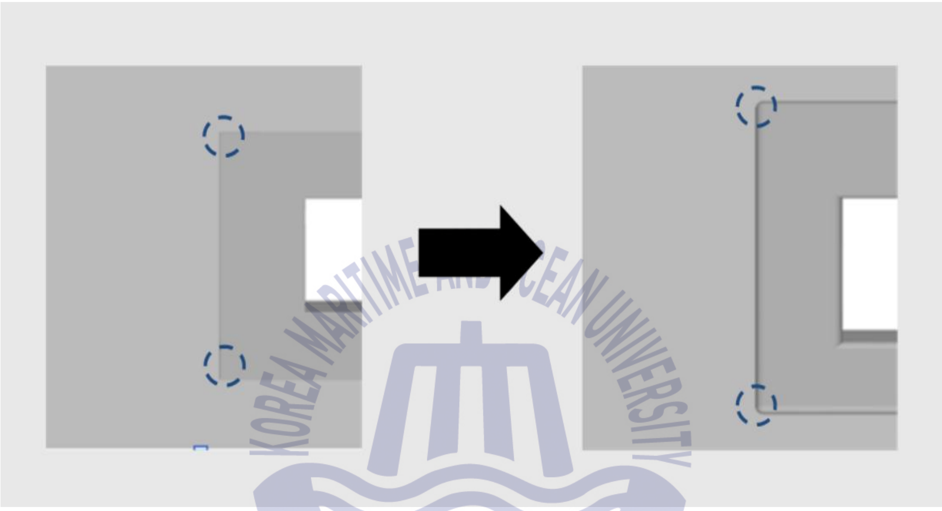


Fig. 15 Fillet shape of die

In general, setting the fillet is imperative, because if the fillet is set too low, the element will still disappear and if it is given too much, the edge of the billet will be eroded. We have prepared a model that has not been filled with fillet as in Fig. 15, and a fillet is applied to each edge of the billet and die with the highest contact angle. The fillet value was determined by considering the peeling effect and the element extinction phenomenon through the flow frontal simulation of the billet. In order to investigate the influence of the die dimension, the coefficient of friction was set as a variable. However, in a view to confirm the influence of the fillet, the tendency was analyzed by setting the assumed value to 0.1 when there was no fillet between the experimental value and the calculated value.

3.2.4. Effect of die exit dimensions

The extrusion ratio is the factor that affects the curvature of the extrudate at the exit dimension of the die. The extrusion ratio is organized as the cross-sectional area of the billet / the cross-sectional area of the die exit, and the influence there of is evaluated independently. Fig. 16 shows the change in curvature according to the die exit dimension obtained through the experiment.

The Fig. 15 shows the graph of the curvature change with respect to the height and the width of the die exit. The experiment was carried out with W fixed at 5.6mm in left side of Fig 15, and H fixed at 17mm in right side of Fig 16.

Exit height ratios H is the height of the billet / die outlet, and Exit height ratios W is the width of the billet / width of the die outlet. The curvature tended to increase with increasing H and W ratio.

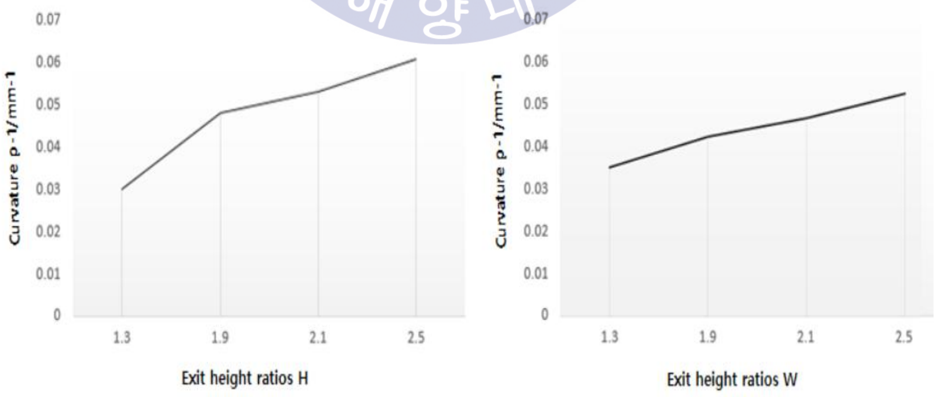


Fig. 16 Experimental result according to H and W

In other words. The curvature increased as the billet extrusion ratio increased. From the analysis of the graph, it can be seen that H influences curvature change twice more than W. This curvature change is an additional stress change that occurs during the flow process of the billet and is not affected by the width and height of the die exit at the initial stage of the extrusion process.

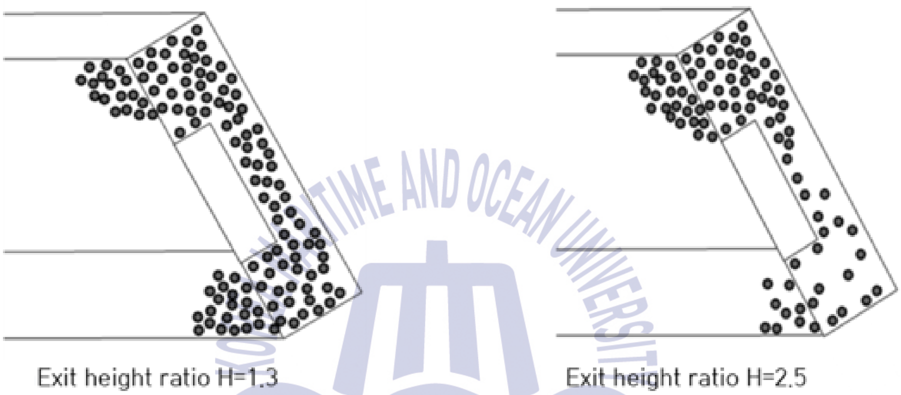


Fig. 17 Dead metal zone of die when H is 1.3 and 2.5

In order to set the conditions of the die, there is a need to verify and verify the simulation results based on such experimental data.

Fig. 17 shows the illustration of the flow diagram at the minimum value 1.3 and the maximum value 2.5 of the exit height ratio H.

In the figure, the difference in the size of the non-flow area when the H value is 1.3 is not large. However, when the value of H is 2.5, the difference between the upper non-flow area and the lower non-flow area is larger than before. It is considered that the change of the curvature due to the height H of the outlet of the die is caused by the difference between the upper and lower non-flow regions due to the addition of the non-flow portions as the die outlet becomes smaller.

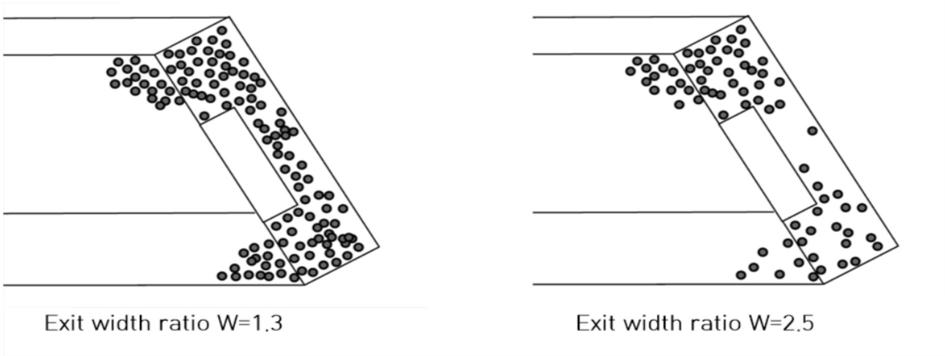


Fig. 18 Dead metal zone of die when W is 1.3 and 2.5

Fig. 18 shows the illustration of the non-inferior part at the minimum value 1.3 and the maximum value 2.5 of the exit width ratio W. When W is 1.3, the difference between the upper part and the lower part is larger when W is 2.5 than the difference between the upper part and the lower part. It can be seen that the curvature deformed by W is also induced by the difference between the non- is.

In conclusion, it was found that both the H and W variables of the die outlet influence the curvature with the same mechanism that induces the difference in speed between the lower and upper sides of the die outlet by giving the difference between the upper and lower non-flow regions.

Because both H and W affect the curvature, we design the die and fix the W when it is verified. As the value changes, hold the variable for the non-homogeneous change H, and calculate the extrusion ratio The experimental tendency was evaluated.

3.3. Punch design

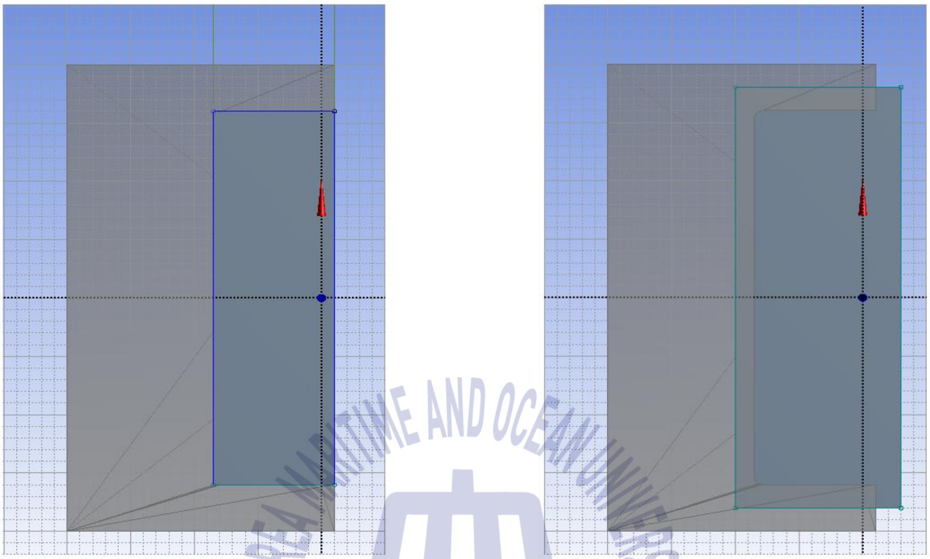


Fig. 19 Punch size to fit the die precisely (left) ,
Punches larger in size than die (Right)

The extrusion method used in this study is a direct extrusion method in which the billet is pushed to the front of the die by punching. Thus, the design of the punch also affects the material flow. In the initial stage of the research, it was experimentally designed to fit the size of the billet as in the left side of Fig. 19. As a result, the curvature of the billet lost tendency and the curvature deviation was large as in the right side of Fig 19. The reason for this is that it is completely in contact with the numerical value, but it seems that the billet element has escaped from the gap created by using the elements of the tetrahedron instead of the tangential element of the cube, Therefore, we solved the problem by designing the punch to be larger than the billet so that the element does not come out as shown in the right figure. Based on these considerations, we can get a complete simulation model as shown in Fig. 20.

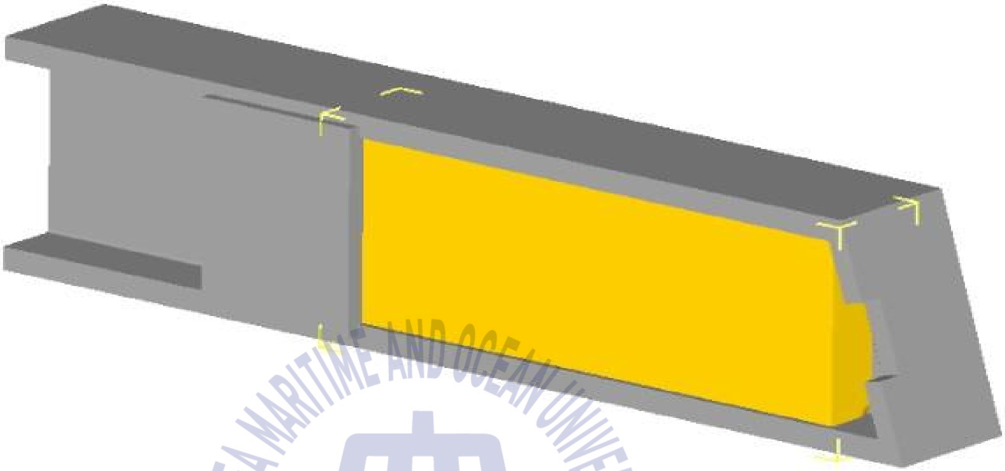


Fig. 20 Completed simulation model

3. Result and Discussion

3.1 Analysis effect of die fillet on curvature

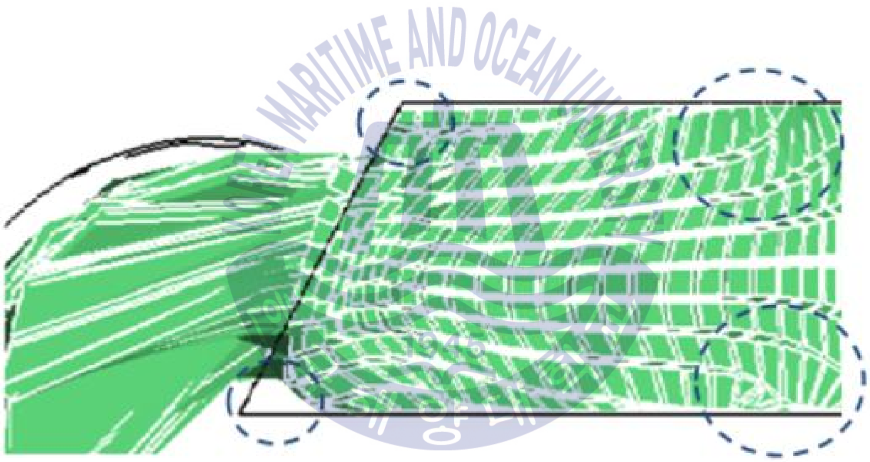


Fig. 21 Flow frontal simulation with no fillet

Fig. 21 simulates the flow front of the billet when the die has no fillet. When you look at the dotted line on the back side, you can see that the element is peeled from the edge of the die and sucked in from the start of the extrusion. The fillet values were confirmed to be necessary. For the setting of the appropriate fillet values, a flow front end experiment was conducted for fillet values of 0.3 mm and 0.5 mm.

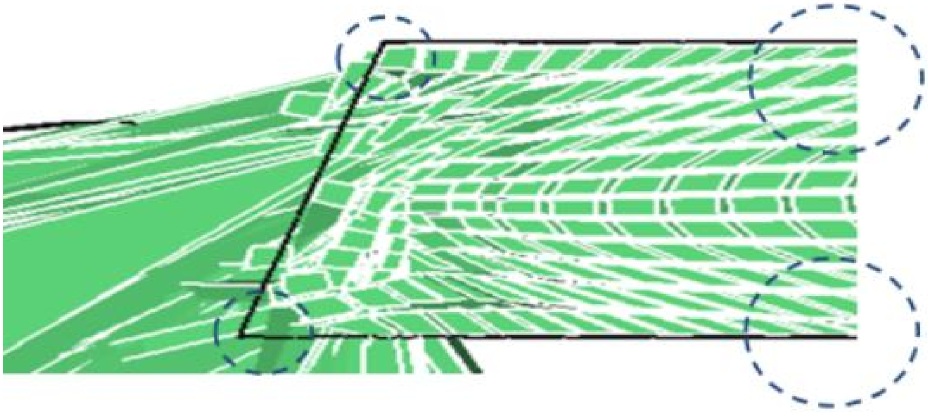


Fig. 22 Flow frontal simulation with 0.3 mm fillet

In Fig. 22, the disappearance of the element at the back side is greatly reduced, but the vacancy appears in the nonflow region below the die front. As a result, the fillet value of 0.3 mm is found to be an unsatisfactory fillet value under the condition of the set friction coefficient of 0.1.

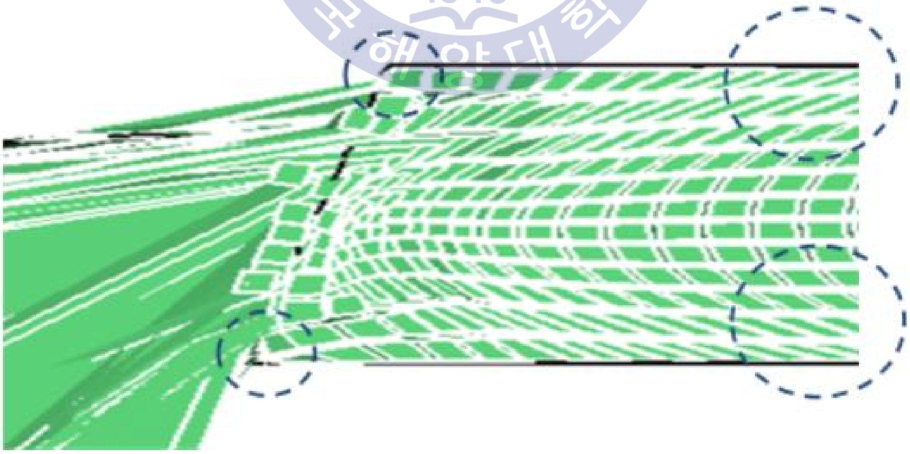


Fig. 23 Flow frontal simulation with 0.5 mm fillet

In Fig. 23, the disappearance of the element is hardly observed in the rear side, and the vacancy is not seen in the non-flow region under the die front. If the fillet value is 0.5 mm under the condition of the set friction coefficient of 0.1, it can be understood that at least the element does not disappear and the non-flow part can be analyzed.

In this experiment, it is shown that as the fillet value increases, the element is not extinct in the flow front end and the non - flow part is well formed. In order to confirm this, we experimented to fix the appropriate friction coefficient and fillet value by changing the fillet value according to the friction coefficient.

3.2 Simulation comparison

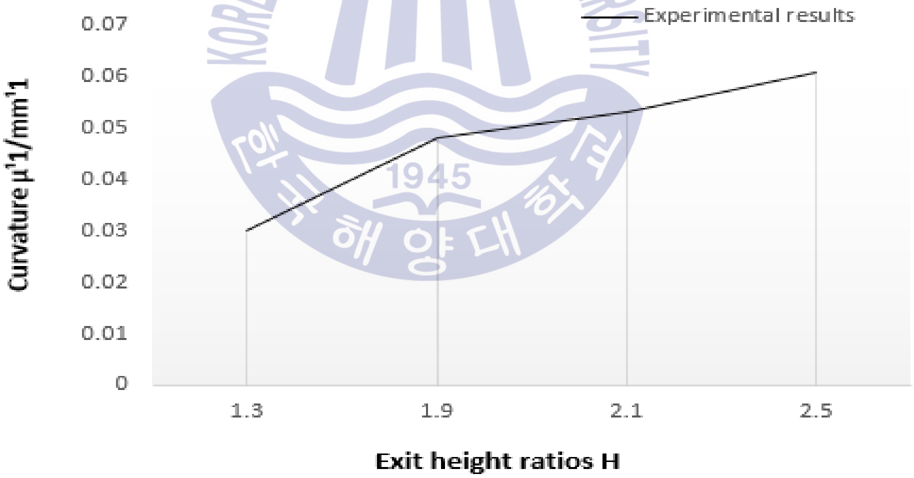


Fig. 24 Experimental result according to H

The experiment was carried as Fig. 24 with the parameters as the frcition coefficient and the fillet as variables. Based on the actual experimental results, simulation conditions were estimated to obtain the correct die dimension conditions such as fillet and friction coefficient through simulation. To earn a confidence, simulation is performed at least 150 times. The most optimized test platform is proposed by comparing the difference between the actual experimental value and the following simulation value.

Since the influence of the friction coefficient and the influence of the fillet value interact, the fillet value was set from 0.1 mm to 0.8 mm according to the friction coefficient and the curvature with respect to each exit height ratios H was shown.

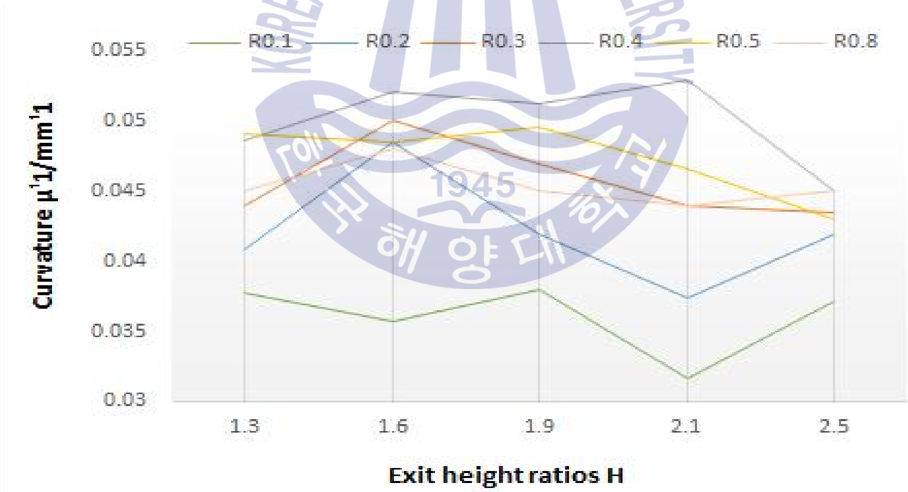


Fig. 25 Effect of friction coefficient 0.2 on curvature

Fig. 25 shows the effect of friction coefficient 0.2 on curvature. The fillet values are separated at the top of the graph. In the above graph, the friction factor - fillet graph with a definite tendency according to the exit width ratio was not found, and the deviation between the lines was also large. In general, the curvature tends to decrease with increasing H, and no tendency is observed according to the fillet value.

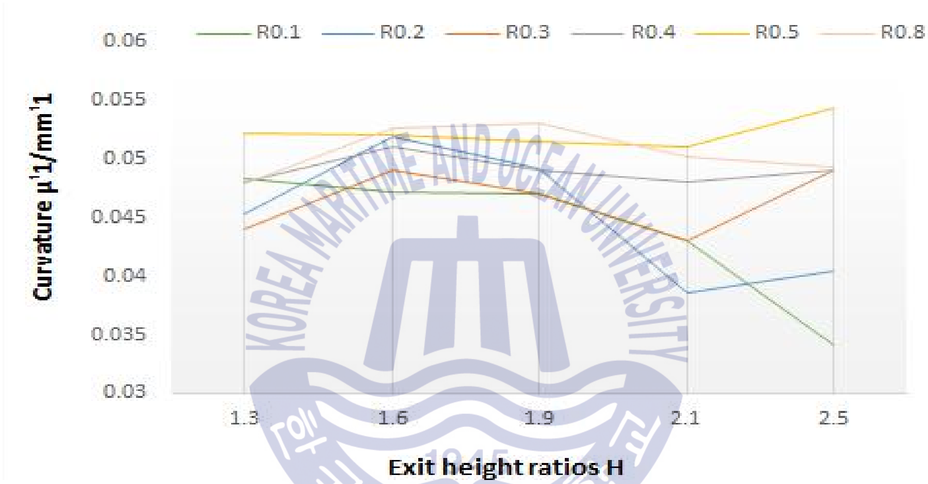


Fig. 26 Effect of friction coefficient 0.4 on curvature

Fig. 26 shows the effect of friction coefficient 0.4 on curvature. Likewise, they did not have a clear trend according to the exit width ratio. The deviation between the leading lines was smaller than that when the coefficient of friction was 0.2, and the curvature was drastically reduced until the fillet value was 0.4 mm when viewed roughly, but it was found that the curvature was moderately increased with respect to H at 0.6 and 0.8 there was. Also, the higher the fillet value, the higher the curvature value

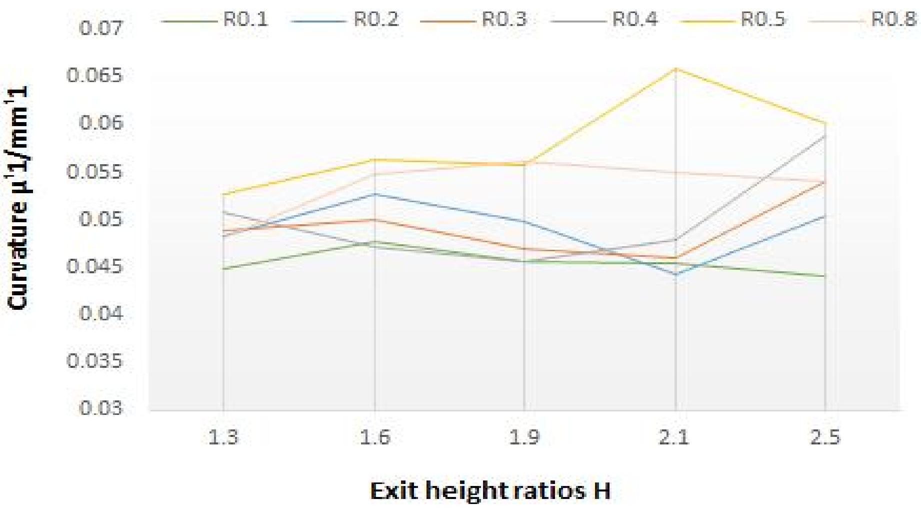


Fig. 27 Effect of friction coefficient 0.6 on curvature

Fig. 27 shows the effect of friction coefficient 0.6 on curvature. The graph shows a pattern similar to that when the coefficient of friction is 0.4, but it shows a more clear trend. The curvature was decreased drastically until the fillet value was 0.2 mm and 0.4 mm, and the curvature was clearly increased with respect to H at 0.6 and 0.8. Similarly, the higher the value of the fillet, the higher the curvature value was, and this was also a more definite form.

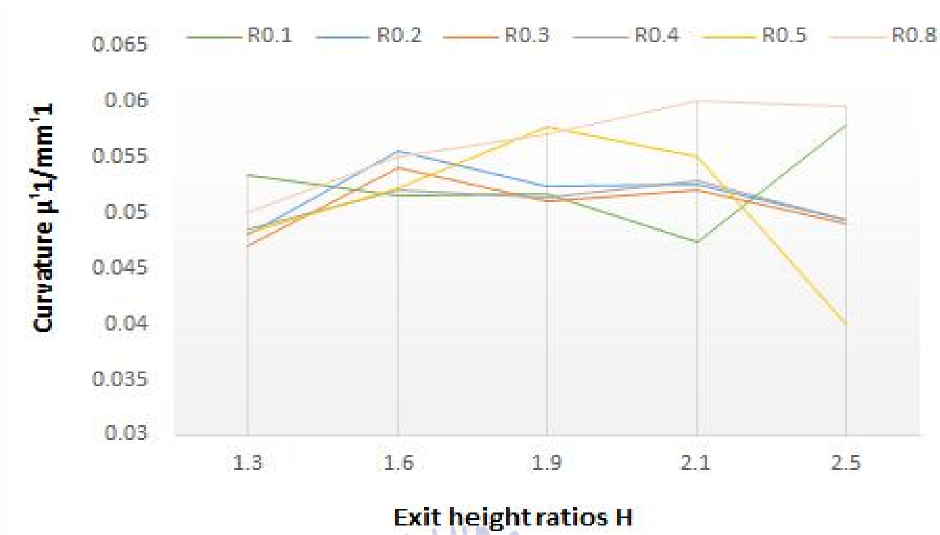


Fig. 28 Effect of friction coefficient 0.8 on curvature

Fig. 28 shows the effect of friction coefficient 0.8 on curvature. It was expected that the curvature value would increase according to the friction coefficient based on the results of the previous simulation. However, it was found that the curvature did not change and had no tendency except for the case where the fillet value was 0.8 mm. It can be seen that the change in the coefficient of friction affects the size of the dead metal zone of the material, thereby causing a speed difference between the upper and lower sides of the billet to increase the curvature. However, when the coefficient of friction is more than a certain level, It can be seen that the elements constituting the dead metal part disappear in the analysis of the dead metal part and cause a problem in the curvature analysis. The curvature was decreased drastically until the value of curvature was 0.2, 0.4, 0.6. At 0.8, the curvature was clearly increased with respect to H.

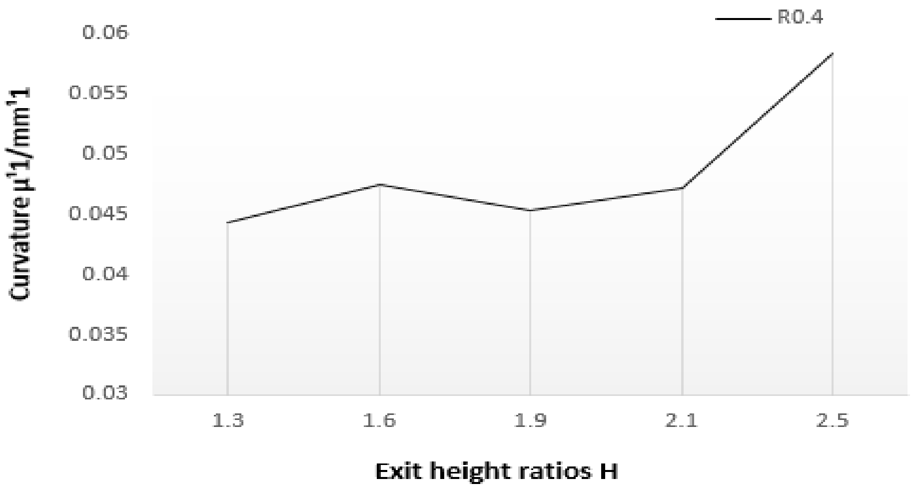


Fig. 29 Curvature in friction coefficient 0.4 and 0.4 mm fillet size

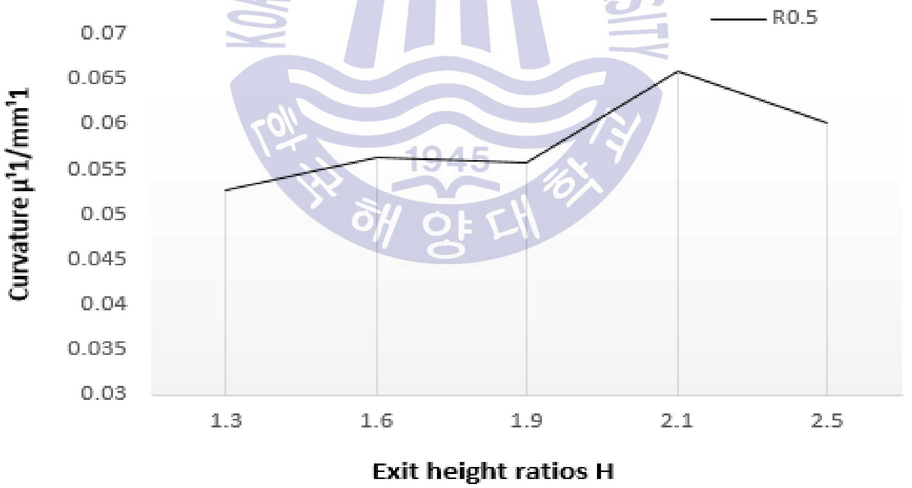


Fig. 30 Curvature in friction coefficient 0.6 and 0.5 mm fillet size

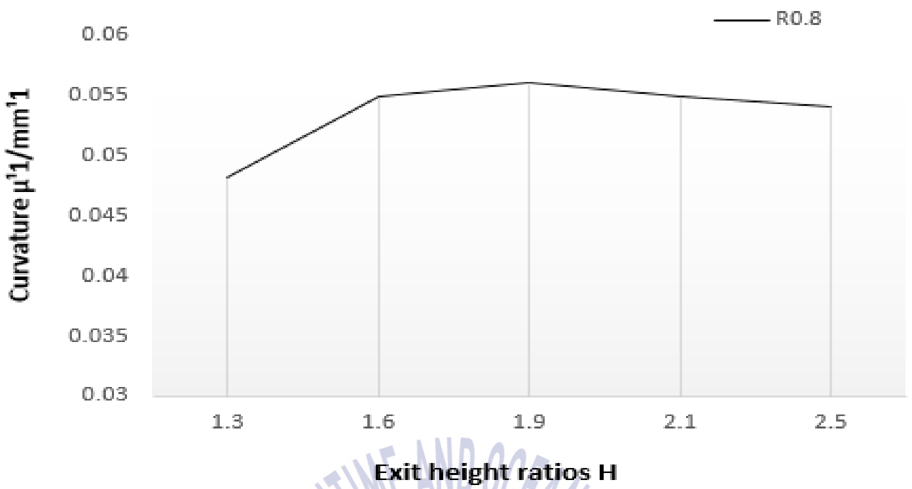


Fig. 31 Curvature in friction coefficient 0.6 and 0.8 mm fillet size

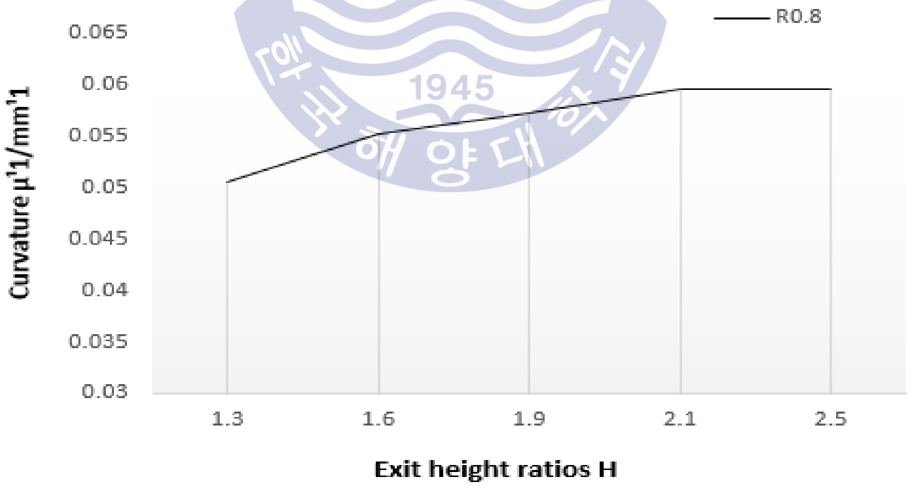


Fig. 32 Curvature in friction coefficient 0.8 and 0.8 mm fillet size

The above four graphs are a collection of graphs showing the same behavior as the actual experimental values in the total experimental results. We found that the larger the coefficient of friction, the larger the fillet value is needed, but the fillet value has a limit for the billet height value. The reason for this is that the shape of the element is a tetrahedron, so that if the fillet becomes too large, the effect of interfering with the flow of the billet is more likely to occur than to prevent the peeling effect. In this experimental condition, friction coefficient 0.8 is the maximum value at the edge of the billet. Therefore, it can be seen that the maximum value of the friction coefficient and fillet according to the variables is 0.8-0.8.

Fig. 29 shows the Curvature in friction coefficient 0.4 and 0.4 mm fillet size. In this case, the minimum value of 0.044 and the maximum value of 0.058 were shown, and the tendency was changed at H 1.9, but the error was not large.

Fig. 30 shows the Curvature in friction coefficient 0.6 and 0.5 mm fillet size. In this case, the curvature value was 0.053 at the minimum value and 0. 065 at the maximum value. In this case, although it can be considered that the trend of the experimental value generally follows, numerical value is slightly different from the actual experimental value.

Fig. 31 shows the Curvature in friction coefficient 0.6 and 0.8 mm fillet size. In this case, the curvature value was 0.048 at the minimum value and 0.056 at the maximum value, and a gentle curve was generally drawn. In this case as well, the tendency of the experimental values is largely followed, but numerical values are slightly different from the actual experimental values.

Fig. 32 shows the Curvature in friction coefficient 0.8 and 0.8 mm fillet size. In this case, the curvature value was 0.051 at the minimum value and 0.059 at the maximum value, and the curvature value was changed in accordance with the theoretical tendency of the graphs. However, the width of the change is too small to be easily analyzed, and the coefficient of friction and the fillet value are too large.

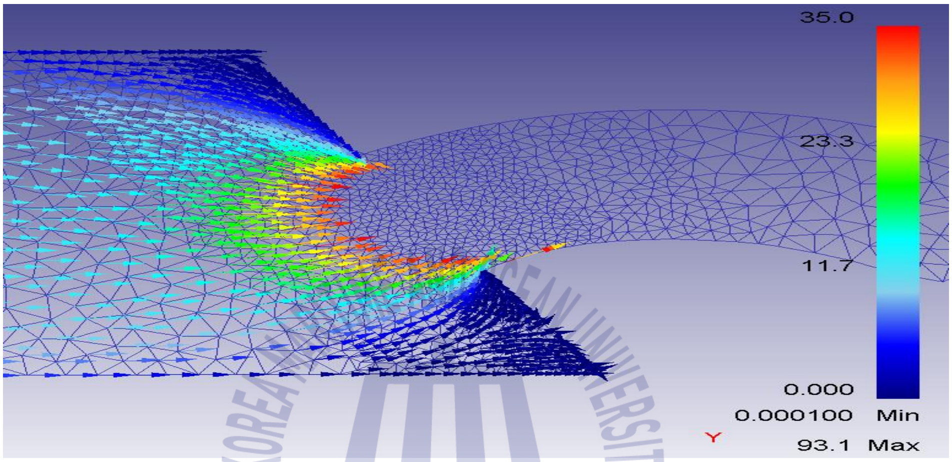


Fig. 33 Velocity contour when cuvarture is occurred

(friction coefficient 0.4 and 0.4 mm fillet size)

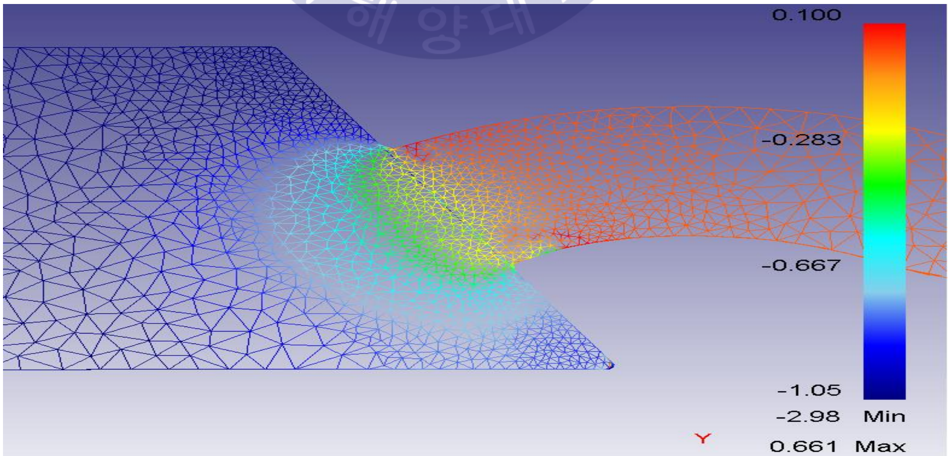


Fig. 34 Mean stress contour when cuvarture is occurred

(friction coefficient 0.4 and 0.4 mm fillet size)

Figure 33 is a contour graph of the velocity at which the curvature is generated in friction coefficient 0.4 and fillet size 0.4mm condition. The above experiment was carried out to confirm whether the upper and lower non-flow portions adequately affect the internal stresses affecting the curvature. It can be seen that there is a clear non-flow part at the top and bottom, which is similar to the true stress contour of Fig. 34. It suggest that the volume difference of the non - inferior part has a significant effect on the curvature and is well represented in the simulation.

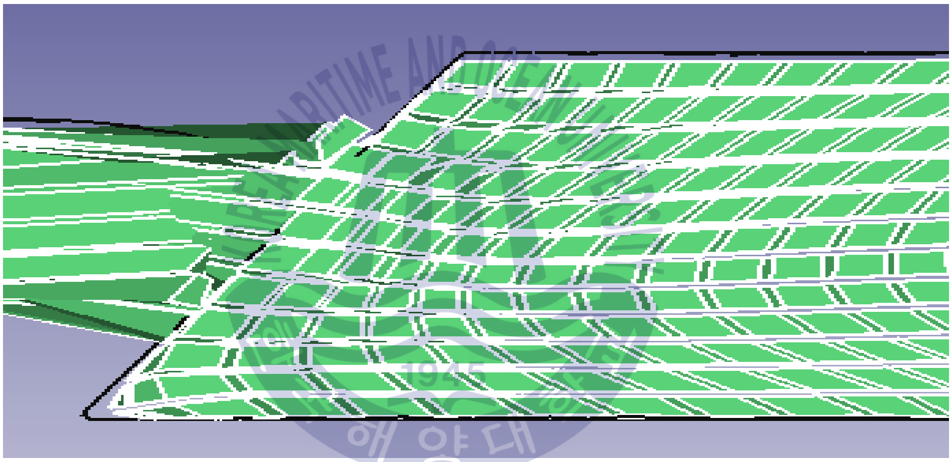


Fig. 35 Flow frontal simulation

(friction coefficient 0.4 and 0.4 mm fillet size)

Fig. 35 shows the flow front of the billet when friction coefficient 0.4 and fillet size 0.4mm condition. No extinction of the upper and lower non-eccentric parts was observed and no pull-out phenomenon was observed in which the element was sucked upwards. Through this, it was confirmed that the element was well generated evenly.

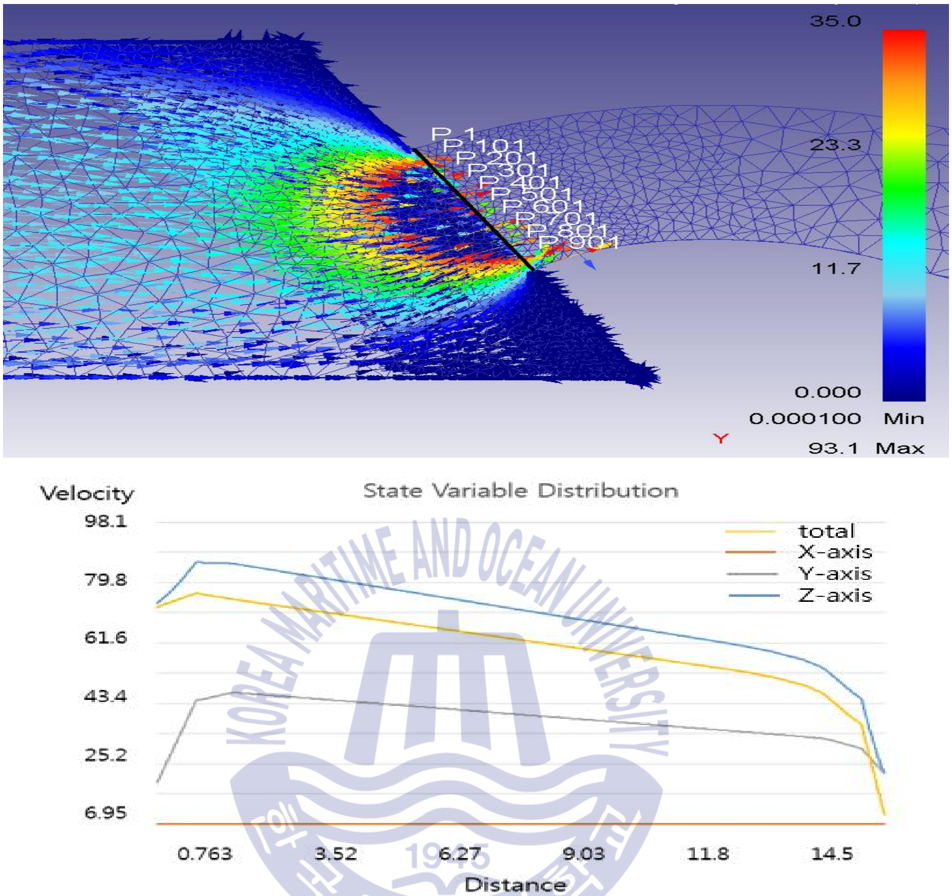


Fig. 36 Graph of velocity versus direction of extrusion from billet thickness direction

Fig. 36 is a graph of 1000 points for the velocity difference between the top and bottom of the billet. As shown in the graph, the velocity at the top was high and its maximum value was 76.44 mm / sec. In the lower part, the velocity was low, and the inflection point of the graph was calculated to obtain the minimum value, which was 33.05 mm / sec.

Similarly, As the graph represents the continuity equation, it is confirmed that the speed difference between the top and bottom is well represented and simulated.

4. Conclusion

In this paper, a new curvature extrusion method is proposed. For the analysis of the curvature extrusion process, various variables such as fillet value, friction coefficient, volume difference of non - flow part were considered. Experimental results show that the numerical values required for die modeling can be obtained and this will be helpful for identifying the mechanism of curvature extrusion in the future.

1. If the value is set too low to set the fillet value, the element will disappear due to the pull-out phenomenon, and the non-flow part will not be generated due to the extinction of the element, thereby affecting the internal stress concentration at the upper and lower parts of the billet .If the fillet value is set to a too large value, the die portion will encroach on the billet portion. This is because the billet is set to the tetrahedral element, so that the corner where the die and the billet meet is empty when there is no fillet, but if the fillet is too large, the die appears to be overlapped with the billet.

In consideration of this effect, therefore, the cross-sectional area of the punch should be larger than the cross-sectional area of the billet so that the billet can not escape out of the punch.

2. In analyzing the tendency of the curvature to change according to

the dimension adjustment of the die outlet in the actual experimental results and comparing it with the simulation value, the dimensions of the die outlet are expressed as H (die exit height ratio) and W (die exit width ratio) As a variable. The time tracking method for observing the movement of elements along time shows that the mechanism of the change of curvature by H and W is due to stress concentration due to the generation of non - . Experimental results show that H influences the curvature by about 3 times as much as W, which means that the non-inferior part is more dominant in H. Therefore, when comparing the influence on the curvature, it is judged that it is appropriate to compare the curvature change according to H, and the result analysis model is designed.

3. The most appropriate coefficient of friction for maintaining the experimental and simulation results was 0.4 and the fillet value was 0.4 mm. After analyzing the curvature, it was concluded that the experimental results were well simulated by analyzing the flow model of the element, the velocity distribution analysis in the extrusion direction from the lateral direction of the billet, and the internal stress change. When the simulation was performed under the above conditions, the numerical value was closest and the tendency of increasing the curvature was apparent, which facilitated the analysis.

This study is expected to contribute to the analysis of new curvature extrusion method and contribute to commercialization through simulation.

References

References

[1] Y. S. Suh , S. W. Choi , 2000. Influence of Die Geometry on Die-Lip Buildup in Plastic Extrusion, Transactions of Materials Processing(2000) 9, 5

[2] W. J. Lim , I. S. Lee, J. S. Je , D. C. Ko , B. M. Kim , 2007, Evaluation of Water-Soluble Lubricant for Cold Forging and Optimization of Coating Process, Transactions of Materials Processing journal , 2007.5, 149-154 (6 pages)

[3] Youngjune Joe , Sangkon Lee , Byungmin Kim , Kaehee Oh , Sangwoo Pa가, 2007, Development of Curvature Extrusion Process for Vehicle Bumper, Transactions of Korea Society of Automotive Engineers journal. 2007.6, 1626-1631(6 pages)

[4] Yoichi Takahashi, Shigefumi Kihara, Ken Yamaji, Mitsunobu Shiraishi, Effects of Die Dimensions for Extrusion of Curved Rectangular Bars, Materials Transactions, Vol. 56, No. 6 (2015) pp. 844 to 849 ©2015 The Japan Society for Technology of Plasticity

[5] J. S. Oh . 2004. Finite Element Analysis on Extrusion Process of Light Weight Alloy (Aluminum, Magensium) , master's thesis

[6] P. K. Oh , S. K. Yu , 2002, A Study on Optimum Computation of Extruding Force for the Extrusion , The Korean Society For Technology of

Plasticity , 2002.11, 9-14(6 pages)

[7] Alexander R. Bandar, 2005, Modeling Microstructure Evolution in the Dead-Metal Zone of Indirectly Extruded 6061 Aluminum, The Program for the Degree of Doctor of Philosophy in Materials Science and Engineering

[8] H. Takuda, N.Hatta, 1998, A Simple Approach to Plane Strain Extrusion with Dead Metal Zone Using Upper-bound Theorem, Metals and Materials International (MMI)

[9] Chul Ho Jin, Dae Yun Park, In Tai Jin, 1999, Rigid Plasticity Finite Element Analysis of the Bending of Extrusion Product Using the Square dies, The Korean Society For Technology of Plasticity '99 journal pp.80~83

[10] J. K. Um ,2016, Study on Acquisition of Flow Stress at the Room Temperature and Effect of the Flow Stress on Plastic Deformation, PhD's thesis

[11] Gyewon Jang, Woosik Lee, Daeup Kim, Jinhwa Jeon, Kaehee Oh, 2008, Development of Aluminum Control Arm applied for Curvature Extrusion Process, The Korean Society Of Automotive Engineers, 2008.4, 1507-1510(4 pages)

[12] J. Y. Kim, Development of Extrusion on Temperature and Running-in angle of Magnesium Alloy (AZ31), PhD's thesis

[13] JongHo Song, A Study on Developmen of Process Design System for Cold Forging of Gears using 3-Dimensional FE Analysis, PhD' s thesis

[14] W. J. Kim, The analysis of Hydrostatic Extrusion for Magnesium Alloy(AZ31), Master' s thesis