The Influence of Surface Roughness of Drawbead on Non-Symmetry Deep Drawing Cold Rolled Steel Sheet

A. Watanapa, S. Torsakul

***Abstract*—**This study was aimed to explain the influence of surface roughness of the drawbead on non-symmetry deep drawing cold rolled steel sheet to improve the drawability of cold rolled steel sheet. The variables used in this study included semi-circle drawbead with 3 levels of surface roughness which are 6.127 µm Ra, 0.963 µm Ra and 0.152 µm Ra and cold rolled steel sheet according to 3 grades of the JIS standards which are SPCC, SPCE and SPCD with the thickness of 1.0 mm and the blankholder force which is 50% of the drawing force and the depth of 50 mm. According to the test results, when there was the increase in the surface roughness of drawbead, there would be the increase in deep drawing force, especially the SPCC cold rolled steel sheet. This is similar to the increase in the equivalent strain and the wall thickness distribution when the surface roughness of the drawbead increased. It could be concluded that the surface roughness of drawbead has an influence on deep drawing cold rolled steel sheet, especially the drawing force, the equivalent strain and the wall thickness distribution.

***Keywords*—**Drawbead, Deep Drawing, Drawing Force, Equivalent Strain, Surface roughness

I. Introduction

DRAWING steel sheet is an important process in the manufacturing of automobile and electronic parts, especially the deep drawing steel sheet which requires tensile force and compression force. There are also numerous variables which could affect the drawability such as materials, drawing ratio, punch radius, die radius, blank holder force, friction and lubrication [1-3]. However, there are still limitations for deep drawing, especially deep drawing thin wall high depth materials. Although various variables are controlled, there could be problems in controlling the flowing of steel sheet. Therefore, drawbead is usually designed in deep drawing die in order to control the material flow in the die. This is the control of the metal flow through bending and unbending the metal sheet according to drawbead shape during drawing sheet. The use of drawbead means more labor in drawing into the die. However, drawbead could reduce the blank holding force [2-5]. There have been many research studies on similar topics including drawbead force in drawing metal sheet by Nine [7] who designed many drawbead shapes with various factors affecting restraining force in drawbead. There are also studies on drawbead shapes to analyze equivalent strain by Samuel [6] and Naceur [8] who studied an appropriate amount of restraining force in metal sheet forming process.

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Nevertheless, there is one interesting variable for non-symmetry deep drawing and that is surface roughness of drawbead which control the material flow through drawbead.

This research would examine the influence of drawbead on non-symmetry deep drawing cold rolled steel sheet to analyze drawing force, equivalent strain and wall thickness distribution of any works with surface roughness of 6.127 µm Ra, 0.963 µm Ra, and 0.152 µm Ra. There were 3 grades of drawing cold rolled steel sheet according to the JIS 3 standards which are SPCC, SPCE and SPCE with the thickness of 1.0 mm.

II. Tooling and Materials for Study

A. Preparation for Experiments

1. Preparation of Experiment Materials

The materials which would be used for the manufacturing would define the quality of such product. Therefore, the materials for this research were SPCC, SPCE and SPCD which are low carbon steel through cold formation and most of them are in automobile part industry and the quality must conform to the TIS 2012 standards which are comparable to ISO 3574 and ISO 3141 standards regarding the type of metal for general formation and deep drawing.

The sheet for the experiment was 220 x 160 mm in size and this value was measured according to the calculation from the basic equation of the blank size with the application of the studied shape until the size and the shape were determined. The blank size was extended for 10 more mm. in circumference as shown in Fig. 1 and Fig. 2.

2. Design of Drawing Die

The functional principle of die holder is to adhere to the die table which can go up and down and to adhere to pressure die and die holder. There were upper shore and guide post as the shore for validity in pumping up and down. Lower shore included punch, blank holder whose function is to adhere and press the sheet by transferring the pressure from cushion pin and the force could be adjusted. Punch holder would adhere to the table. The details are shown in Fig. 3.

3. Design of Drawbead

Semi-circle drawbeads made of tool die SKD11 were made with 3 levels of surface roughness as in 6.127 µm Ra, 0.963 µm Ra, and 0.152 µm Ra. These are shown in Fig. 4.

B. Experiment

1. Installation of drawing press

After the die was made ready, it was placed on 80 ton hydraulic press to adhere to the upper shore and lower shore as shown in Fig. 5.

TABLE I
MECHANICAL PROPERTIES OF LOW CARBON STEEL ACCORDING TO JIS G 3141 [9]

Material Type	Applications	Tensile Strength (MPa)	Elongation (%)	Hardness (HRB)
SPCC	Commercial	270 (min)	36 (min)	-
SPCE	Deep Drawing	270 (min)	40 (min)	53 (max)
SPCD	Deep Drawing	270 (min)	39 (min)	57 (max)

TABLE II
CHEMICAL PROPERTIES OF LOW CARBON STEEL ACCORDING TO JIS G 3141 [9]

Material Type	Applications	C (%)	Mn (%)	P (%)	S (%)
SPCC	Commercial	0.15 (max)	0.60 (max)	0.05 (max)	0.05 (max)
SPCE	Deep Drawing	0.10 (max)	0.45 (max)	0.03 (max)	0.03 (max)
SPCD	Deep Drawing	0.12 (max)	0.50 (max)	0.04 (min) (max)	0.04 (max)

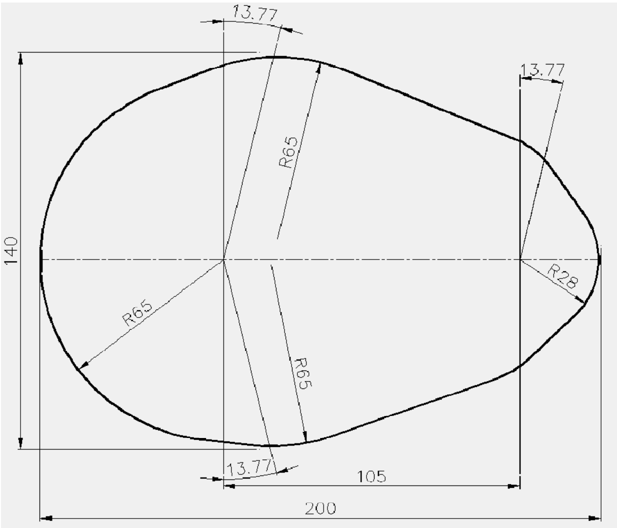


Fig. 1 Blank size according to calculated estimation

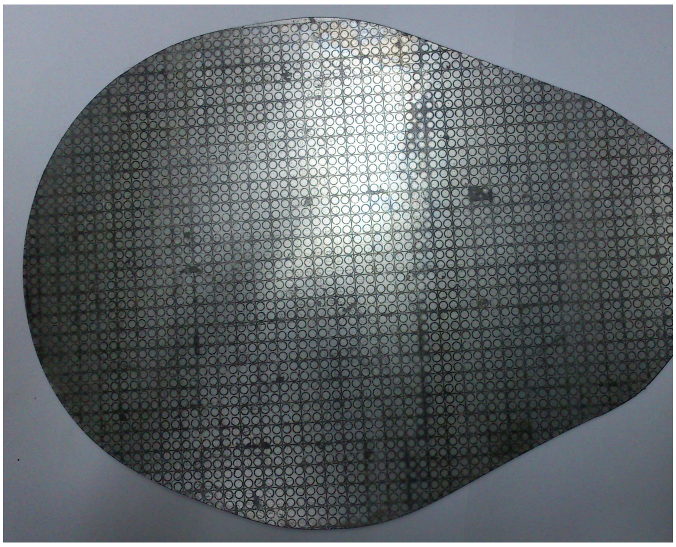


Fig. 2 Blank size with grid to measure equivalent strain

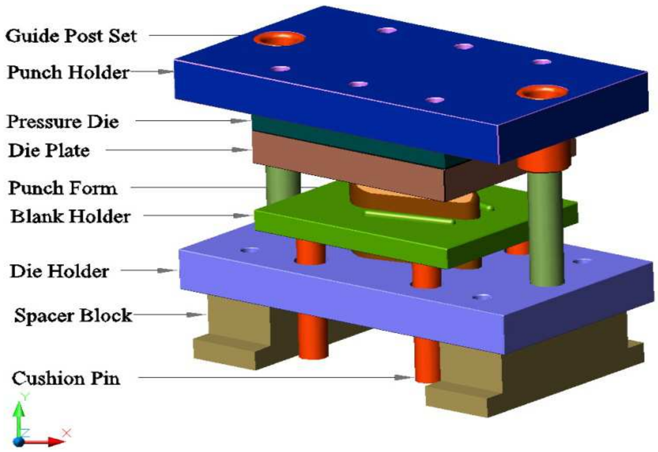


Fig. 3 Components of Non-Symmetry Drawing Die

Fig. 4 Drawbeads with 3 levels of surface roughness from left to right: 6.127 µm Ra, 0.963 µm Ra, and 0.152 µm Ra

2. Test Result Collection

a. Drawing force measurement

Mini data logger is a tool to store basic data of the system and it includes scanner or multiplexer digital-voltmeter and the data recorder which could receive input from analog sensor and then the data are transferred into digital format and stored in memory for further usage as shown in Fig. 6.

The device for oil pressure measurement was installed and the mini data logger was connected to the hydraulic press as shown in Fig. 7.

Fig. 5 Installation of die on 80 ton hydraulic press

Fig. 6 Device for oil pressure measurement and mini data logger

Fig. 7 Installation of the device for oil pressure measurement to the hydraulic press

b. Equivalent strain measurement

There are equivalent strain, major strain and minor strain which take place at the end of the process and these could be used to measure many cases of formation and to analyze the critical areas of the main piece of work from forming process as shown in Fig. 8 and according to Equation 1 to 4.

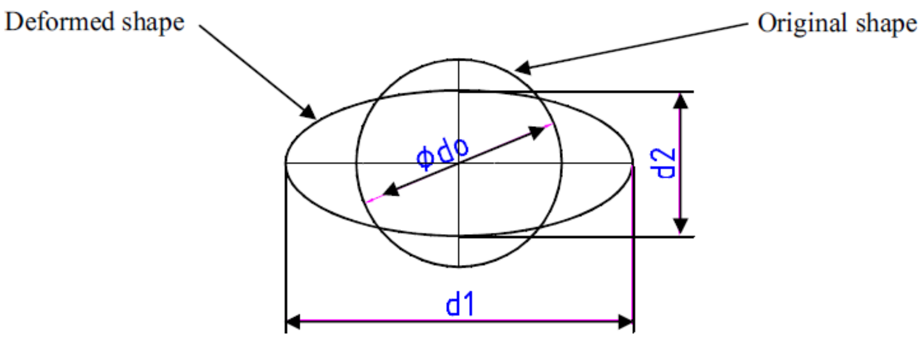


Fig. 8 Changes in circle grid

$$\varepsilon_1 = \ln \frac{d_1}{d_0} \qquad \text{Major Strain (1)}$$

$$\varepsilon_2 = \ln \frac{d_2}{d_0} \qquad \text{Minor Strain (2)}$$

$$\varepsilon_3 = \ln \frac{t_2}{t_0} \qquad \text{Thickness Strain (3)}$$

$$\bar{\varepsilon} = \sqrt{\frac{2}{3}\left(\varepsilon_1^2 + \varepsilon_2^2 + \varepsilon_3^2\right)} \qquad \text{Equivalent Strain (4)}$$

A comparison of the strain forces from the equivalent strain equation would yield strain results. Changes in both major and minor axes of the grid in 10 points would be measured as shown in Fig. 9 and the results would be used to calculate the major strain ε_1 , minor strain ε_2, thickness strain ε_3 and to calculate the equivalent strain.

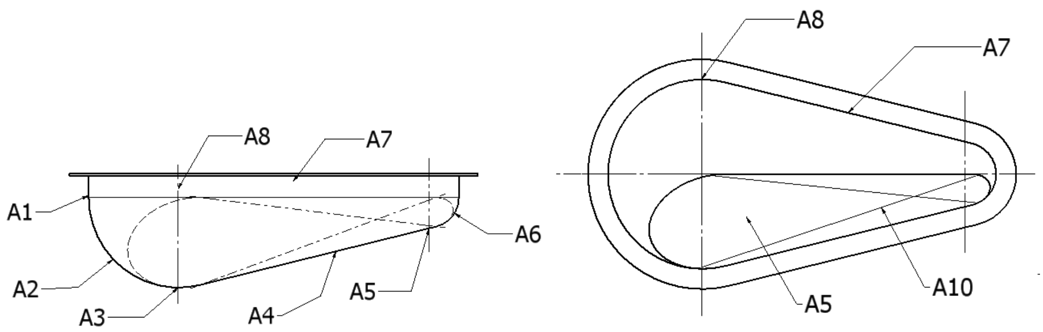


Fig. 9 Points to measure strain on the work

c. Thickness measurement

Point micrometer is a device to measure the thickness of the workpiece. To measure, the workpiece would be split in vertical line and then the thickness would be measured from 10 points to find out the changes in the thickness of each point. The tool is shown in Fig. 10.

Fig. 10 Point Micrometer

III. Results and Discussion

According to the test results for each variable and the analysis of drawing force and blank holder force for drawbead at every level of surface roughness with the blankholder force of 50%. The results also came from the test of drawing force, equivalent strain and wall thickness distribution.

A. Study of drawing force

According to the experiment with 3 types of material and 3 levels of drawbead surface roughness at blank holder force of 50%, it could be concluded in Fig. 11.

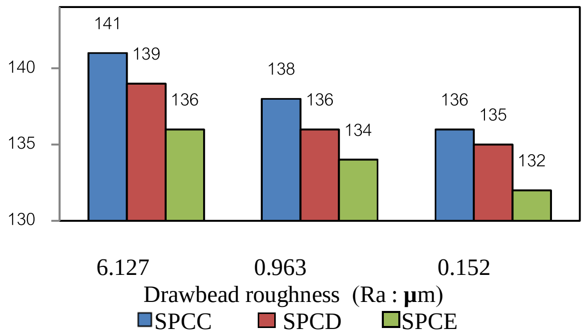


Fig. 11 Drawing force and drawbead surface

According to Fig. 11, the relationship between drawing force (kN) and the drawbead surface roughness of the used materials (JIS: SPCC, SPCE and SPCD) is shown. It was found that at the drawbead roughness of 6.127 µm, SPCC showed the highest drawing force of 141 kN. At the drawbead roughness of 0.963 µm, SPCC showed the highest drawing force of 138 kN. At the drawbead roughness of 0.152 µm, SPCC showed the highest drawing force of 136 kN.

According to Fig. 11, it could be seen that the drawing force decreased gradually due to the fact that the drawbead roughness had an influence on drawing non-symmetry cold rolled steel sheet. There was friction between drawbead surface and blank size surface which had common movement. High drawbead surface roughness could cause friction. All 3 types of metal sheet had different values of drawing force because the mechanical properties of the metal sheet had different values of stretching and thickness. Therefore, the drawing force varies according to the type of material.

B. Study of strain in workpiece

According to the test of strain in each point of the workpiece (Fig. 12) through 3D drawbead surface (Ra : 6.127, 0.963, 0.152 µm) which is the metal sheet (JIS: SPCC, SPCE, SPCD) with the blank holder force of 50%, the results would be shown according to the type of material.

Fig. 12 Workpiece with grid to measure the strain

1. Results from strain measurement of SPCC

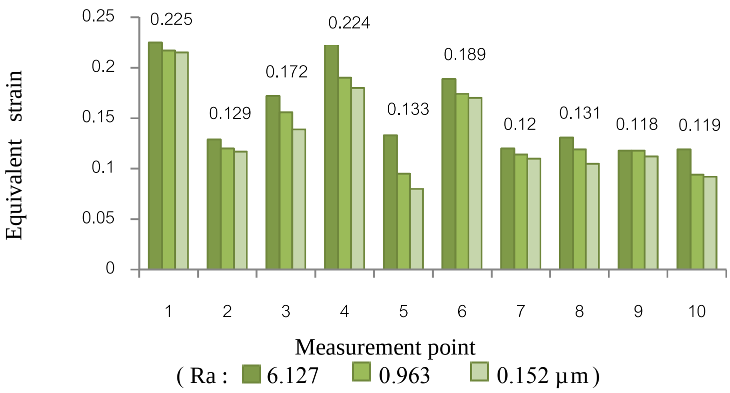


Fig. 13 Equivalent strain from 10 points of SPCC material

2. Results from strain measurement of SPCD

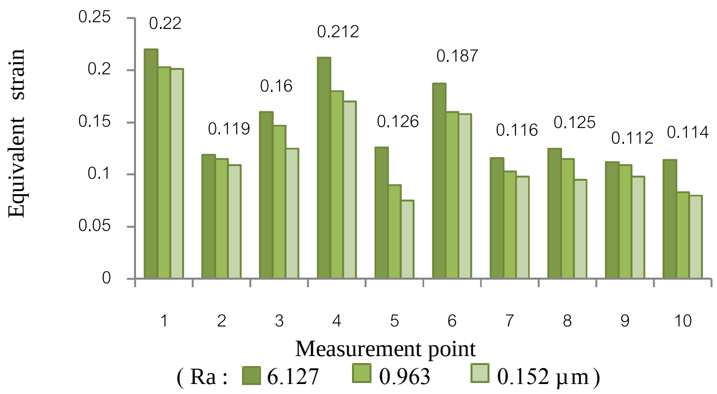


Fig. 14 Equivalent strain from 10 points of SPCD material

3. Results from strain measurement of SPCE

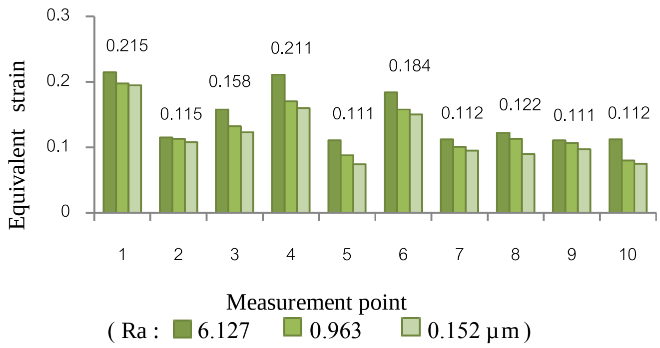


Fig. 15 Equivalent strain from 10 points of SPCE material

The test of drawing force and equivalent strain was done on 3 levels of drawbead surface roughness (Ra: 6.127, 0.963, 0.152 µm) with the blank holder force of 50% and grid size of 2.5 mm to measure the workpiece by camera OMC and Point micrometer. The 10 points were measured and then the values were calculated according to the equivalent strain equation 4.

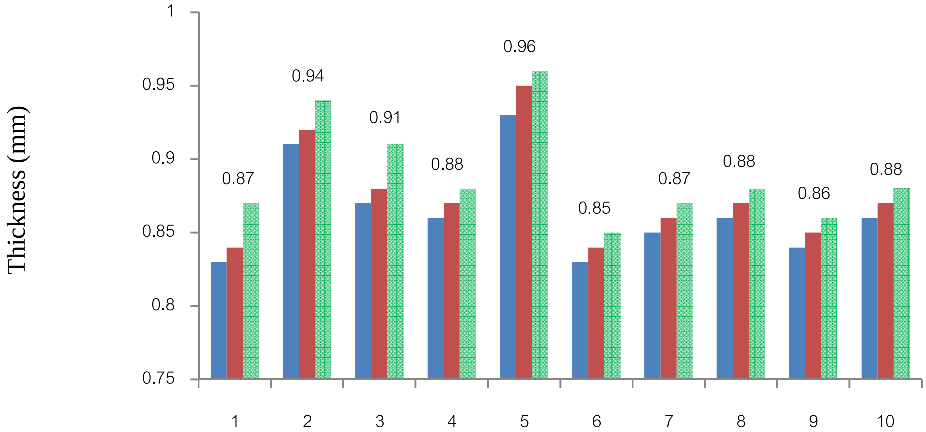
According to Figs. 13-15, the relationship between strain in each point and drawbead surface roughness was shown. When the strain of SPCC was considered at the drawbead surface roughness of Ra: 6.127 µm, the highest equivalent strain was found at point 1 with the value of 0.225. At the drawbead surface roughness of Ra: 0.963 µm, the highest equivalent strain was found at point 1 with the value of 0.217. At the drawbead surface roughness of Ra: 0.152 µm, the highest equivalent strain was found at point 1 with the value of 0.215. According to Fig. 13, points 7-10 yielded similar values whereas for points 2-4, the equivalent strain increased. As for SPCD and SPCE, the strain increased in proportion.

According to Figs. 13-15, the highest strain was found at the highest drawbead surface roughness because high strain could cause the slope of stress. When the drawing force is taken into consideration, the highest force for forming process would create friction, material stretch and the highest strain. The fine drawbead surface would create lower friction, material stretch and strain than the rough drawbead surface.

C. Study of wall thickness distribution

The results from the test of wall thickness of the workpiece after the forming process were shown below. The test was done with 3 levels of drawbead surface (Ra: 6.127, 0.963, 0.152 µm) with blank holder force of 50%. The 10 points on the workpiece were defined and measured using Point Micrometer for the thickness.

i. Results from 10 point thickness test of SPCC

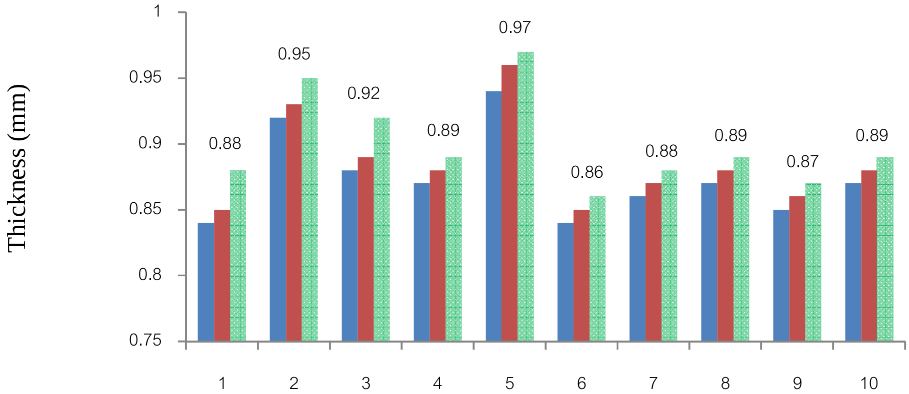


Measurement point

(Ra : 6.127 0.963 0.152 µm)

Fig. 16 Thickness of the workpiece from 10 points of SPCC material

ii. Results from 10 point thickness test of SPCD

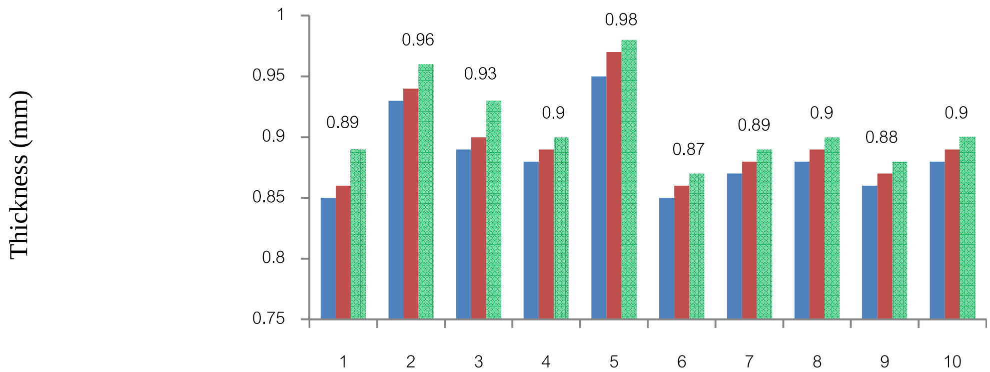


Measurement point

(Ra : 6.127 0.963 0.152 µm)

Fig. 17 Thickness of the workpiece from 10 points of SPCD material

iii. Results from 10 point thickness test of SPCE



Measurement point

(Ra : 6.127 0.963 0.152 µm)

Fig. 18 Thickness of the workpiece from 10 points of SPCE material

According to Figs. 16-18, the thickness of the workpiece from 10 points was shown. It was found that Point 1 yielded the lowest thickness of the workpiece whereas Point 5 yielded the highest thickness. Points 2-4 and Points 6-10 were likely to have lower thickness gradually. SPCE material had the most numbers of thickness in the workpiece and SPCC material had the least numbers of thickness in the workpiece.

The metal sheet SPCC which underwent forming process through rough drawbead surface would yield thinner wall than moderate drawbead surface and fine drawbead surface in all 10 points because rough drawbead surface could cause high friction and the material would stretch according to the forming trajectory. This is in inverse proportion according to Young’s modulus theory or Modulus of Elasticity (E) or stiffness from the drawing force test.

IV. Conclusion

The different kinds of rough drawbead surface were designed to test the relationship between drawbead and workpiece for non-symmetry drawing cold rolled steel sheet. The research results are similar to the research by Yang [3] in that high friction between die surface and workpiece surface could affect the low formality of the metal sheet.

The conclusions could be drawn as follows:

i. The rough drawbead surface had an influence on drawing. It was found that the high level of drawbead surface roughness could increase drawing force, especially the metal sheet SPCC which needed the highest drawing force, followed by the metal sheets SPCD and SPCE, respectively.

ii. The rough drawbead surface varies in direct proportion to the equivalent strain. The high level of drawbead surface roughness could lead to high equivalent strain. It was found that the metal sheet SPCC yielded the highest equivalent strain. The metal sheets SPCD and SPCE yielded lower equivalent strain, respectively.

iii. The drawbead roughness varies in inverse proportion to the workpiece thickness. The high level of drawbead surface roughness could lead to lower level of workpiece thickness. It was found that the metal sheet SPCC yielded the lowest thickness value. The metal sheets SPCD and SPCE yielded higher thickness values, respectively.

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