The Effect of Aluminum Profile Thickness and Type of Lubricant on Punch Force

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Abstract. The problem lies in the length of time it takes to make holes in the key housing on the aluminium door frame profile using a drilling machine, manual grinding, and filing. The aim of the study was to obtain a prototype for a portable door housing key hole punch. The method of making a press tool for a key housing punch on an Aluminum door frame profile in a portable manner includes the design of the frame and the shape of the hole, making a prototype of a portable punching mechanism frame, making a punch with a wire Electric Discharge Machine (EDM) in the exact shape of the key housing hole, testing the punching on different door frame profile thickness and lubrication variations, as well as data analysis. The test results show that (1) the sharp edge angle of the 3-degree punch is too small which makes it easy to break after the punch is used more than 20 times; and (2)The average punch force resulting from perforation without lubrication compared to oil lubrication decreased by about 0.5% and between with oil lubrication compared to grease lubrication decreased by about 4%.

Keywords: door lock housing, door Aluminum profile, lubrication, punch and anvil, portable punching equipment

1 Introduction

Perforating metal plates can be carried out in various ways, including by drilling, grinding, milling, or perforating using a punch and die for various hole shapes, ranging from circular shapes or certain shapes. Perforation using punch and die is generally carried out for materials in the form of metal plates ranging from relatively thin thickness to thick enough thickness with relatively good perforation results when using a precise press tool and the use of materials that are quite hard and sharp. Problems begin to arise if the holes are not in the form of a single flat plate, but in the form of a rectangular profile which of course has holes in the inside. Difficulties are encountered in being able to place the die in axis across the surface of the plate to be punched. Accidents can occur if the movement position of the punch is not in line

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with its partner mold, due to a collision that can blunt or cut the sharp surface or break it.

2 Related Works

In previous experiments, preliminary results have been obtained indicating that punching plates using a punch and a lead bearing can produce relatively good holes, but for simple shapes in the form of a combined semicircular pair with longitudinal grooves, the punching is still less precise. Perforating the plate using a punch is assisted by using the compressive force of a car jack that is available and can be purchased in the market. Lead bearings or hard rubber or wood may be used in preliminary experiments. Rubber is a hydrocarbon polymer contained in latex (the thick sap of plants that freezes when exposed to free air). In industry, synthetic rubber can be made. Rubber can be deformed by a large force that can return to its original shape (almost all of it) if the force is removed [1].

Manufacture of the door frame profile punching device in the form of a rectangular hole in the center with a thickness of up to 1.5 mm using a punch and a Lead bearing. The compressive force will be measured using a Compression Testing Machine for the design requirements of the force on the lever that most adults can perform with a force on their right hand. The effect of thickness and lubrication conditions is used as an independent variable and the dependent variable is the force required for the perforation process at various thicknesses, while the controlled variable is the consistency of the thickness of the aluminum material, the consistency of the lubrication conditions (with and without certain lubricants, the similarity of the type of Aluminum material, and the speed of testing). The pressure is made constant. The punch is designed to follow the shape of the key housing on the market, so the results can be directly used to meet the needs of punching the key housing on the market with a certain tolerance for easy insertion of the key housing on the aluminum frame.

Punching with a precise punch can improve the method of making blanks by using a punch which results in removing residual burrs due to perforation [2]. Inaccuracy in dimensions between the punch and the die can result in the residue in the form of burrs due to making holes using a punch.

To test the effect of six (0.009, 0.064, 0.12, 0.175, 0.231 and 0.287 mm) on finely cutting shear depth, burr height and blanking force on aluminum sheets with a thickness of 0.8, 1, and 1.5 mm, blanking was used 6, 8, 10, and 12 mm die diameter shows that burr, smooth-sheared and punch force are closely related to the clearance value [3]. The effect of differences in clearances, aluminum thickness and blank diameter shows a close relationship to burr height, surface shear, and punch force.

The use of different materials for punch and die may become more cost competitive for metal forming processes and is also a trend with the aerospace and automotive industries using knowledge to improve product quality and cost reduction strategies [4]. Using different punch and die materials can improve product quality and save costs.

In blanking, the part that is not hit by the punch is the part that is used, and the rest is scrap. In punching, the part that is hit by the punch is discarded as scrap, and the remaining part is used [5]. Between blanking and punching as an inverse relationship, for blanking on the inside of the material hit by a punch is used, while punching on the outside that is not hit by a punch is used.

The blanking punch of K340 tool steel is tested with clearances of 5%, 10%, and 15% of sheet thickness. The results show that the blanking clearance size is strongly influenced by the wear intensity of the blanking punch edge and the degree of deflection of the hook product [6]. The clearance of the blank is affected by the wear of the blanking punch edge and the degree of deflection of the hook shape product being made.

The relationship between shear strength and tensile strength for Pure Al and AA 6061 materials was shown to be worth a shear strength of 95.3 MPa and a tensile strength of 161.5 MPa for Pure Al and a shear strength of 216 MPa and a tensile strength of 320 MPa for AA 6061 [7]. Various materials have a relationship between shear strength and tensile strength. For Pure Al the shear strength is about 59% of the tensile strength and for AA 6061 the shear strength is about 67% of the tensile strength.

The quality of the S275 steel hole is 1.4 mm thick with 9 punching dies made with clearance angles of the die of 0.25°, 0.50°, and 0.75° for each die size of 20.225 mm, 13.225 mm, and 12.225 mm. Burr formation and die weight loss were monitored for the 10th, 50th, 100th, 500th, and 1000th punching. The punching results show that the decrease in die weight and wear indication increases with the increase in the number of punching with the largest weight loss in the early stages of punching (10-50th). The lowest weight loss was obtained for molds with clearance angles of 0.75° corresponding to the lowest wear incidence [8]. Metal punching is widely used for mass production because it is simple, productive and inexpensive. The quality of the punched product is highly dependent on the tool geometry, sheet material, punching conditions, punching and molding materials, and tool wear. The decrease in die weight due to wear increases with the increase in the number of punching which decreases the largest in the initial stage up to 50 repetitions and then decreases up to 1000 repetitions.

The blanks of 0.1 to 1 mm of mild steel sheet with a diameter of 1 to 4 mm were analyzed by the plastic-elastic FEM based on the incremental plasticity theory to evaluate the effect of clearance, friction, sheet thickness, punch/die size and blanking layout on the sheet deformation indicates that the reduction in clearance increases the blanking load which in turn increases the coefficient of friction [9]. The effect of reduced clearance can increase friction which is simultaneously accompanied by the effect of sheet thickness, punch/die size and blanking position on sheet deformation.

The objective of hard coatings for blanking/piercing tools is to explore the possibility of reducing lubrication and replacing expensive tungsten carbide materials in blanking/piercing through hard coatings showing that hard PVD coatings are successfully applied to blanking/piercing, even to softer tool steels, so as to reduce friction and wear and reduce punch costs [10]. Hard material coating with PVD has been successfully applied to blanking/piercing, but it is necessary to choose a softer material that reduces friction and wear and ultimately lowers punch costs.

Thin sheet metal blanking and punching products with elastic media are of low quality, due to the large geometric distortion of the separate parts and of the part in the cut zone, which is why these methods can be recommended for the manufacture of non-critical parts that do not require high accuracy [11]. The blanking and punching methods of thin sheet metal with elastic media can be used for the production of non-critical products that do not require precision.

Product costs and component weight are reduced as much as possible by reducing tooling costs in the sheet metal industry which make up a large part of the overall cost of producing a component. It is very important to keep costs down by ensuring that the tools work for long periods of production without interruption. The piercing die project is a design and development project consisting of a number of parts such as housing, punch, punch holder, stripper, die cutting, top plate, bottom plate etc. for piercing a 12 hole products taking into account the important parameters of the die, such as the cause of the burr, the cause of the failure of the punch, the cost of the failure effect, the tool life, and the productivity that the piercing die delivers can increase tool life, productivity, and without increasing trial costs in the design [12]. Efforts to reduce product costs and component weight are reduced from tooling costs in the component industry that can work for long periods of time without interruption, thereby increasing productivity and reducing trial costs in designs.

A new technology that is able to improve the surface quality of sheared products from SK85 material by quenching and tempering through a combined process of blanking and press shaving in the first stage of piercing and shaving in the second stage by placing the product in a hydrochloride acid solution (pH 1.0 solution, soaking time 100 hours at temperature 30oC) to obtain a hole product with dimensional accuracy and good edge surface quality for thicknesses up to 4 mm and hardness up to 55 HRC which is equivalent to TS 2075 MPa grade material [13]. New technology has been obtained by combining blanking and press shaving in the first stage of piercing and shaving at a later stage by immersion in a hydrochloride acid solution.

A slight clearance punching on ultra high strength steel sheets, JSC980Y using a punch with a slightly edge radius can improve the quality of the sheared edge. There were no cracks at the punch edges due to the relaxed concentration of deformation in the punch with a slightly edge radius and delayed fracture. An edge radius of 0.13 mm is effective for improving the quality of the sheared edges of JSC980Y and can be polished [14]. The presence of a punch with an edge of 0.13 mm radius can improve the edge quality of JSC980Y and can polish the surface.

Different operations performed on one die punch setup in one stroke on 3 separate setups (piercing, slotting, and profile blanking) for door hinge products can reduce production rates and increase cycle times and costs. The analysis of Von-Mises stress and fatigue life was carried out on the Ansys 14.0 workbench analysis and the results were compared with the theoretical results which differed by 5% from the permissible limit. The blanking and piercing operation cycle time is about 4 minutes with a production cost of about 6 Indian Rupees (₹, INR) [15]. A series of 3-step piercing, slotting, and profile blanking of door hinge products can reduce production rates and increase cycle times and costs. The results of the analysis of Von-Mises stress and fatigue life by Ansys 14.0 show a difference of 5% from the allowable limit between experimental and theoretical.

Three different advanced high-strength steels (AHSS) (DP, TRIP, TWIP) were shown to vary in decisive blanking parameters such as clearance, shear angle and sheet position angle. The force transfer curves show that process parameters, such as shear angles (0o, 2.5o and 5o), sheet position angles (5o, 10o, 15o) and clearance (5%, 10%, 15%) have a significant influence on the applied forces occurred during the cutting process [16]. The cutting forces in blanking are affected by the shear angle, sheet position angle, and clearance.

The main objective of punching die design and analysis is to design and simulate interchangeable dies and punches and reduce material weight by changing the material set of the die and eliminating production time losses and reducing manpower from sheet loading and unloading [17]. Swapping the punch on the same die can reduce material weight and eliminate production time losses and reduce manpower for loading and unloading punched product sheets.

Perforations at 3 different angles (0o, 3°, 6°) for their effect on the perforation process of two samples of AA1050, and 2 samples of AISI304L steel showed that increasing the angle of the punch tip led to a reduction in the force on the piercing process [18]. The effect of the punch tip angle causes a decrease in the force on the piercing.

3 Materials and Methods

The punch material used for piercing the aluminum profile of the door frame is SKD 11 with a chemical composition is shown in Table 1 and the heat-treatability and hardness achieved are shown in Table 2 [19].

Table 1. Chemical composition of SKD 11 [19].

JIS	DAIDO Brand	Chemical composition (%)									
		C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V
SKD11	DC11	1.40 ~ 1.60	≤ 0.40	≤ 0.60	≤ 0.03	≤ 0.03	≤ 0.25	≤ 0.50	11.00 ~ 13.00	0.80 ~ 1.20	0.20 ~ 0.50

Table 2. Heat treat-ability and hardness SKD 11 [19].

Heat treatment temperatur (°C)			Hardness			Transformation temperature (°C)	
Annealing	Hardening	Tempering	Annealing (HB)	Hardening (HRc)	Tempering (HRc)	Ac	Ar
830-880 Slow cooling	1,000-1,050 Air cooling	150-250 Air cooling 500-530 Air cooling	≤ 255	≥ 61	≥ 58	815-875	765-705

The door frame profile material made of Aluminum alloy type AA1100 is shown in Table 3 [20].

Table 3. AA1100 material for door frame [20].

Materials	Chemical composition (%)						
	Al	Cu	Fe	Mn	Si	Zn	Residuals
AA1100	99.0 ~ 99.95	0.05 ~ 0.20	0.95 max	0.05 max	0.95 max	0.1 max	0.15 max

Punch materials used in perforating aluminum door profiles before forming the sharp edges is shown in Figure 1.

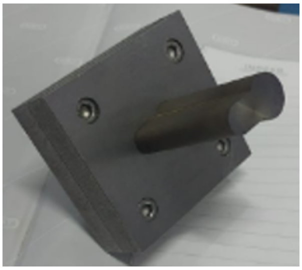

Fig 1. Punch material used in perforating aluminum

TarnoGrocky Universal Compression Testing Machine for perforating Aluminum door profiles and Punch results from machining the sharp side shape with a CNC Milling Machine is shown in Figure 2.

Fig 2. TarnoGrocky Universal Compression Testing Machine for punching Aluminum door profiles and Punches as a result of machining the shape of the sharp side with a CNC Milling Machine.

The base used in the perforation is Nylon plastic material and the punch holder is shown in Figure 3.

Fig 3. The base used in the perforation is Nylon plastic material and its punch holder

The punch material is made of SKD 11 type tool steel whose hardening temperature reaches 1050° which is cooled in air, while the tempering temperature can be selected at 300° to reduce the brittleness from about 61 HR_C to 58 HR_C. The hardening punch set at 1050° in the muffle furnace is shown in Figure 4.

Fig 4. Hardening punch set at 1050° in Muffle furnace

The results of perforating the Aluminum Profile in the initial experiment without lubrication with a thickness of 0.9 mm and a punching force of 1045 kg which showed neat results and without burrs are shown in Figure 5.

Fig 5. The results of perforating the Aluminum Profile in the initial experiment without lubrication

4 Results and Discussion

The force of the AA1100 profile perforation with variations in the thickness of the material to 0.9 mm, 1.1 mm, and 1.3 mm with treatment conditions without lubrication, with lubricating oil, and with lubricating grease with three repetitions are shown in Table 4.

The average punch force resulting from perforation without lubrication compared to oil lubrication decreased by about 0.5% from 1671.4 kg to 1662 and between with oil lubrication compared to grease lubrication decreased by about 4% from 1662 kg to 1598.1 kg.

Table 4. Table captions should be placed above the tables.

Punching force for AA1100 profile door lock housing (kg)										
No.	Treatment	Profile thickness (mm)								
		0.9			1.1			1.3		
	Code	1a	1b	1c	1d	1e	1f	1g	1h	1i
1	Without lubri- cation	1606.6	1563. 2	1 674	1761. 8	17 07.2	1684. 4	16 18	1740.4	1686.8
	Code	2a	2b	2c	2d	2e	2f	2g	2h	2i
2	Oil lubrication	1597.6	1665. 6	1 597.0	1769. 6	17 18.0	1744. 2	16 77.0	1644.2	1707.0
	Code	3a	3b	3c	3d	3e	3f	3g	3h	3i
3	Grease lubrica- tion	1471.0	1441. 0	1 404.0	1663. 0	15 45.4	1585. 8	15 37.6	1613.2	1589.4

The relationship between the perforation force on the Aluminum profile and the stroke with a thickness of 0.9 mm shows an average result of 1614.6 kg from a minimum range of 1563.2 kg and a maximum of 1674.0 kg with a stroke range from 1.32 mm to 1.96 mm which is possible because the Nylon plastic base has been partially positioned has been used as the basis for the previous punching, so that the surface flatness has been partially deformed due to the stresses in the previous punching is shown in Figure 6.

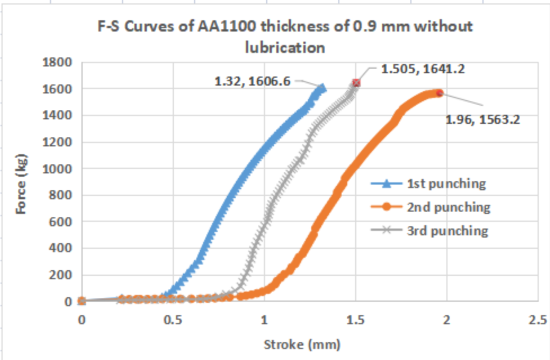

Fig 6. The relationship between the perforation force of the AA1100 profile on the stroke with a thickness of 0.9 mm

The relationship between perforation force and stroke in various thicknesses of Aluminum profile is shown in Figure 7. At 0.9 mm thickness Aluminum profile shows a punching force of 1606.6 kg; the thickness of the Aluminum profile of 1.1 mm shows a punching force of 1707.2 kg, and the thickness of the Aluminum profile of 1.3 mm shows a punching force of 1567.2 kg. The comparison between the punching force at the thickness of the Aluminum profile 0.9 mm and 1.1 mm showed an increase of 6.26%, while between the thickness of 1.1 mm to the thickness of 1.3 mm it decreased by 8.2%.

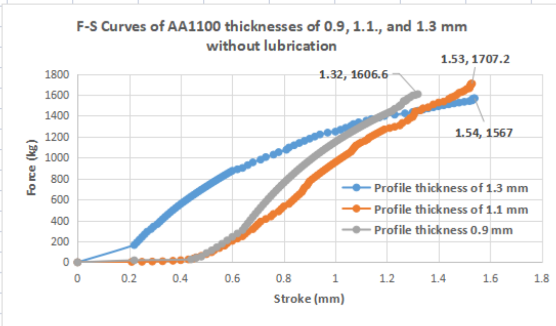

Fig 7. Relationship between perforation force and stroke in different thickness of Aluminum profile

The profile of AA1100 after perforation of various thicknesses and conditions without lubrication is shown in Figure 8.

Fig 8. AA1100 profile after perforation of various thicknesses and conditions without lubrication

The results of perforating the shape of the door lock housing for a profile thickness of 0.9 mm without lubrication or dry conditions are shown in Figure 9. It appears in each punched result there is a hole made after perforating the aluminum door frame profile, because the punch is not equipped with an ejector to help release it. In making the sharp side of the punch, an angle of 3^{o} is chosen to obtain adequate sharpness. The results of the perforation show a clean edge of the remaining cutting by punch or without burr which the perforation is categorized as successful.

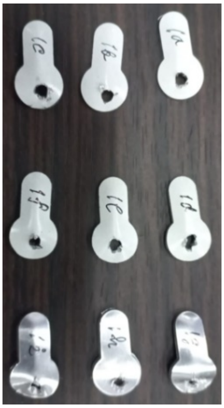

Fig 9. The results of perforating the shape of the door lock housing for a profile thickness of 0.9 mm without lubrication or dry conditions

Punch partially fractured after being used for more than 20 trials is shown in Figure 10, on the sharp edge that is broken it is indicated that the punch angle of only 3^{o} is too small and the depth of 5 mm is too deep compared to the thickness of the profile punched for only 1.5 mm thickness, so it needs to be remade with a sharp side angle of 10^{o} to anticipate the ease of breaking after being used for a certain amount. The depth of the indentation of the tip of the punch is made enough 3.5 mm and at the bottom corner a sufficient radius is made so that the perforation is easily removed by ejecting from the center of the punch axis. The brittle nature can be reduced by the tempering process after hardening.

Fig 10. Punch partially fractured after being used more than 20 times

A new punch with a sharp edge of the 10^{o} punch tip which has been equipped with an eject hole in the blank for removal is shown in Figure 11.

Fig 11. A new punch with a sharp edge of the punch tip 10o which has been equipped with eject holes in the blanks

The results of the perforation of the key housing shape after being obtained without the need to make a circular hole for its release, because the ejector hole has been provided is shown in Figure 12.

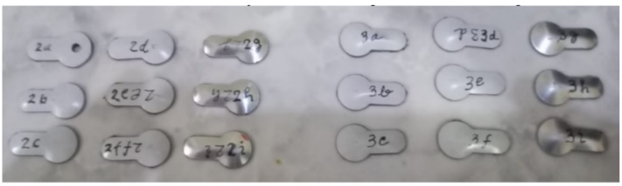

Fig 12. The results of perforating the shape of the key housing after being obtained without the need to make a circular hole for its release under conditions: (a) with oil lubricant, and (b) with grease lubricant

5 Conclusions and Recommendation

The conclusions from the test results of perforating Aluminum profiles with punch and anvil from Nylon for various thicknesses and lubrication are:

1) The sharp edge angle of the 3o punch is too small which makes it easy to break after the punch is used more than 20 times; and
2) The average punch force resulting from perforation without lubrication compared to oil lubrication decreased by about 0.5% and between with oil lubrication compared to grease lubrication decreased by about 4%.

Recommendations for future work:

1) The sharp side angle of the punch is made larger to about 10^{o} so as not to break easily and the indentation depth is made as deep as 3.5 mm for a profile thickness of 1.5 mm and equipped with an ejector through the center or punch axis; and
2) In each perforation, grease lubricant should be used or at least use oil lubricant.

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References

1. S. Hadi, Advanced Materials Technology, ISBN: 978-979-29-6366-3, Andi Offset, Yogyakarta, Indonesia, 2018.
2. K. Junlapen, K. Mizuochi, and N. Koga, “Precision punching of 5052 aluminum alloy sheets,” J. of Japan Inst. of Light Metals, vol. 59(9), pp. 486-490, May 2009.
3. Z. Tekiner, M. Nalbant, and H. Gürün, “An experimental study for the effect of different clearances on burr, smooth-sheared and blanking force on aluminium sheet metal,” Mat. & Design, vol. 27(10), pp. 1134-1138, June 2006.
4. C. Afteni, G. Costin, I. Iabob, V. Păunoiu, and T. Virgil, “A review on sheet metal rubber-pad forming,” The Annals of Dunărea De Jos, Univ. of Galaţi, Fascicle VI, Tech. in Mach. Build., pp. 1-6, August 2018.
5. V. Boljanovic, Sheet Metal Forming Processes and Die Design, Industrial Press, New York, USA, 2004.
6. J. Mucha, and J. Tutak, “Analysis of the influence of blanking clearance on the wear of the punch, the change of the burr size and the geometry of the hook blanked in the hardened steel sheet,” Mat., vol. 12(8) 1261, pp. 1-16, April 2019.
7. R. K. Guduru, K. A. Darling, R. Kishore, R. O. Scattergood, C. C. Koch, and K. L. Murty, “Evaluation of mechanical properties using shear-punch testing,” Mat. Sci. and Eng.: A, vol. 395(1-2), pp. 307-314, December 2005.
8. N. A. Jaafar, A. B. Abdullah, and Z. Samad, ”Effect of punching die angular clearance on punched hole quality of S275 mild steel sheet metal,” The Int. J. of Adv. Manuf. Tech., 101(5-8), 1553-1563, November 2018.
9. S. Maiti, A. Ambekar, U. Singh, P. Date, and K. Narasimhan, “Assessment of influence of some process parameters on sheet metal blanking,” J. of Mat. Proc. Tech., vol. 102(1-3), pp. 249-256, December 2000.
10. B. Podgornik, B. Zajec, N. Bay, and J. Vižintin, “Application of hard coatings for blanking and piercing tools,” Wear, vol. 270(11-12), pp. 850-856, February 2011.
11. I. E. Semenov, and S. V. Povorov, “Simulation of thin-sheet metal blanking and punching by elastic mediums,” IOP Conf. Series: Mat. Sci. and Eng., vol. 537, 032027, June 2019.
12. G. S. Arvind, Y. M. Jai, B. J. Yogesh, Design and modification of piercing die to increase tool life and productivity. Int. J. of Research Pub. in Eng. and Tech. [IJRPET], vol. 3(7), pp. 112-126, July 2017.

13. M. Murakawa, M. Suzuki, T. Shionome, F. Komuro, A. Harai, A. Matsumoto, and N. Koga, "Precision piercing and blanking of ultrahigh-strength steel sheets," Proc. Eng., vol. 81, pp. 1114-1120, October 2014.
14. K. Mori, Y. Abe, Y. Kidoma and P. Kadarno, "Slight clearance punching of ultra-high strength steel sheets using punch having small round edge," Int. J. of Machine Tools and Manuf., vol. 65, pp. 41-46, October 2013.
15. S. P. Avadhani, P. Phadnis, R. Nikhil and S. P. Patil, "Design and analysis of blanking and piercing die punch," Int. Research J. of Eng. and Tech. (IRJET), 04(05), 2760-2765, May 2017.
16. A. Mackensen, M. Golle, R. Golle and H. Hoffmann, "Experimental investigation of the cutting force reduction during the blanking operation of AHSS sheet materials," CIRP Annals, vol. 59(1), pp. 283-286, 2010.
17. A. K. Kumaresh, B. Balaji, M. R. Kumar, "Design and analysis of punching die," IJRET: Int. J. of Research in Eng. and Tech., vol. (05)04, pp. 249-255, April 2016.
18. H. A. A. Alasharif, "The Effect of Punch Shear Angle on Shear Force During the Piercing Process," Master Thesis, Department of Mechanical Engineering, Institute of Graduate Programs, Karabuk University, Turkey.
19. Anonymous, 2021, "Beyond the Special, DC11 is equivalent with SKD11", Daido Steel Co. Ltd., available at: www.daido.co.jp
20. Anonymous, 2022, 1100 aluminium alloy, available at https://en.wikipedia.org/wiki/1100_aluminium_alloy#:~:text=The%20alloy%20composition%20of%201100,Iron%3A%200.95%25%20max