

Development of the Gliding Hole of the Dynamics Compression Plate

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Abstract. The gliding hole of the dynamics compression plate is designed to facilitate relative movement of pedicle screw during surgery application. The gliding hole shape is then geometrically complex. The gliding hole manufactured using machining processes used to employ ball-nose cutting tool. Then, production cost is expensive due to long production time. This study proposed to increase productivity of DCP products by introducing forming process (cold forming). The forming process used to involve any press tool devices. In the closed die forming press tool is designed with little allowance, then work-pieces is trapped in the mould after forming. Therefore, it is very important to determine hole geometry and dimensions of raw material in order to success on forming process. This study optimized the hole sizes with both geometry analytics and experiments. The success of the forming process was performed by increasing the holes size on the raw materials. The holes size need to be prepared is diameter of 5.5 mm with a length of 11.4 mm for the plate thickness 3 mm and diameter of 6 mm with a length of 12.5 mm for the plate thickness 4 mm.

1. Introduction

Dynamic Compression Plate (DCP) is one type of plate osteosynthesis or bone implants. Osteosynthesis is one of the way to provide bone stiffness temporary during healing the fracture bone until recovering bone stiffness permanently [1]. DCP included bone implant is widely applied to the patient due to a simple type and multipurpose used mainly for temporary fixation of long bones such as femur and tibia. DCP has been introduced in the world in 1969 and continued to modify. Up to now DCP is still used as one method of osteosynthesis. DCP is designed to employ such as compression, neutralization or tension of fractured bones. There are three sizes DCP reserved for large bone and small bone. There are (a) DCP width of 4.5 to fractures of the femur and especially to the humerus, (b) narrow DCP 4.5 for fractures of tibia and humerus and (c) DCP 3.5 for fractures of forearm, fibula, pelvis and collarbone [1].

There are many cases in developing countries including Indonesia, which can cause accidents musculoskeletal including natural disasters such as earthquakes and traffic accidents can continue to improve in line with the increasing number of vehicles on the highway. That impacts needs of bone implants such as DCP to be higher in developing countries including Indonesia.



The high demand for bone implants in Indonesia is not in line with Indonesia's purchasing power against bone implants available in the market. Costs required to perform a bone implant operations in Indonesia around US \$ 700, while the average expenditure on health per capita per year is only about US \$ 110. The high costs of bone implant operations in Indonesia one of them caused by a plate of bone implants used are made in a foreign country, such as Switzerland that Indonesia has to import at a high cost. With the use of implant plate that come from overseas, the equipment used for osteosynthesis process must also be from the same produsen, which means to be imported, and of course the cost is not cheap [2].

Manufacture of typical implant products in the country especially involves several machining processes (approximately 80-90% of production time). High production costs occurred in manufacturing implant such as DCP due to difficulty of machining gliding hole used to a cutting tool noose type. This process takes a long time especially set-up a cutting tool, besides the cutting tool having higher price. The forming process is only performed during when bending of the DCP and carried out separately from the production machines. Due to long production time and production costs productivity of DCP product becomes low.

Recently manufacturing implant conducted by additive process [6,7,8,9,10,11,12] such as laser additive [13,14,15,16] and electron beam additive [17,18] especially for customised products related to special manner. This type of manufacturing is high cost at machine investment and very low productivity. By considering manufacturing, a typical product such as DCP can be improved its productivity by production process such as metal forming and casting.

This study proposed to increase productivity of DCP products by introducing forming process (cold forming). Forming processes have several advantages in terms of productivity and mechanical properties such as good mechanical properties due to the strain hardening [4,5]. The DCP implant products can also be proposed by metal forming employed a press machine. Thus, the resulting product will be highly dependent on the system of press dies mounted on the pressing machine.

DCP implant manufacturers by forming will be largely determined by the system dies used. This study used a closed die system, where the flow of material will be severely limited by the narrow space. This narrow space result to possibility of the product will be difficult to be removed [3]. Easy to whether the process of releasing the product from the mold is strongly influenced by the initial size of the workpiece. Therefore, it is necessary to determine the exact size of the beginning of the test specimen (workpiece), so that DCP implant products produced through the process of forming this can be easily removed from the mold.

2. Methods

Design of DCP established shape of gliding hole including dimensions prior to develop product by forming process. The design of DCP shown on Figure 1 was assigned as a target of production. The shape of gliding hole was developed by forming the predetermined holes using penetrator dies. Design and manufacture of the press tool was not discussed in this study. The press tool was assembled on press machine with capacity of 30 tons (Figure 2). Once forming process has acquired two pieces of DCP products. Because of the press-tool using a narrow gap system, it should consider the mould release system. Product release mechanism was employed by four trust springs. Prior to produce the DCP with material of steel AISI 316L, the machine was tested on workpiece made of aluminium to investigate behaviour of the material flow due to workpiece was plastically deformed on limited space.

2.1. Population and sample

A total of 18 of the workpiece is prepared with the following sizes: three pieces of work piece size of $120 \times 10 \times 3$ (mm²), three workpiece size of $120 \times 11 \times 3$ (mm²), three workpiece size of $120 \times 12 \times 3$ (mm²), three workpiece size $120 \times 10 \times 4$ (mm²), three workpiece size of $120 \times 11 \times 4$ (mm²), and three pieces of work piece size of $120 \times 12 \times 4$ (mm²). All workpieces manually machined by milling.

2.2. Research variables

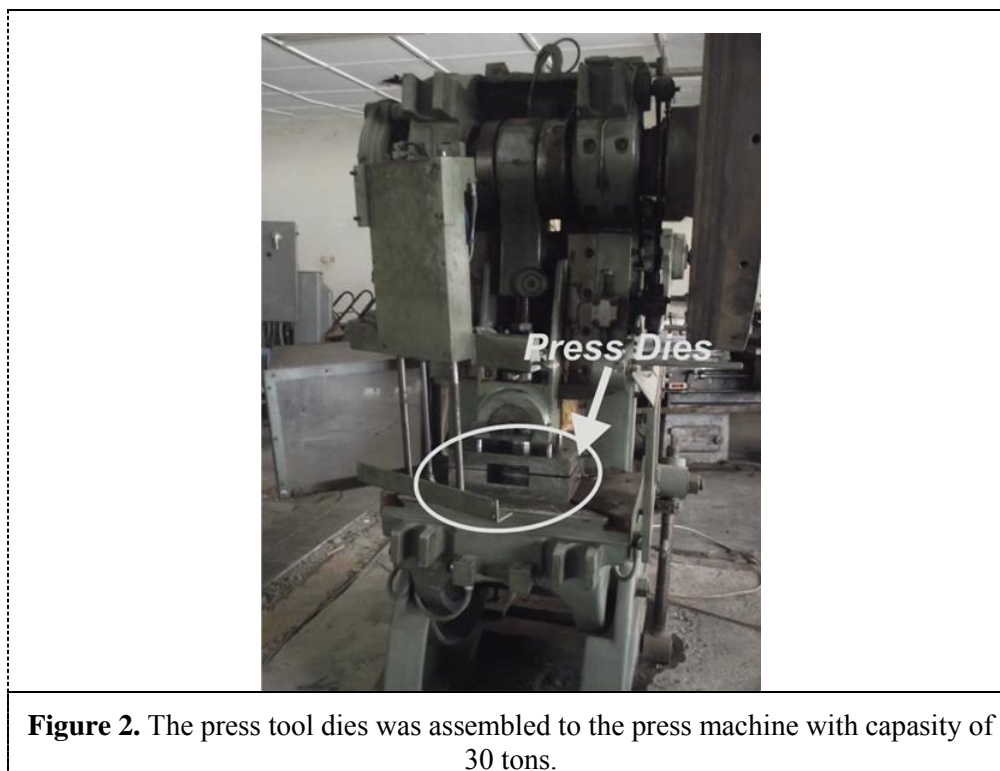
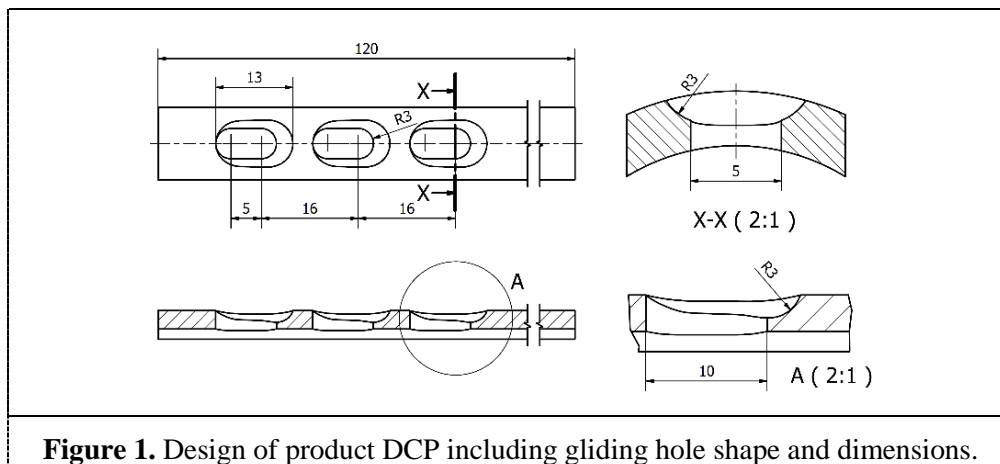
The variables of this research is the width of the specimen, specimen thickness and the diameter of the circle hole.

2.3. Materials

The specimens material to be used in this study is an aluminium plate that has a thickness of 3 mm and 4 mm. Perforated plate using a cutting tool diameter of 4 mm, 5 mm and 6 mm.

2.4. Instruments

Testing machine that will be used in this research is a pressing machine Hoffman PDN 66×225 (Figure 2), which has been fitted with press-tool. Measurement of workpiece dimensions using callipers and micrometres.



3. Results and Discussion

DCP product development are tested using aluminum material used to evaluate the behavior of the material flow, especially in the section of the gliding hole. The accuracy in determining the sizes of raw materials for manufacturing the gliding hole to be the aim of this study. The most important factor to consider when using narrow mold in the manufacture of products from metal through plastic deformation process is the ease of the product to be removed from the mold. On the other hand, measures should be fixed according to the product dimensions designed products.

The first scenario assigned the hole size on the raw material of 4 mm and width of 10 mm. This determination considering the proximity to the width of the hole products designed by 5 mm. Three workpieces made with the width of each of 10 mm, 11 mm and 12 mm. Tests on three shows that the raw material to a width of 10 mm product can be released from the mould, while the width of 11 mm and 12 mm product cannot be separated from the mould. The product of width of 10 mm, the hole area of the deformed material laterally, but in distant parts of the hole a little deformed. This makes the product becomes buldings on both lateral sides. The similarity pattern shown by the bulding plate thickness of 3 mm and 4 mm (Figure 3). While the outer sides of the plate developed curved wall on the region not perfectly plastically deformed (Figure 4). The curve wall due to presence of a gap that means not fully filled by material flow. That region due to bending momen only. Meanwhile, region highly deformed suppres material to flow and filled mold as straight wall obtained.

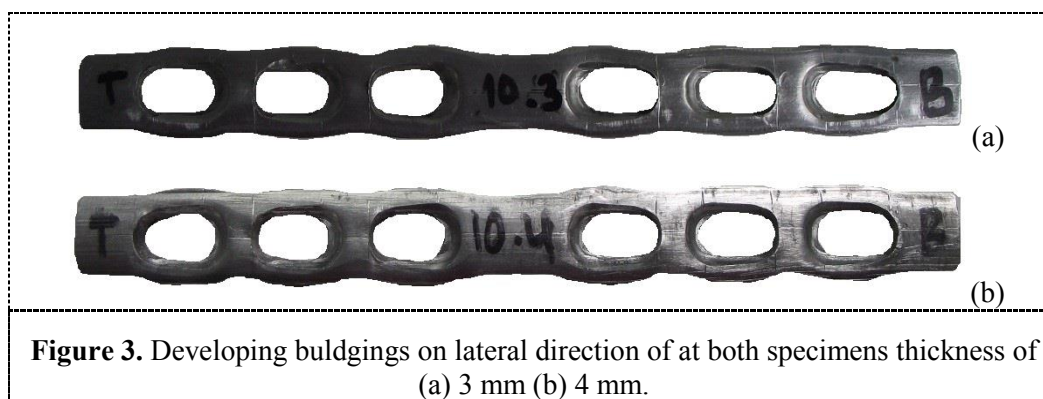


Figure 3. Developing buldings on lateral direction of at both specimens thickness of (a) 3 mm (b) 4 mm.

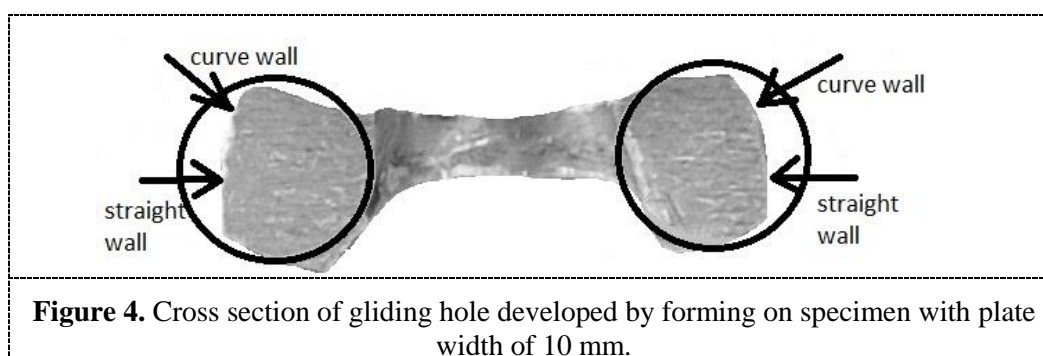


Figure 4. Cross section of gliding hole developed by forming on specimen with plate width of 10 mm.

The DCP product tested using plate width of 11 mm and 12 mm developed straight wall on both side (Figure 5). The straight walls due to flow material during deformation restrained by the lateral walls of the mould. At the plate width of 11 mm was shown bulging form especially on the part away from the hole (the central part of the product). This area is affected by plastic deformation holes and not by deformation thickness. That was elucidated by the thick plates before and after plastic deformation having the same. At 12 mm of width plates straight wall was obvious. Volume limited gap causes the material flow toward the side of the curve. In this section encountered left over plastic deformation (formed flash). Material flow also towards the free side (longitudinal direction) indicated

by an increase in length of the product. Constrains on the wall resulted in enormous pressure so that the product cannot be separated from the mould. To release the product from the mould was conducted by removing a series of press tool system (part by part). The result of a better product was obtained with this condition, such as flattened on the lateral side due to fully filled by material with no gap (Figure 6). These straight sections indicate material flow occurs through shear deformation mechanism.

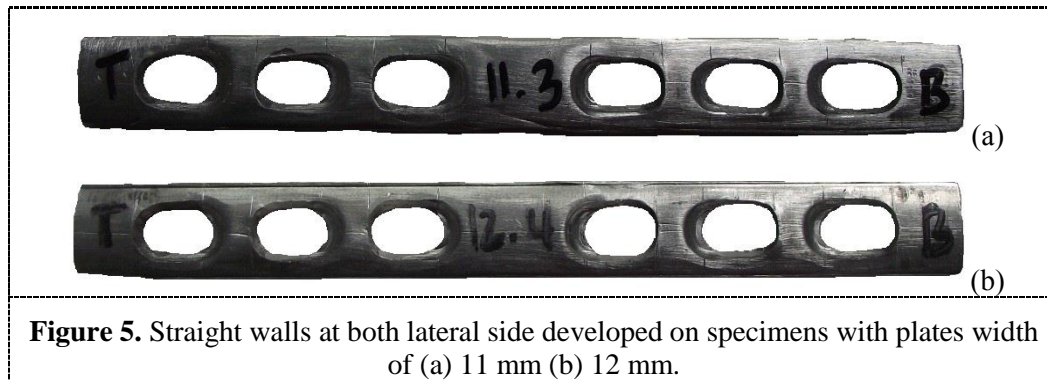


Figure 5. Straight walls at both lateral side developed on specimens with plates width of (a) 11 mm (b) 12 mm.

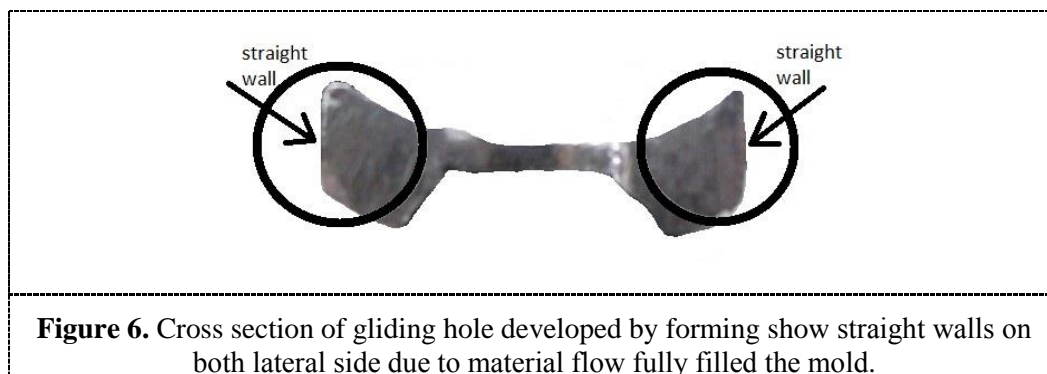


Figure 6. Cross section of gliding hole developed by forming show straight walls on both lateral side due to material flow fully filled the mold.

The second scenario was introduced to reduce the amount of pressure on the walls as a result of plastic deformation to the lateral side. The working principle of this scenario is to collapse the sides of the hole to make a gliding hole. In general, the changes made are as follows: a) the workpiece with a width of 10 mm length of the hole was changed to 11 mm (actual ± 10.7 mm) and width of the hole to 4.5 mm (± 4.6 mm actual); a) the workpiece with a width of 11 mm length of the hole was changed to 11 mm (actual ± 10.3 mm) and width of the hole to 5.5 mm (± 5.6 mm actual); and c) the workpiece with a width of 12 mm length of the hole was made into a 11 mm (actual ± 10.3 mm) wide hole into 6 mm (actual ± 6.2 mm).

By changing the dimensions of raw materials, in general the products can be released from the mould. No changes to the thickness of the workpiece with a thickness of 3 mm (actual ± 2.7 mm) and thickness of 4 mm (± 3.5 mm actual). It shows the setting steps press machine according to the desired. Therefore, the flow of material occurs only by the pressure of a pressure that forms gliding hole in the workpiece. Workpiece width changes occurred significantly to the field of the hole, while on the field between holes small amendments. It happened on the workpiece with a width of 10 mm, a result obtained products field extends not straight (wavy). Workpiece with a width of 12 mm showed the same width values in the field of the hole and between holes, in order to obtain products straight sides prolonged.

Workpiece with a thickness of 3 mm, the width of the hole in the arch in showing a consistent size of about 5.9 mm. This suggests that the gliding hole formed either narrow section. The width of the hole which was originally 4.6 mm and 5.5 mm enlarged to 5.9 mm, while the width of the hole which was originally 6.2 mm to 5.9 mm smaller. Good shape narrow hole also occurs in 4 mm thick, except

the workpiece with a width of 11 mm. This hole was precisely enlarged from 5.7 mm to 6.4 mm. This enlargement was caused by suppressing the urge passage holes laterally shifting more dominant than the hole so that the hole is not filled completely. Establishment of a good part of the narrow hole was also indicated by the width of the narrow hole that was consistent dimensions of approximately 10 mm.

The formation of the curve gliding hole with the mechanism of this process has shown good results. This can be seen from the dimensions of length (12.4 mm) and width dimensions (about 7 - 7.5 mm to 3 mm thick and 7.8 mm to 4 mm thick) gliding hole formed consistently. Similarly, the long dimension of the hole was consistent of 12.4 mm. The thickness of the thin section gliding holes for 3 mm thick plate was 0.6 - 0.9 mm, while for the 4 mm thick plate was 1 - 1.3 mm.

The size of the hole on the raw material can be determined theoretically by calculating the volume of gliding hole. Geometric shapes gliding holes are modelled with CAD is shown in Figure 7 (a). Volume geometry for DCP products designed slab thickness 3 mm and thickness of 0.6 mm of the thinnest part (Figure 7 (b)) about 34.58 mm³. The magnitude of the volume must be equal to the volume of pit geometry compensation is made on the basis of the geometry of the narrow slot on the product. With the method of trial and error can be determined dimensions of the holes on the raw materials that correspond to 3 mm thick plate was shown as in Figure 8(a). The hole in the raw material base of the hole was enlarged to the length of the hole 10 mm to 11.4 mm and the width of the hole of 5 mm to 5.5 mm. The centre point of the geometry of circles that do not form indentations must also be shifted by 0.25 mm from its basic position.

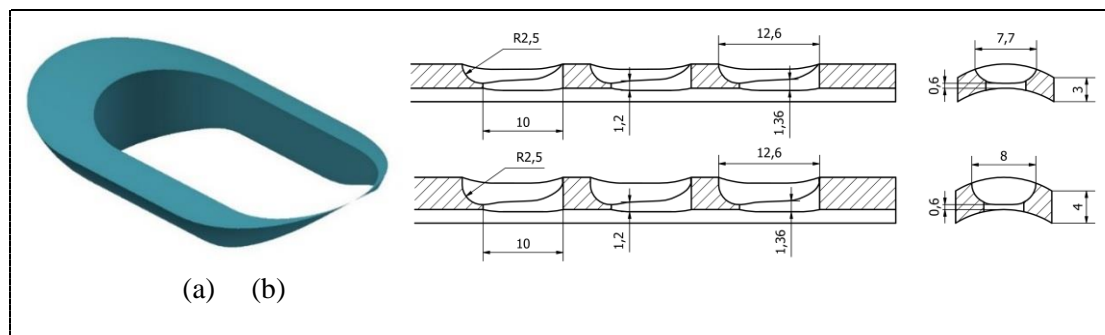


Figure 7. (a) Gliding hole geometry developed by CAD model, (b) gliding hole dimensions of DCP designed with each thickness of 3 mm and 4 mm.

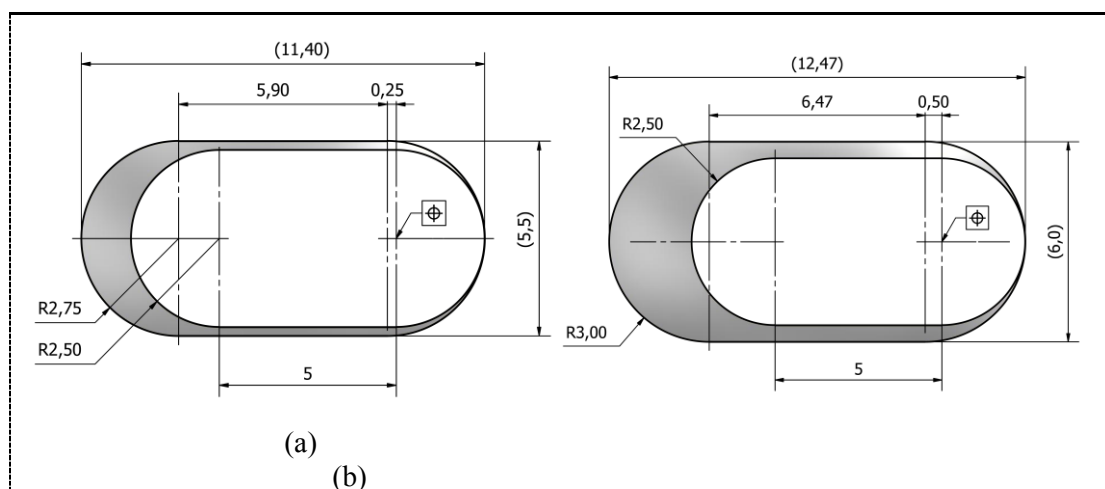


Figure 8. Dimensions of holes might by replaced to raw material with thickness of (a) 3 mm and (b) 4 mm

By the same method and maintained the thin section plate thickness of 0.6 mm (Figure 8 (b)), then the plates with a thickness of 4 mm gliding hole geometry volume calculation result was 89.74 mm^3 . Therefore, the size of the hole in the raw material was converted to a length of 12.47 mm and a width of 6 mm. By applying the results of these calculations, dimensions and holes sizes of raw material becomes as shown in Figure 9. Thus, the scenario making holes gliding was changed from the expanded hole to be the breaking down inner sides of the hole. This method can be applied to produce the DCP with the forming process. The width of the products made can be obtained by setting the width of raw materials by 12 mm.

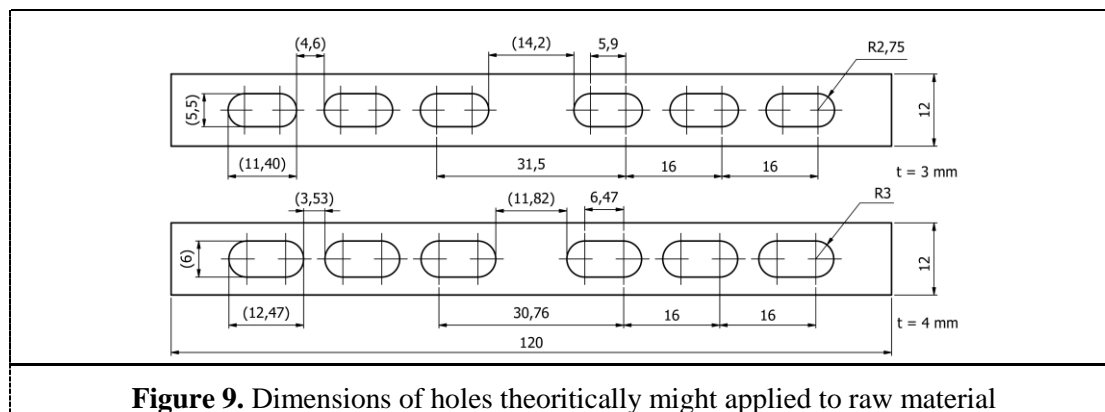


Figure 9. Dimensions of holes theoretically might applied to raw material

4. Conclusion

The gliding hole of the dynamics compression plate is designed to facilitate relative movement of pedicle screw during surgery application. The gliding hole shape is then geometrically complex. The gliding hole manufactured using machining processes used to employ ball-nose cutting tool. Then, production cost is expensive due to long production time. This study proposed to increase productivity of DCP products by introducing forming process (cold forming). The forming process used to involve any press tool devices. In the closed die forming press tool is designed with little allowance, then work-pieces is trapped in the mould after forming. Therefore, it is very important to determine hole geometry and dimensions of raw material in order to success on forming process. This study optimized the hole sizes with both geometry analytics and experiments. The success of the forming process was performed by increasing the holes size on the raw materials. The holes size need to be prepared is diameter of 5.5 mm with a length of 11.4 mm for the plate thickness 3 mm and diameter of 6 mm with a length of 12.5 mm for the plate thickness 4 mm.

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