ISSN 2079-6226: Proceedings of the 2012 Mechanical Engineering Conference on Sustainable Research and Innovation, Volume 4, 3rd-4th May 2012

Performance Measurement for Raw Material Utilization in Blanking

Mr.George Guchu, Prof S.M.Maranga and Eng Dr. B.W Ikua

***Abstract*—**Productivity measures have been widely used in manufacturing industry in order to indicate how well resources like materials, energy and labour are used. The study was carried out on raw material utilization at blanking stage for firms that process sheet metal into round blanks for subsequent operations like drawing into finished products. Blanking data was obtained from selected companies involved in making of aluminium and steel blanks. From this data a mathematical model and FORTRAN code was developed to simulate expected material utilization for various blank sizes.

The findings of the study present model utilization results that are comparable to actual utilization. The results can thus be used by firms to bench mark expected actual utilization and continuously improve to attain the set standards.

***Keywords*—**Bench mark, efficiency, effectiveness, performance measure.

I. INTRODUCTION

Performance refers to the outcome that has been achieved whereas measurement is the process of quantifications of the outcome. Performance measurement is defined as the process of quantifying efficiency and effectiveness of an action [1] [2]. Effectiveness refers to the extent to which customers requirement are met, while efficiency is a measure of how economically the firms resources are utilized.Most performance measures can be grouped into one of the following six general categories. However, organizations may develop own categories based on their strategies.

1)Effectiveness: A process characteristic indicating the degree to which the process output (work product) conforms to requirements.

2) Efficiency: A process characteristic indicating degree to which the process produces the required output at minimum resource cost.

3) Quality: Degree to which the product or service meets the customer requirements

4) Timeliness: measures whether unit of work was done correctly and on time.

5) Productivity: The relationship between output and inputs.

6) Safety: Measures the overall health of an organization and working conditions of its employees.

Traditional performance measures focused on profit or loss, Return On Investment (ROI), return on sales, price variances and productivity [3]. These parameters are mainly financial for example cost of production per unit, and thus not sufficient to measure the performance of a manufacturing company engineering activities as they lack enough data with which the engineering process can be improved. With advent of modern manufacturing systems it has been observed that traditional performance measures have had many limitations Table 1.1 and development of new performance measures is vital. Globersone [4] has stated that a performance measurement system of an organization should include, a set of well defined measurable criteria; standards of performance for each criterion; routines to measure each criterion; procedures to compare actual performance to standards and procedures for dealing with discrepancies between actual and desired performance. Modern performance measures should be characterized by the following criteria;

1)Ensure high quality products and services, minimal customer complaints and minimal rejection rate or rework.

2) Continous improvement

3) Quality culture emphasizing proactive and preventive approach.

4) Timeliness reduced cycle time and quicker delivery of products and or service.

5) Productivity focus on overall productivity improvement

6) Communication, technology, education and training.

Table 1.1: Comparison between traditional and non traditional performance measures [1]

Traditional performance measures	Non traditional performance measures
Based on accounting system	Based on company strategy
Mainly financial measures	Mainly non financial measures
For middle and high managers	For all employees
Lagging metrics (weekly or monthly)	On time metrics (hourly or daily)
Difficult, confusing and misleading	Simple, accurate and easy to use
Lead to employee frustration	Lead to employee satisfaction
Neglected at shop floor	Frequently used at shop floor
Have a fixed format	Have no fixed format (depend on need)
not vary between locations	Vary between locations
Do not change over time	Change over time

Productivity is defined as the optimal use of all resources, such as materials, energy, labour and/ or technology, or as output per employee per hour [5]. In a broad sense productivity is defined as the ratio of output to inputs or doing more with less [6], [7]. Increases in manufacturing productivity come from two primary inputs to the production process, that is, labour and raw materials. Productivity measures in organizations involved in production or services can be established through;

1. Establishing productivity objectives.
2. Measuring productivity.
3. Determining the factors and relationship that affect the organization's productivity.

G.K.Guchu, Department of Mechanical Engineering, JKUAT (e-mail:gguchu@yahoo.com).

S.M.Maranga, Department of Mechanical Engineering, JKUAT (e-mail:smmaranga@yahoo.com).

B.W.Ikua, Department of Mechatronic Engineering,JKUAT (e-mail:ikuabw@jkuat.ac.ke).

Total productivity improvement results from many small mutually supporting changes hence it is important to measure productivity of specific activities and verify that actions taken to improve productivity in one area do not decrease it in another.

Sheet metal forming is one of the most widely used manufacturing processes for the fabrication of a wide range of products with a high ratio of surface area to thickness [8]. Sheet metal refers to metal formed into thin at pieces, thickness ranging from 0.25 mm to 6 mm. A sheet thicker than 6 mm is generally referred to as plate. There are numerous processes employed for making sheet metal parts.

The term press working is used commonly in industry to describe general sheet manufacturing operations performed on presses. A sheet metal part produced in presses is called a stamping. Metals that can be made into sheet are aluminium, brass, copper, steel, tin and titanium. The reason behind sheet metal forming gaining a lot of attention in modern technology is due to the ease with which metal may be formed into useful shapes by plastic deformation in which the volume and mass of the metal are conserved and metal takes the shape of the forming tool [9].Sheet metal operations done on a press can be grouped into two categories.

- Cutting operations; include blanking, slitting, punching, notching and perforating.
- Forming operations; include drawing, bending and squeezing.

Blanking is a shearing process where a punch and die are used to create a separate piece from sheet metal. The part cut out is called the blank and is the required part of the operation. The hole and material left out are discarded as waste. In punching or piercing the hole is the desired product, material punched out to form the hole being waste. The difference between blanking and piercing process is illustrated in Figure 1.1.

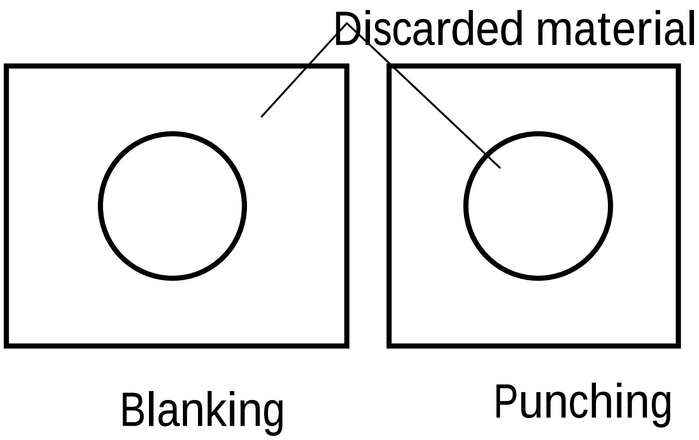

Fig 1.1 Difference between blanking and punching

II. METHODOLOGY

Raw material utilization ρ is given by

$$\rho = \frac{A_B}{A_S} \tag{1.1}$$

where

ρ =Raw Material utilization
A_B = Blank area
A_S = Strip area

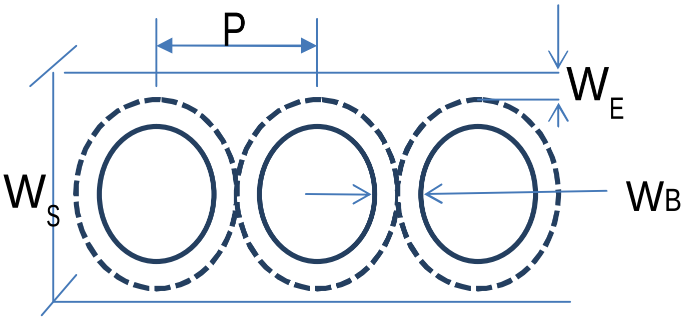

Fig 1.2 Scrap allowance

Bridge allowance between blanks and edges of the strip is important as excessive allowance is wasteful of material, while insufficient allowance will result in a weak scrap strip that can lead to breakage, misfeeds and may consequently lead to slowed down production and or unnecessary die maintenance due to partial cuts which deflect the punches resulting in naked edges. For curved outlines of blanks, the edge allowance recommended is 1.25 t where t is the stock thickness [10].

Taking into account scrap allowance as shown in Fig 1.2 the equations for pitch, width and utilization are;

$$P = D + W_B \tag{1.2}$$

$$W_S = D + 2W_E \tag{1.3}$$

$$\rho = \frac{A_B}{2W_S} \tag{1.4}$$

Multi line layout of circular blanks is used for small simpler blanks normally with diameters less than 100 mm [11]. This saves on material economy and enhances productivity.

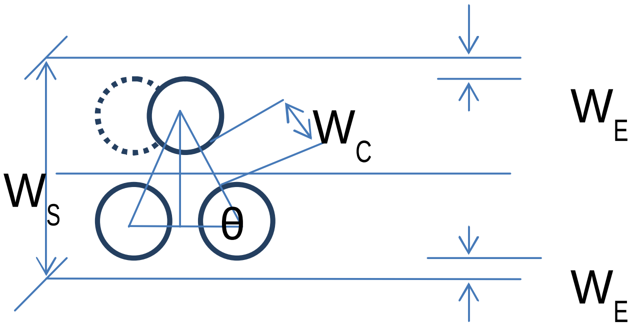

Fig 1.3 Multi line layout

For two lines circular layout the minimum blank width is calculated from Figure 1.3

$$W_S = D + 2W_E + (D + W_C)\sin\theta \tag{1.5}$$

For three lines circular layout the minimum blank width becomes

$$W_S = D + 2W_E + 2(D + W_C)\sin\theta \tag{1.6}$$

In general the strip width for multi line circular blanks is given by

$$W_S = D + 2W_E + (i - 1)(D + W_C)\sin\theta \tag{1.7}$$

where

W_S = Strip width
W_E = Edge scrap allowance
W_C = Allowance between blanks
i = Number of rows
D = Blank diameter
ϴ= 60^o for circular blanks arrangement

For circular blanks the general utilization equation is

$$\rho = \frac{\pi D^2}{4(D + W_C)(D + 2W_E) + (i-1)(D + W_C)0.87} \qquad 1.8$$

A Fortran code [12],[13] was written to simulate expected blanking utilization based on equation 1.8.

III. DATA COLLECTION

Data on blanking was collected from three firms that convert sheet or coil stocks into circular blanks. The data collected consisted of;

- Blank shapes and diameter range
- Blank layouts on strip
- Strip thickness and strip widths for different blank sizes
- Utilization levels for different blank sizes over time

IV. RESULTS AND DISCUSSION

The simulated results for material utilization in blanking for different blank diameters are shown in Table 1.2. From this Table the variation of utilization with blank diameter is shown in Figure 1.4. In this figure utilization increases with increase in blank diameter from a diameter of 6 inches. This is true as the edge scrap allowance and blank allowance is approximately 0.25 and 0.125 inches respectively. This implies there is more material wastage in blanks of smaller diameters , high number of rows give high utilization and this drops as diameter increases, as this imply multi line layout is only applicable for small blank diameters [11]

Table 1.2 Calculated material utilization for blanking

Blank diameter Inches	Number of rows No	Pitch inches	Width inches	Utilization Percent
4.50	3	4.625	12.7970	80.61
5.00	2	5.125	9.7090	78.92
5.50	2	5.625	10.6440	79.36
6.00	1	6.125	6.2500	73.86
6.50	1	6.625	6.7500	74.20
7.00	1	7.125	7.2500	74.50
7.50	1	7.625	7.7500	74.76
8.00	1	8.125	8.2500	74.99
8.50	1	8.625	8.7500	75.19
9.00	1	9.125	9.2500	75.37
9.50	1	9.625	9.7500	75.53
10.00	1	10.125	10.2500	75.68
10.50	1	10.625	10.7500	75.81
11.00	1	11.125	11.2500	75.93
11.50	1	11.625	11.7500	76.04
12.00	1	12.125	12.2500	76.14
12.50	1	12.625	12.7500	76.24
13.00	1	13.125	13.2500	76.32
13.50	1	13.625	13.7500	76.40
14.00	1	14.125	14.2500	76.48
14.50	1	14.625	14.7500	76.55
15.00	1	15.125	15.2500	76.61
15.50	1	15.625	15.7500	76.67
16.00	1	16.125	16.2500	76.73
16.50	1	16.625	16.7500	76.79
17.00	1	17.125	17.2500	76.84
17.50	1	17.625	17.7500	76.88
18.00	1	18.125	18.2500	76.93
18.50	1	18.625	18.7500	76.97
19.00	1	19.125	19.2500	77.01
19.50	1	19.625	19.7500	77.05
20.00	1	20.125	20.2500	77.09
20.50	1	20.625	20.7500	77.12
21.00	1	21.125	21.2500	77.16
21.50	1	21.625	21.7500	77.19
22.00	1	22.125	22.2500	77.22

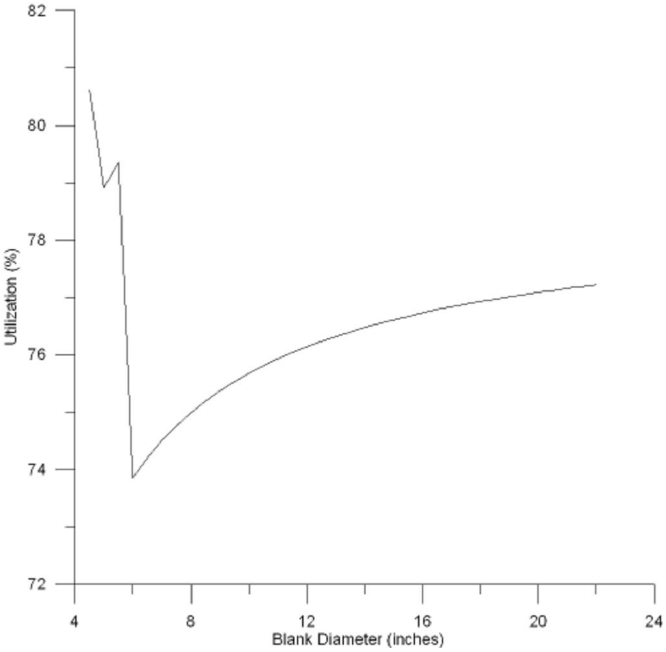

Fig 1.4 Variation of utilization with blank diameter

The actual raw material material utilization per different runs collected from aluminium manufacturing facility in Kenya is as in Table 1.3. From this Table utilization is high for multi line layout (three rows) blank diameters of 4.5 inches, decreases slightly up to 5.5 inches blank diameter that consists of two rows.

Table 1.3 Actual Blanking utilization over time

Die size Inch	Blanking Productivity									Average
4.5	0.727	0.728	0.729	0.729	0.729	0.729	0.730	0.731	0.732	0.733	0.730
5	0.709	0.710	0.711	0.711	0.711	0.713	0.713	0.713	0.714	0.714	0.712
5.5	0.717	0.717	0.718	0.718	0.719	0.719	0.720	0.721	0.722	0.724	0.719
6	0.683	0.683	0.684	0.684	0.685	0.686	0.686	0.686	0.687	0.687	0.685
7	0.687	0.687	0.689	0.689	0.689	0.690	0.691	0.691	0.693	0.693	0.690
11.5	0.694	0.694	0.695	0.697	0.697	0.697	0.698	0.698	0.698	0.699	0.697
12.5	0.700	0.700	0.700	0.700	0.700	0.701	0.701	0.702	0.703	0.704	0.701
13.5	0.704	0.705	0.705	0.705	0.707	0.707	0.707	0.708	0.709	0.709	0.707
14.5	0.710	0.710	0.710	0.713	0.713	0.714	0.714	0.714	0.715	0.715	0.713
15.5	0.715	0.716	0.716	0.717	0.717	0.718	0.719	0.719	0.720	0.721	0.718
16.5	0.721	0.721	0.722	0.723	0.723	0.723	0.723	0.724	0.724	0.725	0.723
17.5	0.725	0.725	0.726	0.726	0.726	0.727	0.727	0.727	0.727	0.727	0.726
18.5	0.729	0.729	0.729	0.730	0.731	0.731	0.731	0.731	0.732	0.733	0.731
19.5	0.733	0.734	0.734	0.736	0.736	0.736	0.736	0.737	0.738	0.738	0.736
20.5	0.738	0.738	0.739	0.740	0.740	0.740	0.740	0.740	0.740	0.741	0.740
21.5	0.745	0.746	0.747	0.748	0.750	0.750	0.750	0.756	0.762	0.767	0.752

From blank diameter of 6 inches (single line layout), utilization increases with increase in blank diameter as expected based on earlier theoretical simulation results. A table of material utilization variation between the blanking model and actual is shown in table 1.4.

Table 1.4 Material utilization variation between blanking model and actual

Die size inches	Actual percent percent	Model percent	Variation
4.5	72.96	80.61	7.65
5	71.22	78.92	7.65
5.5	71.92	79.36	7.44
6	68.51	73.86	5.35
7	68.99	74.20	5.21
11.5	69.67	76.04	6.37
12.5	70.11	76.24	6.13
13.5	70.66	76.40	5.74
14.5	71.28	76.55	5.27
15.5	71.78	76.67	4.89
16.5	72.29	76.69	4.50
17.5	72.63	76.88	4.25
18.5	73.06	76.97	3.91
19.5	73.58	77.05	3.47
20.5	73.96	77.12	3.16
21.5	75.21	77.19	1.98

Comparing the projected blanking utilization results and the actual blanking utilization results Figure 1.5 and Figure 1.6 shows a trend, that is utilization pattern is similar though there is a difference of seven percent to two percent depending on blank diameter between the actual utilization results and model utilization results Table 1.4. This serves as a bench mark that identifies area for improvement as it can yield significant savings in materials. For example, from a production rate of 360 metric tonnes per month a saving of three percent can result in savings of eleven metric tonnes of raw material.

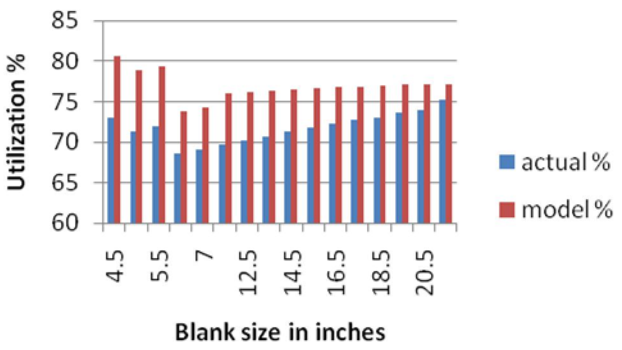

Fig 1.5 Histogram of model versus actual utilization

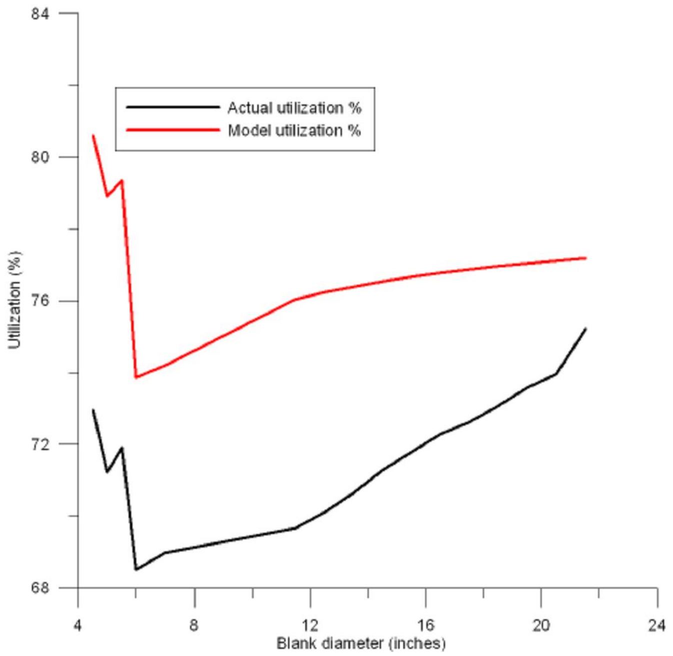

Fig 1.6 Graph of model versus actual utilization

V. CONCLUSION

In this study, model to determine theoretical raw material utilization during blanking was developed. Actual raw material utilization efficiency data for round blanks was collected for comparison with the model results. From the study, it was seen that the blanking model presented utilization trend that was comparable to the actual blanking utilization. However, it was observed there was a variation of seven percent to two percent depending on blank diameter between the model and actual results. The model can thus be used to bench mark the expected actual blanking utilization levels. Extreme variations between model and actual utilization efficiency would indicate problems that require addressing through statistical process control tools.

REFERENCES

[1] Nelly A., Gregory M. and Platts K., “Performance measurement system design,” *International Journal of Operations and Production Management*,vol. 15(4), pp. 80 -116, 1995.

[2] Neely A., Mills J., Richards H. and Gregory H., “Performance measurement system design: developing and testing a process based approach,” *International Journal of Operations and Production Management*, vol. 20(10), pp. 1119-1145, 2000.

[3] Maani K.E., Puttterill M. S. and Sluti D.G., “Empirical analysis of quality improvement in manufacturing,” *International Journal of Quality and Reliability management*, vol. 11(7), pp. 19-37, 1994.

[4] Globerson S., *Performance criteria and incentives system*. Elsevier, 1989.

[5] Khan T.A., “Material productivity,” *Technical Report Pakistan Engineering Council*, 2008.

[6] Chase R.B. and Aquilano, *Production And Operations Management*. Mc GrawHill, 2004.

[7] Giuntini R. and Gaudete K., “Remanufacturing:the next great opportunity for boosting united states of america productivity,” *Journal of Business Horizon*,vol. Nov/Dec, pp. 41-48, 2003.

[8] Nye T.J., “Stamping strip layout for raw material utilization,” *Journal of Manufacturing Systems*, vol. 19/No 4, pp. 239-248, 2000.

[9] Kalpakjian S. and Schmid S. R., *Manufacturing Process for Engineering Materials*. Pearson Education Inc,pp 336-400, 2003.

[10] Paquin J.R. and Crowly R.E., *Die Design Fundamentals*. Industrial Press INC New York, 1987.

[11] Boljanovic V., *Sheet metal forming process and die design*. Industrial press,2004.

[12] Koffman E. B. and Friedman F. L., *Fortran With Engineering Applications*.Addison Wesley, 1993.

[13] Kreitzberg C. B. and Shneiderman B., *Fortran Programming: A Spiral Approach*. Harcourt Brace Jovanovich Inc, 1982.