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Design and Analysis of Punch and Die of a Micro Blanking Tool

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Abstract*: Stamping dies one of the essential industries in engineering. The sheet metal blanking procedure is a shearing operations. In the blanking procedure the sheet metal is detached from the bulky portion of stock through the application of shearing force on the sheet. Nowadays, the increase of gadgets and smart phone is because of the 4th industrial revolution. This situation leads the demand for micro parts that will include in electronic devices. The main problem occurred in sheet metal stamping is damage to the punch after running thousands of stamping process. This paper focuses on designing a micro blanking dieset that meet the industrial demand. The study is conducted using solidworks to design the micro blanking dieset and perform analysis using FEM. The result of FEA will be calculated using e-fatigue to get the lifecycle for the punch.

Keywords: Micro-blanking, lifespan, station optimisation, AutoCAD, ABACUS/ CAE.

I. INTRODUCTION

During the sheet metal blanking technique where the sheet metal portion is detached from the large portion by applying shearing force, the removed part is named as blank. It is not scrapping also, but rather than desired part shape. Die, press and sheet metal specimen are the components involved in the blaking procedure. The sheet metal is mounted over blanking press of die. The die cavity is well designed to the desired cutout shape according to the standards. Blanking process is a typical process that was commonly used in industries worldwide. Products such as mechanical chain, automotive body parts, automotive parts and many more will undergo blanking process to produce the parts. Nowadays, this world watches the rising of 4th Industrial Revolution where Internet of thing become a necessary and got much demand.

Furthermore, this situation leads to the increasing of electronic devices. The use of electronic devices becomes common for people, even a kid has a smart phone, and a car has a lot of electronic devices nowadays. To date, the growing requirements of micro parts keeps increasing. Hence, the manufacturing procedure of micro parts have to meet the demand. Micro sheet metal forming is a simplified micro manufacturing procedure to produce the micro parts. In this technology, the tool is an feature that embraces a vital role since it directly disturbs the geometry and the quality of the micro part.

The size of the tool is a major challenge in the manufacturing process. Damage to the punches is one of the major problems during high production stamping operation. Usually the problems during high production stamping are tool wear. After thousands time of stroke punch will have tool wear and more seriously punch can break apart. For micro blanking punch, the punch is small and the probability to broken also increased. The design of micro stamping tool influences the cutting force and die lifetime, the precision of stamping which may not be proper and design need to be considered. Commonly there are a few types of punch face that are single flat, double flat, bevel shear and double bevel shear. Design of the cutting punch also can affect the piercing force. The die and sheet metal part are also very critical so that the die strength can be control to avoid defects such as rupture. During high production strokes, the structure of die will be affected by the stress that occurs. Furthermore, the product quality and defects should be controlled. This study has a few aims that are to propose 3d model design of punch and die for micro sheet metal forming part. Besides, this study aims to analyse the design using three different materials for micro forming parts by using FEA and lastly to analyse sheet metal punch lifecycle using fatigue calculator.

II. LITERATUR REVIEW

The sheet metal is a metal formed by industrial procedures in thin and flat sheets.

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Sheet metal is the primary forms used in metal production and can be cut and bent in several ways; infinite everyday objects are made of sheet metal. The thickness can change significantly, fragile sheets are considered foams or sheets, and sheets with a thickness of more than 6 mm are considered sheets of steel or structural steel (Boljanovic, 2004). Shearing is the method of cutting out of sheets using a die and punch, relating shear stress along the thickness of the piece. A die and punch or a couple of cutting edge are used in shearing. Shearing occurs by plain plastic deformation locally trailed by fracture, which spreads bottomless into the thickness of the blank. The clearance between the die and punch is an important parameter, which decides the shape of the sheared edge. During blanking proceure, a shearing procedure is employed, where a portion of sheet metal is detached away after the main piece of stock by spread on adequate shearing force. The detached part is named as blank, and is usable but relatively the chosen part. There are a few shearing processes to be included.

- Separating process: Separating a portion from the residual sheet, without creating any scrap. The punch makes a cut line which might be curved, straight, or angled.
- Partin process: Detaching a portion from the residual sheet, by stamping away the material among fragments.
- Slotting Process: A punching act that forms four-sided holes in the sheet. Occasionally labelled as piercing regardless of the dissimilar shape.
- Perorating process: Piercing a close design of a large amount of holes in a single action.
- Nibbling process: Punching a series of small overlapping slits or holes along a track to cutout a larger contoured shape.
- Lancing process: Making a fractional cut in the sheet. The material is left aside for bending and formation of a shape, such as a tab, vent, or louver.
- Notching process: Punching the edge of a sheet, forming a notch in the shape of a portion of the punch.

Lately micro blanking in the mass production primarily mentions the manufacturing of electronic parts (Lubis & Ristiawan, 2017). Multi punches for instance, close to ten punches tooling is used for creating these parts. In micro blanking, the used material should be prescribed more detailed than at macro level by the microstructures and grain boundary properties. The researcher stated that if an average of grain size approaches the material thickness, the blanking behavior would be affected obviously (K. Fujimoto et al., 2006). Blanking and punching dies are branded as cutting dies. They are simple, mixture, or complex. Creating a blanking die is inexpensive and is quicker in process compared to a trim die. The major parts are die block, stripper plate, punch plate, back plate, punches, pilots, die-set and fasteners.

- Die Plates are made of aluminum or steel plates and agrees to the dimensions of the die. They work as the basis for rising the working die apparatuses. These portions can be machined, milled or grounded to make it parallel and flat within a critical tolerance (Reddy et al., 2016).
- Stripper Plate: Stamping dies need some form of stripping the part from the end of the punch upon extraction. Common kinds of strippers for achieving strippler plate consist of Fixed, Urethane and spring. Stripping force differs based on part material form and thickness as well as the punch to matrix clearance.
- Guide Pins and Bushings: Guide pins, occasionally denoted as guideposts or pillars, performs along with guide bushings to exactly line up with the upper and lower die shoes. Even though many specialty positioning techniques may be used to connect these components, only two types of guide pins and bushings are present: friction pins and ball bearing style pins (Reddy et al., 2016).
- Screws, Dowels, and Keys: Screws secure the occupied mechanisms between the top and bottom die shoes. The socket head cap screw fastens the stamping dies. The tough tool steel screw regularly labelled as a head screw, provides superior holding strength and power.
- Springs: Springs supplies the force required to hold, strip, or form metal. Numerous springs are employed in stamping dies. The choice of springs are based on several factors, comprising of essential force and travel, the spring's life anticipation, and cost.

Fatigue failure is described as the inclination of a material to fracture using progressive brittle cracking under recurrent change or cyclic stresses of the power significantly lower than the normal strength. Although the fracture is of a brittle type, takes few moments to circulate, subject to intensity and rate of recurrence of the stress cycles. Abaqus CAE software can be used to run fatigue analysis using finite element method.

III. METHODOLOGY

A. Project product

This project product is microelectronics pin connecter. Micro pins functional as to attribute power connections, input and output connections, and communications connections at electronic boards. The size of the micro pin is 7.4mm long, 1 mm width, and 0.1 mm thickness. For this project, there are three types of pins, aluminum, copper, and brass will be analysing.

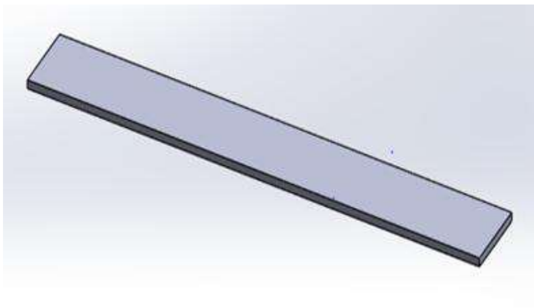

Fig. 1.Project product – 3D model

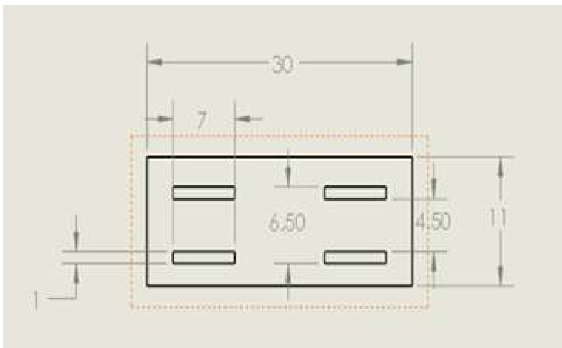

Fig. 2. Project product – 2D model

B. Design micro blanking die

In this section, the 3d design of complete micro dieset will be shown. The assembly of the upper die, middle die and lower die will also be showed. Apart from that, all components in the complete dieset will be list in the table. Besides, material and dimension of upper die, middle die, and lower die will be discussed.

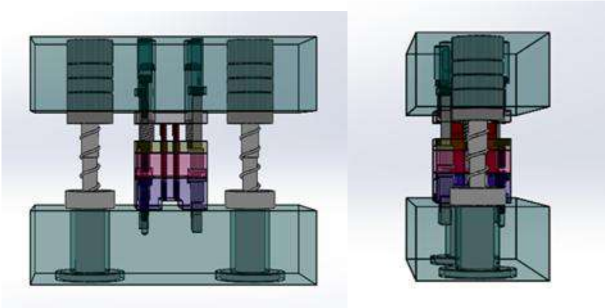

Fig. 3.Full view of the dieset design

C. Progressive Die component redesign

The upper die consists of the top plate and blanking punch. Besides, there are a few components on the upper die that is dowel pin, socket head screw, stripper bolt, and guide post. Top plate and blanking die were assemble using socket head screw.

- Upper Die – upper die component it consists of a top plate punch holder and backup pressure plate.,

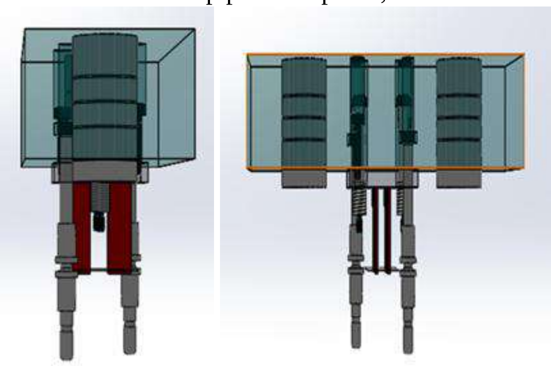

Fig. 4.Upper die design from side view and front view

The middle die consists of a stripper plate alone. The components like dowel pin socket head screw and guide pin post are assembly at the middle plate.

- Middle Die – For middle die component, it consists of a stripper plate and thrust plate.

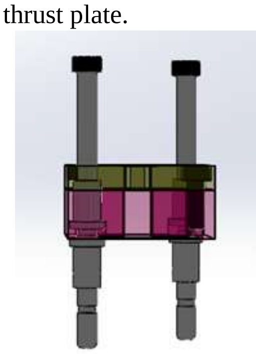

Fig. 5.Design of middle die and stripper plate

The lower die consists of a lower plate and blanking die. A few of components are assembled at the lower plate, and Dowel pins are used to align the lower die. Then socket head is used to assemble the plate and blanking die.

- Lower Die – consists of a ground block, cutting plate, guide fence, and lower clamping plate.

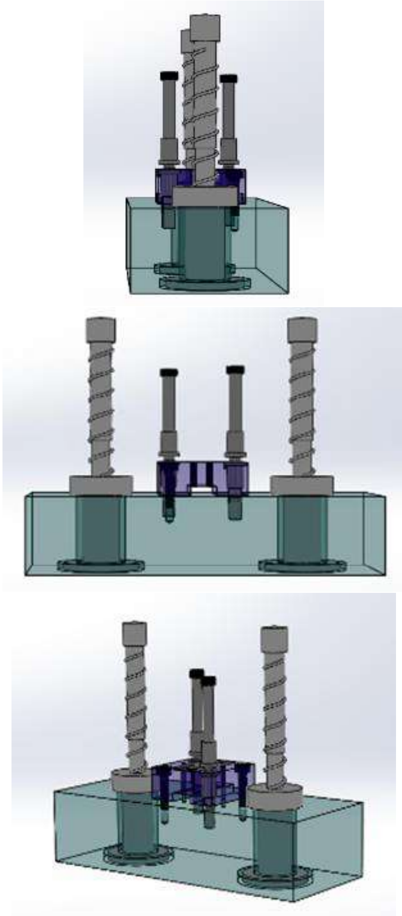

Fig. 6.Design of bottom die, side view, front view & 3D view

D. Assembly cross section & bill of material

In this part, will be showing the assembly of a complete die in three-dimensional (3D) cross-section for the complete die will show in the figure below and will be numbered and listed in a table by part. The standard part such as an elastomer, bolt screw and thickness of each plate will be shown in the figure.

Table- I: Bill of material

No	Components	Materials	Dimension
1	Stripper pin post	Standard	8-40
2	Dowel pins	Standard	1.5-6
3	Stripper bolt	Standard	4-20
4	Stripper bold spring	Standard	4-9
5	Socket head screw	Standard	3-10
6	Stripper guide pin bush	Standard	8-10
7	Guide post bush	Standard	10-35
8	Guide post	Standard	10-100
9	Blanking punch	AISI D2	34 x 34 x 5
10	Cutting die	AISI D2	34 x 34 x 13
11	Stripper plate	Mild steel	34 x 34 x 10

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E. Stamping calculation

Stock material conservation is a decisive factor in means should be tried to attain this without sacrificing the piece part. Economic factor, also known as material utilisation. The economy of any strip layout in percentage is found out by the following formula. All calculation was calculated by using formula.

Material Utilization,

Economic Factor = (A x R)/(B x V) 100% (1)

A =Blank area (mm2)

R =Number of rows per strip

B =Width of strip

V =Pitch of strip

Cutting Force, F=L x T x (2)

Where:

F =Cutting force

L =Total length of the cutting edge (perimeter punch)

T =Material thickness

σs =Shear strength

Total Force = Cutting Force + Bending Force (3)

Stripping Force = 10% x Total Force (4)

F. Finite Element Method (FEM)

FEA consists of pre-processing, solution and post-processing phases. The objectives of pre-processing is to develop suitable finite element mesh, allocate apposite material properties, and spread over boundary conditions in the form of restraints and loads. For this project, the punch will be applied by three different pressure applied based on the three materials that are aluminium, brass, copper,

Part Module	Parts are the essential blocks of an Abaqus/CAE model. A part module can be used to create part, but in this project, the model of die set punch was design used solidworks software. Thus, the model was converted to IGES file. Then IGES file of the model was imported into the Abaqus CAE in the part module process.
Property Module	Property unit requires the possessions of a part or part section by making a section and passing on to the part. Usually, sections denote the materials that have distinct.
Assembly Module	The assembly segment creates examples of the parts and to position the instances comparative to each other in a global coordinate system, thus creating the assembly.
Step Module	This section describes an order of one or more analysis steps. The step sequence provides a convenient way to capture changes in the loading and boundary conditions of the model.
Load Module	Before applying pressure to the model, the area of applied pressure must be identified. Based on the calculation of the total blanking force of three materials (Aluminium, Brass, Copper) that have calculated before, the pressure of those materials will be known from the equation.
Mesh Module	Unlike structured meshing, free meshing uses no preestablished mesh patterns. When a region is mesh using the structured meshing technique, the pattern of the mesh based on the region topology can be predicted.
Job Module	The Job module will be used to run the analysis, to submit it for analysis, and to monitor its progress. If desired, multiple models and jobs can be run and monitor the jobs simultaneously.

G. Life-cycle fatigue

Fatigue failure is defined as the tendency of a material to fracture using progressive brittle cracking under repeated alternating or cyclic stresses of an intensity considerably below the normal strength. Although the fracture is of a brittle type, it may take some time to propagate, depending on both the intensity and frequency of the stress cycles. Nevertheless, there is very little, if any, warning before failure if the crack is not noticed. The number of cycles required to cause fatigue failure at particular peak stress is generally quite large, but it decreases as the stress is increased. There are several steps running the fatigue test analysis. Firstly, load the maximum and minimum stress from FEA result. Second, load materials property of the product. Third, apply the modifying factor and fourth stress concentration factor must be obtained. Lastly, the result of fatigue life analysis will be obtained.

IV. RESULT AND DISCUSSION

The table below showed the output result value for punch analysis from the Finite Element Analysis. The result from the table above showed us the maximum values for stress, displacement, and reaction force. Generally, as can be seen from the table, pressure is different for those three materials. This is because the total blanking force is different for those materials because each material has its ultimate strength. Ultimate strength is a factor that affects the calculation and lifetime cycle.

Table- II: Results for a maximum value of the properties for three different materials used

	Aluminium	Brass	Copper
Force	6827.82kN	20kN	35.32kN
Pressure	922.63Pa	2702.7Pa	4772.972Pa
Stress	1471 Pa	4309Pa	7601Pa
Displacement	0.3779mm	1.107mm	1.955mm
Reaction force	98.83N	289.5N	511.3N

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The maximum stress occurred for aluminium is 1471MPa, while brass is 4309 MPa and lastly copper with 7610MPa. The highest maximum stress is copper; it is maybe because of its shear strength is the highest among those three materials. The minimum stress output of the three materials is 26.75MPa for aluminium, 78.37MPa for brass and 183.4 MPa for copper. From minimum stress output copper still got the highest value among those three.

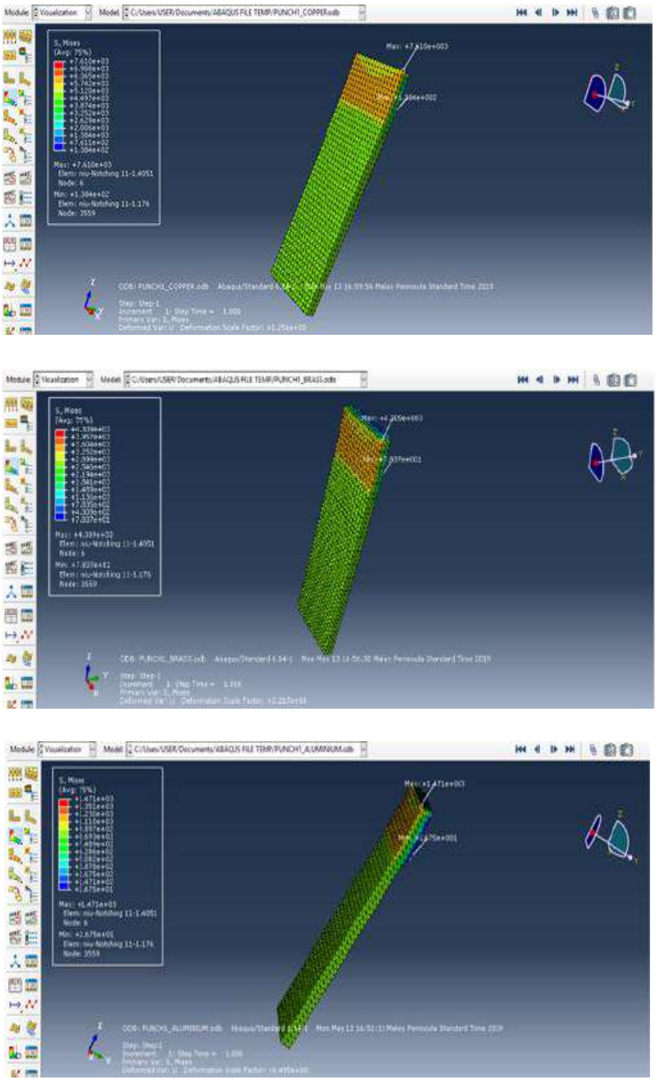
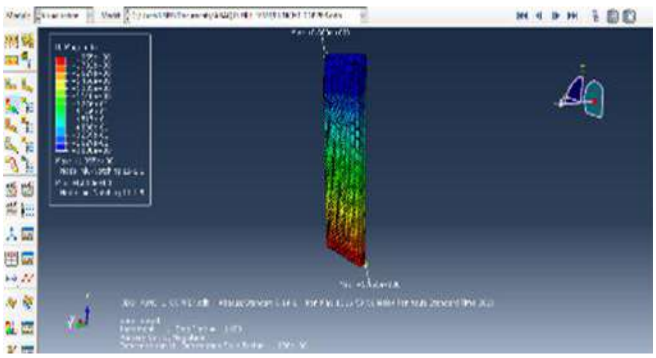


Fig. 7.Analysis result stress (a) Copper, (b) Brass, (c) Aluminium



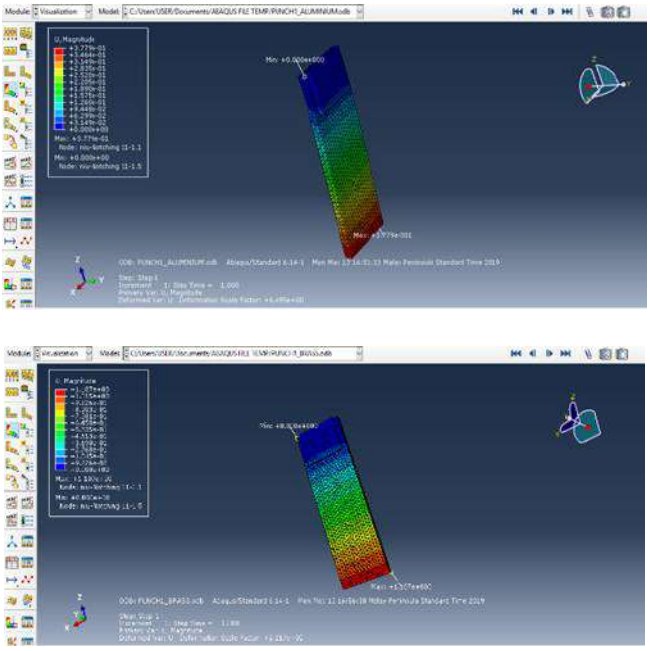


Fig. 8.Analysis result displacement for different design (a) Copper, (b) Brass, (c) Aluminium

Analysis Results

N_f = 54500

Specified

- S_{max} or e_{max} = 1471 MPa
- S_{min} or e_{min} = 26.75 MPa
- Material Type = steel
- Material Name = AISI D2 Steel
- S_u = 2500 MPa
- E = 209900 MPa
- Surface Finish Type = machined
- Loading Factor Type = axial
- K_t = 1.9
- Use Fatigue Notch Factor = No
- Mean Stress Definition = None

Default

- S_{FL} = 1250 MPa
- N_{FL} = 1.00E+06
- S_f' = 4040 MPa
- b = -0.085
- k_{SF} = 1.000
- k_L = 1.000
- k_{size} = 1.000

Calculated

- S_a or e_a = 722 MPa
- S_m or e_m = 749 MPa
- S_m = 331 MPa
- S_{eq} = 964 MPa
- b_{eq} = -0.131

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N_f = 30100

Specified

- S_{max} or e_{max} = 4309 MPa
- S_{min} or e_{min} = 78.37 MPa
- Material Type = steel
- Material Name = AISI D2 Steel
- S_u = 2500 MPa
- E = 209900 MPa
- Surface Finish Type = machined
- Loading Factor Type = axial
- K_t = 1.9
- Use Fatigue Notch Factor = No
- Mean Stress Definition = None

Default

- S_{FL} = 1250 MPa
- N_{FL} = 1.00E+06
- S_f' = 4040 MPa
- b = -0.085
- k_{SF} = 1.000
- k_L = 1.000
- k_{size} = 1.000

Calculated

- S_a or e_a = 1161 MPa
- S_m or e_m = 1239 MPa
- S_m = -392 MPa
- S_{eq} = 825 MPa
- b_{eq} = -0.154

Analysis Results

N_f = 17800

Specified

- S_{max} or e_{max} = 7610 MPa
- S_{min} or e_{min} = 13.84 MPa
- Material Type = steel
- Material Name = AISI D2 Steel
- S_u = 2500 MPa
- E = 209900 MPa
- Surface Finish Type = machined
- Loading Factor Type = axial
- K_t = 1.9
- Use Fatigue Notch Factor = No
- Mean Stress Definition = None

Default

- S_{FL} = 1250 MPa
- N_{FL} = 1.00E+06
- S_f' = 4040 MPa
- b = -0.085
- k_{SF} = 1.000
- k_L = 1.000
- k_{size} = 1.000

Calculated

- S_a or e_a = 1766 MPa
- S_m or e_m = 1844 MPa
- S_m = -857 MPa
- S_{eq} = 1010 MPa
- b_{eq} = -0.142

Fig. 9.Analysis result for lifecycle punch (a) Aluminium, (b) Brass, (c) Copper

From minimum stress output copper still got the highest value among those three. The maximum displacement value for aluminium is 0.3779mm, while brass is 1.107mm and 1.955mm for copper. Copper still got the highest value of displacement and aluminium got the lowest value. Minimum displacement is the same for the three materials that are 0mm. Based on the graph above, fatigue limit of three materials can be observed. Aluminium lifecycle is 54500 while brass is 30100 and copper is 17800. We can see the decrease of lifecycle value from aluminium to copper. From the graph also, we can conclude that aluminium is the most suitable materials for blanking in this project. It is because its lifecycle is the highest, and from the finite element analysis out also state that aluminium is the most suitable materials.

V. CONCLUSION

This project occurred based on several problems that have been stated in the problem statement. Damage to the punches is one of the major problems during high production stamping operation. Usually the problems during high production stamping are tool wear. After thousands time of stroke punch will have tool wear and more seriously punch can break apart. For micro blanking punch, the punch is small and the probability to broken also increased. The objective of this project is to design a complete micro-blanking dieset and analyse it using FEA and E fatigue to gained lifecycle value. The complete micro-blanking dieset was designed using solidworks intergrated with 3d Quickpress software. For early stage, before designing the complete dieset, the product and strip layout were designed first. The design of micro blanking dieset was completed with the simulation of the dieset performing blanking process.Then, micro punch of the dieset is inserted to Abaqus CAE software to undergo finite element analysis. Punch was choosed because it is a critical part of dieset that failure always occurred.

The punch was applied with three different pressure from three materials of sheet metal forming parts. Next, output value of stresses, displacement and reaction force occurred.From the result of finite element analysis, the value of maximum stress and materials property of AISI D2 for punch was inserted to E-fatigue. All modifying factor has been modified correctly. Lastly, the fatigue calculator calculated the fatigue limite of the three materials which is Aluminium lifecycle is 54500 while brass is 30100 and copper is 17800.

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