Experimental evaluation and optimization of warpage in injection molded nylon66 bevel gear using numerical simulation and neural network

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ABSTRACT: Uneven cooling of injection molded part sets up uneven distribution of stresses. These stresses warp the part and affect its dimensional accuracy. Lack of injection molding machine control leads to this defect in plastic parts. So as to keep the warpage minimum, accurate prediction of optimum process parameters is very important. Finite element analysis software, Moldflow Plastic Insight, Taguchi statistical design of experiment, and artificial neural network model are used to find optimum process parameter values. The optimum combination of process parameters that minimized the warpage is found out. Most effective factor contributing to warpage is melt temperature for this problem. The value of warpage obtained by using recommended process setting is reduced by 5.3% after optimization. Neural network model, formulated based on finite element simulation data, gives results with acceptable accuracy and can be used as an alternative to the costly and time consuming finite element simulation process.

1 INTRODUCTION

Injection molding is one of the most versatile, efficient and widely used manufacturing processes for the manufacture of plastic products with various shapes, sizes, and dimensions. Number of defects may occur during the injection molding process such as sink marks, warpage, weld lines, air traps, short shots etc. These defects are caused mainly due to improper process parameter settings, mold design, geometry of part as well as plastic material used to manufacture the part. Among these defects, warpage is the result of unequal stress in the molded part when the stress is strong enough to strain or distort the piece.

Chen et al. (2009) used Design Of Experiments (DOE) approach to determine optimal process parameter setting. ANOVA and regression models are formed for the results of simulation and experiment. Hakimian and Sulong (2012) discussed about warpage and shrinkage properties of injection molded micro gears polymer composites using Taguchi method. Kramschuster et al. (2005) investigated the effects of processing conditions on shrinkage and warpage behavior of a box-shaped, polypropylene part using conventional and microcellular injection molding. They used fractional factorial design of experiments approach. Wang et al. (2013) investigated the reduction of sink mark and warpage of the molded part in rapid heat cycle molding process. They used design of experiments via Taguchi methods to investigate the effect of processing parameters on warpage.

Taghizadeh et al. studied the warpage in plastic injection molded part using Artificial Neural Network (ANN). Back propagation neural network modeling for warpage prediction and optimization of plastic products during injection molding used by Fei Yin et al. (2011) Back propagation neural network trained by the data from finite element simulations which are conducted on Moldflow software. Farshi et al. (2011) optimized the injection molding process parameters by using Sequential Simplex Algorithm. Using more than one method for solving the problem of warpage is also popular. Hybrid optimization method was proposed by Deng et al. (2010), that combines a Mode-Pursuing Sampling (MS) method with the genetic algorithm for minimizing the warpage of injection molded plastic parts. Ozcelik and Erzumlu (2005) discussed the dimensional parameters effecting the warpage of thin shell plastic parts using Integrated Response Surface Method (RSM) and Genetic Algorithm. Chiang and Chang (2006) used an approach of orthogonal array with grey rational analysis and fuzzy logic to determine the optimal parameter setting for PC/ABS cell phone shell. Various researchers found different process parameters as most significant varying according to the problem under consideration.

2 EXPERIMENTAL DETAILS

A bevel gear (shown in Fig. 1) having diameter of 16.42 mm, gear thickness of 3.52 mm, and a teeth number of 20, is used as a model for this study. The gear is made up of Nylon66 A125 (Manufacturer-Unitika) and its material properties are given in Table 1. These values are taken from Moldflow Plastic Insight (MPI) material database. An 8-cavity mold layout is selected in this study and 3D mesh is used for meshing the model. The model consists of 521984 tetrahedral elements. It is created in MPI software which is a commercial software based on hybrid finite element method for solving pressure, flow and temperature fields. FE model with feeding system and cooling channels is shown in Figure 2.

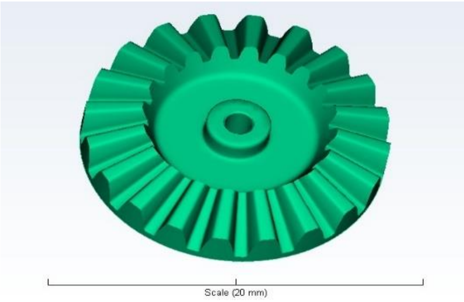

Figure 1. Gear used for this study

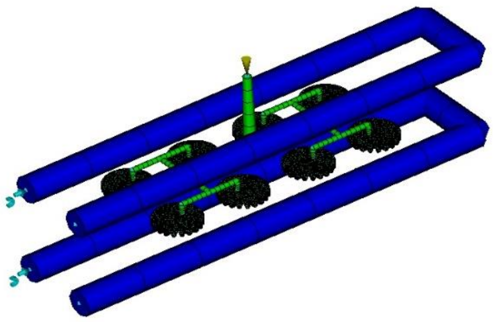
Figure 2. FE model with feed system and cooling channels

The parameters used for the warpage analyses are the melt temperature, mold temperature, packing pressure, injection time and cooling time and are represented by the letters "A", "B", "C", "D" and "E" respectively. Three levels of these parameters are selected taking reference from material database available in MPI and are given in Table 2. Taguchi L_{27} (3^5) orthogonal array are selected for the experimental design.

Table 1. Properties of plastic material (Nylon-66) used for bevel gear.

Properties	Values
Trade name	Unitika Nylon66 A125
Recommended mold surface temperature (°C)	90

Recommended melt temperature (°C)	290
Ejection temperature (°C)	158
Elastic modulus (MPa)	2690

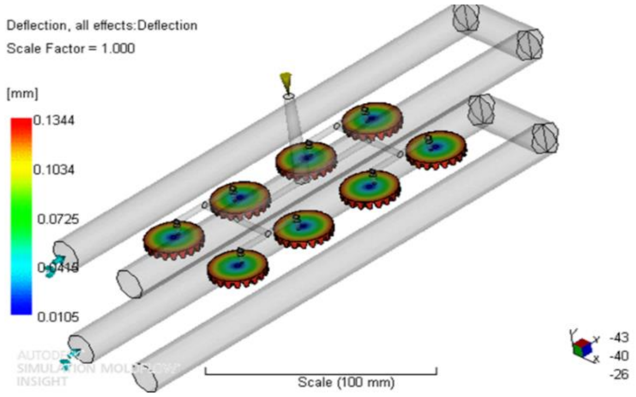

Figure 3. Warpage analysis result of the 8 cavity bevel gear mold

The FE analyses of this system are performed for all the 27 sets of process settings and are given in Table 3 with their warpage values obtained by FE analysis. The analysis sequence used in this case is "Fill + Pack + Warp". The packing time is kept constant at 5 s for all the cases. Other machine and process parameters are kept as default. The results of warpage for one of the analysis are shown in Figure 3. The maximum warpage value of the part and its location can be seen directly from the picture.

Table 2. Setting of the processing parameters.

Level	Experimental factors				
	A:Melt temperature (°C)	B:Mold temperature (°C)	C:Packing pressure (MPa)	D:Injection time (s)	E:Cooling time (s)
1	280	80	30	0.5	15
2	290	90	40	1	20
3	300	100	50	1.5	25

The objective of this study is to minimize the warpage to the greatest extent possible and develop a prediction model for warpage so as to reduce the time and cost involved in repetitive FE analyses. Hence, a neural network model is developed using Matlab neural network toolbox.

3 RESULTS AND DISCUSSION

3.1 *Taguchi method*

The Taguchi method is applied to design the experiment and to determine the effect of process parameters on warpage. The measured warpage values and their S/N ratios are given in Table 3. S/N ratio is used to evaluate the effect of altering a particular parameter value on the desired output.

Table 3. Process settings with their warpage values obtained by FE simulation.

Test No	Process setting					Simulated warpage value (mm)	S/N ratio
	A	B	C	D	E		
1	280	75	30	0.5	15	0.1252	18.04
2	280	75	30	0.5	20	0.1252	18.04
3	280	75	30	0.5	25	0.1252	18.04
4	280	85	40	1.0	15	0.1248	18.07

5	280	85	40	1.0	20	0.1251	18.05
6	280	85	40	1.0	25	0.1244	18.10
7	280	95	50	1.5	15	0.1255	18.03
8	280	95	50	1.5	20	0.1255	18.03
9	280	95	50	1.5	25	0.1255	18.03
10	290	75	40	1.5	15	0.1272	17.91
11	290	75	40	1.5	20	0.1272	17.91
12	290	75	40	1.5	25	0.1272	17.91
13	290	85	50	0.5	15	0.1285	17.82
14	290	85	50	0.5	20	0.1285	17.82
15	290	85	50	0.5	25	0.1289	17.79
16	290	95	30	1.0	15	0.1325	17.55
17	290	95	30	1.0	20	0.1322	17.57
18	290	95	30	1.0	25	0.1318	17.60
19	300	75	50	1.0	15	0.1318	17.60
20	300	75	50	1.0	20	0.1305	17.68
21	300	75	50	1.0	25	0.1318	17.60
22	300	85	30	1.5	15	0.1352	17.38
23	300	85	30	1.5	20	0.1352	17.38
24	300	85	30	1.5	25	0.1352	17.38
25	300	95	40	0.5	15	0.1343	17.44
26	300	95	40	0.5	20	0.1344	17.43
27	300	95	40	0.5	25	0.1344	17.43

"The smaller, the better" quality characteristic is selected while calculating the S/N ratios as goal of this study is to minimize the warpage of the part. The response table of S/N ratios is given in Table 4. S/N response graphs are plotted using the data given in Table 4 and are shown in Figure 4. The optimum combination of process parameters can be determined by selecting the level with highest value for each factor. Hence, the best combination of process parameters for this study is A1, B1, C3, D3 and E1. We have selected E1 instead of E2 because there is a negligible difference between S/N ratios of two levels and, selection of E1 causes reduction of cooling time from 20 s to 15 s. Thus, the cycle time of the process gets reduced by large amounts without compromising the quality of the part. The difference values in Table 4 denote the most significant process parameter for warpage. Melt temperature is found to be most significant process parameter followed by melt temperature and packing pressure. Injection time and cooling time had least effect on warpage of the bevel gear.

Table 4. The response table of S/N ratios.

Level	A	B	C	D	E
Level 1	18.05	17.86	17.66	17.76	17.76
Level 2	17.76	17.75	17.80	17.76	17.77
Level 3	17.48	17.68	17.82	17.77	17.76
Difference	0.57	0.18	0.16	0.01	0.01

The optimum combination of process parameters is not included in the 27 FE analysis test runs given in Table 3. Therefore, a confirmation test is conducted to validate the results obtained by Taguchi method. The corresponding S/N ratio is 18.30 dB which is higher than those obtained in orthogonal array design of experiment. It shows that the results obtained are better and warpage value is optimized.

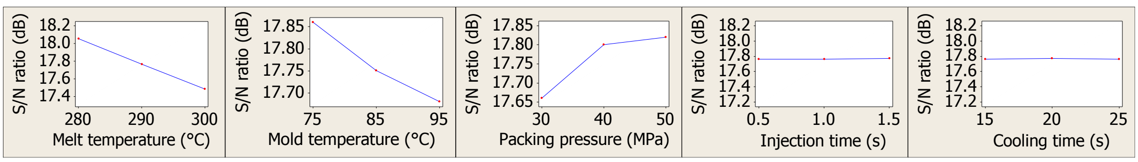

Figure 4. Effect of the processing parameters on warpage

3.2 *ANOVA*

The ANOVA is conducted on the data from the FE analysis results using MINITAB V14 software and the results are shown in Table 6. The confidence interval is set as 95% and significance level as 5% for the ANOVA analysis. If "P value" for any parameter is less than 0.05, then the parameter has significant effect on the result. From the "P value" column of Table 5, it is clearly seen that melt temperature, mold temperature and packing pressure have significant effect on the warpage values.

The percentage contribution of each parameter is calculated using the following equation.

$$(PC)_A = SS_A/SS_{Total} \tag{1}$$

where $(PC)_A$ = percentage contribution of factor A; SS_A = sum of squares of factor A; and SS_{Total} = sum of squares of all factors. Percentage contributions for other factors are calculated using the same method and are given in the last column of Table 5.

Table 5. The ANOVA table for part warpage.

Factor	SS	df	MS	F	P	PC (%)
Melt temperature	0.0003243	2	0.0001622	1569.20	0.000	83.07
Mold temperature	0.0000345	2	0.0000172	166.91	0.000	8.83
Packing pressure	0.0000298	2	0.0000149	144.33	0.000	7.63
Injection time	0.0000001	2	0.0000000	0.42	0.664	0.02
Cooling time	0.0000001	2	0.0000000	0.39	0.685	0.02
Error	0.0000017	16	0.0000001			0.43
Total	0.0003904	26				100.00

3.3 *Neural network model*

A neural network has one or more hidden layers placed between the input and output layers. The layers have processing units called neurons. These neurons are connected by variable weights. All the neurons in the preceding layer give total input to each neuron in the succeeding layer. In this study, neural network is used to predict the warpage values corresponding to optimal process setting determined by Taguchi method and Moldflow recommended process setting. Matlab neural network toolbox is used for this study. A 5-10-10-1 feed-forward backpropogation neural network model is created and trained. The value of warpage by Moldflow recommended process setting and process setting after optimization are found out using this network. Comparison of the predicted and FE simulation values of warpage for the optimal setting and Moldflow recommended setting are given in Table 6.

Table 6. Comparison of warpage before and after optimization.

	A	B	C	D	E	Simulated warpage	ANN
Moldflow recommended process setting	290	90	40	1	20	0.1311	0.1311
Process setting after optimization	280	75	50	1.5	15	0.1216	0.1203
Change rate (%)						-7.24	-8.24

4 CONCLUSIONS

Optimal settings of process parameters for the bevel gear made up of Nylon66 A125 are determined for optimization of warpage. The optimal combination of process parameters for minimization of warpage is 280°C of melt temperature, 75°C of mold temperature, 50 MPa of packing pressure, 1.5 s of injection time and 15 s of cooling time. Melt temperature is the most significant process parameter and contributes 83.07% to warpage. Mold temperature and packing pressure are other significant process parameters while injection time and cooling time have least effect on warpage. The warpage value obtained in the Moldflow recommended process setting is reduced by 5.3% after optimization. A neural network is formulated using Matlab neural network toolbox to predict the warpage values directly. The model predicts warpage values with good accuracy. The optimization methodology used in this study can be employed to minimize the time and cost associated with repetitive FE analyses.

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Selection procedure of fin type and fin configuration for plate fin heat exchanger

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ABSTRACT: The present study aims at selection of fin configuration for required heat duty. In this regard, a novel methodology is developed to select an appropriate fin by comparing different types and sizes of fin. This comparison is based on different constraints. These constraints are fixed frontal area, fixed heat exchanger volume and fixed pumping power. Different graphs are generated for plain fin, offset strip fin and louvered fin according to the constrains.

Keywords: Plate Fin Heat Exchanger, Plain Fin, Strip Fin, Louvered Fin, Configuration

NOMENCLATURE

A Heat exchanger area (m^2)
D Hydraulic diameter (m)
f Friction factor
j Colburn factor
L Length (m)
$\dot{m}$ Mass flow rate (kg/s)
NTU Number of transfer units
P Pumping power
Pr Prandtl number
V Volume (m^3)
ρ Density of fluid (kg/m^3)
μ Dynamic viscosity (Ns/m^2)

SUBSCRIPT

A Fix area
fr Frontal area
v Fix volume
p Fix pressure

SUPERSCRIPT

f Fix parameter
p Problem associate
s Solution associate

1 INTRODUCTION

A proper selection of surface is one of the most important considerations in plate-fin heat exchanger design. There is no such thing as surface that is best for all applications. The particular application strongly influences the selection of surface to be used. Hence, this paper presents selection methodology for the type of fin, based on three types of constrains. These constrains are: fixed frontal area, fixed heat exchanger volume and fixed pumping power. This procedure will help to select the type of fin(configuration of fin) from Kays and London data. There are number of configurations for plain fin, strip fin and louvered fins provided by kays and London [Kays 1964]. However, at the first step of thermal designing of compact heat exchanger, a selection of proper fin type and configuration of fin on hot fluid side and cold fluid side is necessary. Moreover, the cold burn factor j and friction factor f for different fins are function of Reynolds numbers. These factors can be used to specify surface characteristics of different fin configurations. With the help of these parameters comparisons between the different fins on the basis of pumping power, heat transfer and size can be made.

Most common problems in the designing of heat exchanger are rating and sizing. Rating problem is concerned with determination of heat transfer rate and fluid outlet temperatures for prescribed fluid flow rates, while sizing procedure involves determination of heat exchanger dimensions, that is: selecting proper heat exchanger type and determining the size to meet requirements of specified hot and cold fluids inlet and outlet temperatures, flow rates and pressure drops [Shah 2003].

A family of methods for comparing compact heat transfer surface configurations are provided by T A Cowell [Cowell 1990]. A simple approach to surface selection based on the concept of volume performance index (VPI) is presented in [Nunez 1989]. Surfaces, which result in the smallest volume will exhibit higher VPI [Nunez 1989]. Surfaces are compared on the basis of VPI and envelopes for best performance are produced.

Selection of fin of plate fin heat exchanger is required both sides (Hot side and Cold side). There is no method which gives direct selection of fin for selected application. For different fluid and operating condition each fin gives different effectiveness and pressure drop and also gives different size of heat exchanger. There are various methods for comparison of fin surfaces like Area goodness factor, Volume goodness factor and comparison with reference surface however, some difficulties remain with all of them. T A Cowell [Cowell 1990] showed the measurement for the relative values of required hydraulic diameter, frontal area, total volume and pumping power for different surface. Selection procedure based on three different constrains fix frontal area, fix pumping power and fix heat exchanger volume is shown below.

2.1 *Comparison of fixed frontal area*

Application of this condition allows the comparison of heat transfer surfaces without the need for scale to be specified. If A_f is fixed frontal area as per method given in [Cowell 1990]

$$D_A = \sigma \operatorname{Re} \frac{\mu A^f}{\dot{m}} = D_A{}^s D_A{}^p$$

The subscript A implies the fixed frontal area condition, the superscript s implies the solution related component, and the p indicates the problem-related part

$$V_A = \frac{\sigma \operatorname{Re}}{j} \cdot \frac{\mu A^{s^2} NTU^f \operatorname{Pr}^{2/3}}{4\dot{m}} = V_A{}^s V_A{}^p$$

$$P_A = \frac{f}{\sigma^2 j} \cdot \frac{\dot{m}^3 NTU^f \operatorname{Pr}^{2/3}}{2A^f \rho^2} = P_A{}^s P_A{}^p$$

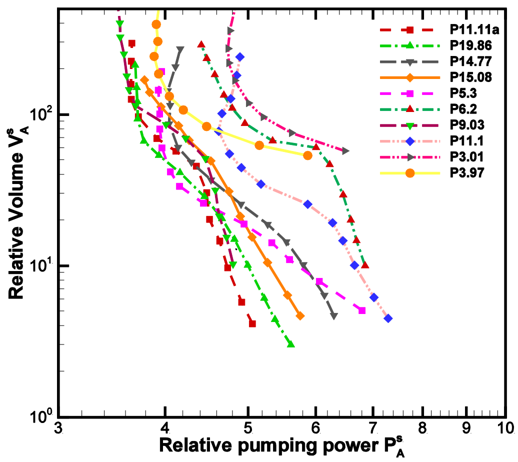

Figure 1 Relative volume vs Relative pumping power for plain fin

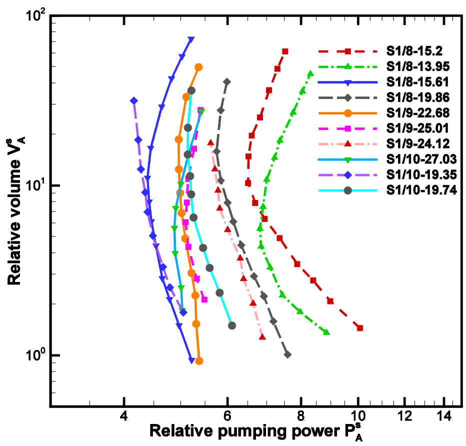

Figure 2 Relative volume vs Relative puming power for strip fin

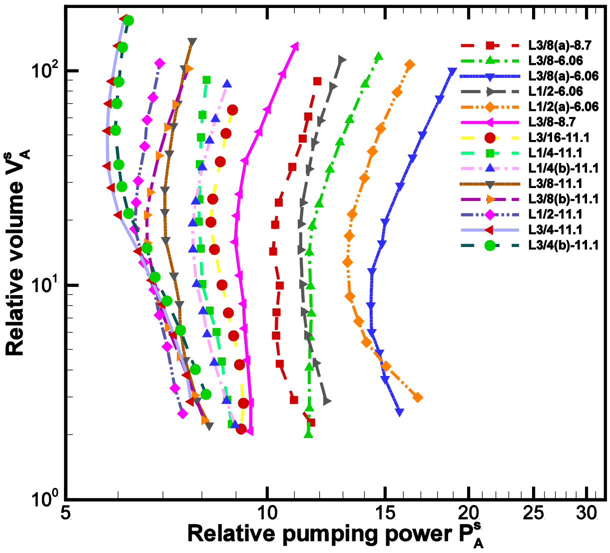

Figure 3 Relative volume vs Relative pumping power for Louvered fin

2.2 *Comparison of fixed heat exchanger volume*

For fixed heat exchanger volume we can write equation of relative frontal area and relative pumping power as below,

$$D_v = \left(\sigma j \operatorname{Re}^{1/2}\right) \cdot \left[\frac{4\dot{m}V^f}{NTU^f \mu \operatorname{Pr}^{2/3}}\right]^{1/2} = D_v{}^s D_v{}^p$$

$$A_{fr_v} = \left(\frac{j}{\sigma \operatorname{Re}}\right)^{1/2} \cdot \left[\frac{4\dot{m}V^f}{NTU^f \mu \operatorname{Pr}^{2/3}}\right]^{1/2} = A_{fr_v}{}^s A_{fr_v}{}^p$$

$$P_v = \left(\frac{f \operatorname{Re}}{\sigma j^2}\right) \cdot \left[\frac{\mu \dot{m}^2 NTU^{f^2} \operatorname{Pr}^{4/3}}{8\rho^2 V^f}\right] = P_v{}^s P_v{}^p$$

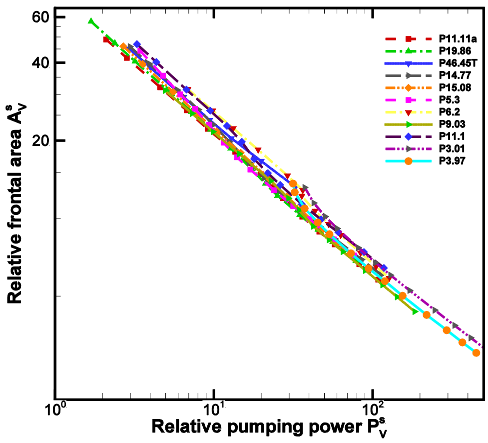

Figure 4 Relative pumping power Vs Relative Frontal area for plain fin

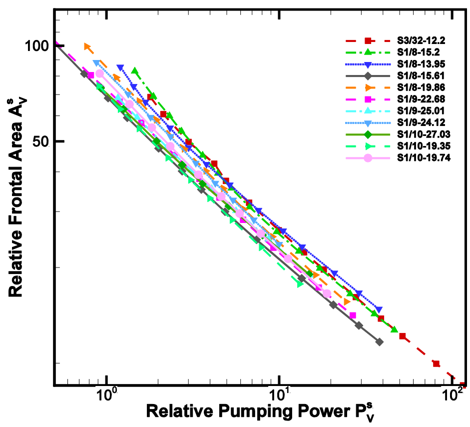

Figure 5 Relative pumping power Vs Relative Frontal area for strip fin

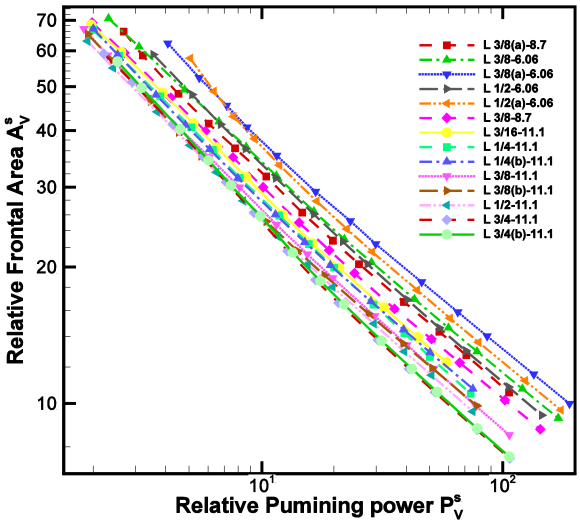

Figure 6 Relative pumping power Vs Relative Frontal area for louvered fin

2.3 *Comparison of fixed pumping power*

If comparisons are now made of the different geometries that are able to deliver the required heat transfer under the constraint that pumping power has a fixed value P''',then hydraulic diameter is given as follows,

$$D_p = \left(\frac{f\,\mathrm{Re}^2}{j}\right)^{1/2} \cdot \left[\frac{NTU^f \dot{m}\mu^2 \,\mathrm{Pr}^{2/3}}{2\rho^2 P^f}\right] = D_p{}^s D_p{}^p$$

$$A_p = \left(\frac{f}{j\sigma^2}\right) \cdot \left[\frac{NTU^f \dot{m}^3 \,\mathrm{Pr}^{2/3}}{2\rho^2 P^f}\right] = A_p{}^s A_p{}^p$$

$$V_p = \left(\frac{f\,\mathrm{Re}}{\sigma j^2}\right) \cdot \left[\frac{NTU^{f^2} \dot{m}^2 \mu \,\mathrm{Pr}^{4/3}}{8\rho^2 P^f}\right] = V_p{}^s V_p{}^p$$

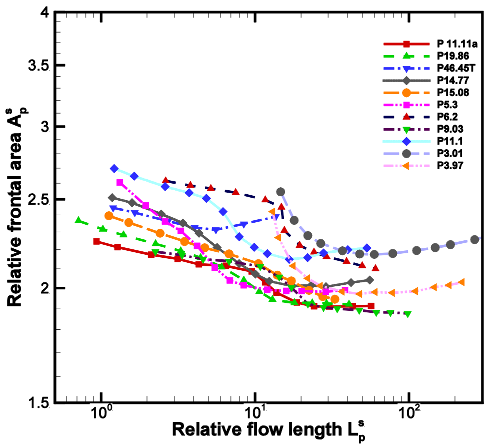

Figure 7 Relative frontal area Vs Relative Flow length for plain fin

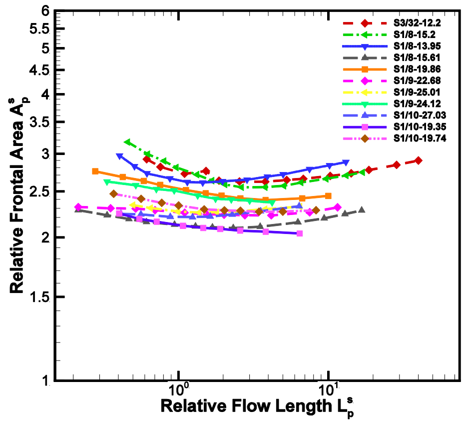

Figure 8 Relative frontal area Vs Relative Flow length for strip fin

Here, the comparison can be more easily interpreted if flow length is considered instead of the volume. Flow length is given by following equation,

$$L_p = \frac{V_p}{A_p} = \left(\frac{f\,\mathrm{Re}^2}{j^3} \right)^{1/2} \cdot \left[\frac{NTU^{f^3}\,\dot{m}\mu^2\,\mathrm{Pr}^2}{32\rho^2 P^f} \right] = L_p{}^s L_p{}^p$$

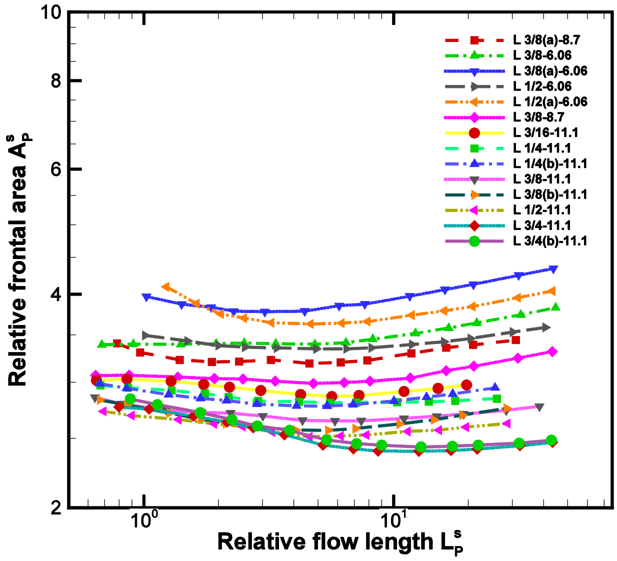

Figure 9 Relative frontal area Vs Relative
Flow length for louvered fin

Fig 7, Fig 8 and Fig 9 are the plots of relative frontal area against Relative flow length for surfaces as plain fin, strip fin and louvered fin. A wide range of comparison can be rapidly made between different geometric solutions.

3 SELECTION PROCEDURE

The selection of fin configuration for the required heat duty and specific constrain can be made by using various graphs shown in Fig. 4 to Fig. 9. The comparison of the characteristics of different types of fins can be made by using the graphs of Pv *vs* Av as shown in Fig 4, Fig 5 and Fig 6 for plain fin, strip fin and louvered fin respectively. From these figures one can get relative frontal area for specified pumping power for all types of fins. Note that the fin having low frontal area is the best selection. Similarly Fig. 7, Fig. 8 and Fig. 9 can be used for the other constrains.

4 CONCLUSION

In the present work a methodology for selection of fin configuration is specified. The selection is based on various constrains. The methodology is found to be satisfactory tool for thermal design of compact heat exchanger.

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Application of fishbone diagram for modification of sheet metal tools: A case study

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ABSTRACT: In this case study, progressive tools used for manufacturing of the sheet metal components of Molded Case Circuit Breaker (MCCB) were studied. The progressive tools used are newly manufactured. By taking the trial of tooling one by one, problems related to tooling are identified. Corrective actions are taken to modify the tool and to eliminate all defects and assignable causes. Based on observations and by combining the causes of defects of all the tools, a detailed fishbone diagram is constructed. With the help of this study and modification of tooling, desired specifications are achieved. Sheet metal components produced by the rectified tool are then validated by calculating C_p & C_{pk} value for all the Critical to Quality (CTQ) dimensions as specified in drawing of component.

1. INTRODUCTION

A Molded Case Circuit Breaker (MCCB) is used to protect the electrical connections and electric circuits from damage caused by current overload and short circuit. In MCCB, operations like ON, OFF & Tripping is performed by the Tripping Mechanism, which consists of press components. Large numbers of Sheet metal tools are utilized to produce press components used in the Tripping Mechanism. For proper working of the tripping mechanism, press components must be as per the required specifications. Study of Sheet Metal Tooling is important, in order to achieve desired specifications.

1.1 Press machine

The press machine used in sheet metal forming operation is MCF 1000 (H Frame) 100T. This machine is only used for automatic blanking operation. It is a power press with 100 tonnage capacity. Its Frame is H type frame. Manufacturing line consists of a Decoiler, Straightener, Feeder and Press machine.

1.2 Progressive die

Progressive dies offer an effective way to convert raw material in the form of coil into a finished product with minimum material handling. When the material is fed from one station to another in the die, the material is progressively completed into finished part. The stock on progressive dies move from one station to another, with distinct operations being performed at every station. After the completion of each stroke, part material is fed by one progression. Usually, the material is perforated in initial stations, which are used by pilot for locating the strip (Vishwanath 2013).

2. LITERATURE REVIEW

The purpose of this literature review, is to develop a base of information in sheet metal tooling. An overview of the literature is presented for progressive tool and also for the problems faced during the working of tools

Podgornik et al. (2011) examined the probability of reducing lubrication and of replacing costly tungsten carbide material in blanking/piercing by introducing coatings in hard tool. Experimental results showed, that (AlCrN) coatings can be effectively used in blanking/piercing applications, on softer steel tools also. It reduces friction and wear, as well as lowers the costs of the tool.

Aurich et al. (2009) presented strategies for burr minimization. Simulation models of burr formation capable of indicating the interaction and dependencies of key process parameters.Specialized burr sensors are used for inspecting and detection of burr.

Nandedkar et al. experimental results showed, that for ratio of die radius to sheet thickness (*R/t*), minimum spring-back is observed up to a defined value of *R/t* ratio and it increases with increase in *R/t* ratio. It was also concluded that first the springback increases with increase in blank holder force, and then continuously decreases with increase in blank holder force.

3. METHODOLOGY

All Progressive tools are trialed on the press machine for problem identification. Before the trial, many factors are responsible for correct working of tool and they are listed in section 4. These factors have been studied and followed while running progressive tools. When tool is running, all the observations are noted down. Minor problems occurring during running of tool are solved simultaneously if possible. After completion of the trial, all the observations regarding tool, as well as the components are studied thoroughly. Based on the observations and detailed study of causes of defects, actions are taken. Factors affecting problems are identified and corrective actions are taken to rectify the tools. Rectifications of tool take considerable time as handling, disassembling and assembling of tool is difficult process. After rectification, tool is trialed again and checked for problems in running of tool. If the problems regarding running of tool or component dimensions still occur, then the tool needs to be rectified again as per observations in 2nd trial. If there is no problem in running of tool, then the component dimensions are checked as per design. If both, running of tool and the dimensions checked are satisfactory then more number of components are produced.

4. STANDARD OF PROCEDURE (SOP) FOR TOOL SETUP

- **Die placement –** The die should be set in a manner to facilitate the material feed parallel to the tool. Always place the center of the estimated tonnage in the center of the press. Die should always be in center along the length of bolster plate.
- **Die clamping –** Make sure that the clamps are in the correct position and they are not interfering with die parts. Make sure that the bolts and fasteners are fully tightened and secure.
- **Material properties and dimensions –** Before using coil, always check the hardness and grade as per requirement. Check coil width and thickness before entering in tool.
- **Pitch and progression –** The amount of feed pitch and progression should be set correctly in feeder. Overfeeding or underfeeding will result in a misfeed and can damage the die.
- **Feed line height** – Feed line height is the height at which the strip is fed into the die. Height of feeder should be at same height of die entry
- **Shut height** – Make sure that the shut height of the die is set correctly. Avoid hitting setup blocks. For setting shut height of new tool, move the ram of machine slowly to confirm the required shut height.
- **Coil Centering** – Coil should be in center, while placing in the straightener and feeder.
- **Stock condition-** Ensure that the coil is properly straightened and feeds smoothly through the die.
- **Die protection-** Ensure that all die protection equipments, such as misfeed sensors and proximity switches are installed and functioning properly.

- **Feed and pilot release-** Timing of the feed release should be exact, so that the pilots can easily locate the strip. Usually this is performed by moving the press down in inching mode and releasing the feed roller when the lead of the pilots has entered the pilot hole.
- **First hit condition –** Before taking the first stroke, make sure that the strip has entered in the die correctly. Strip should be passed through guide plate or guiding lifter in the die. Ensure that the strip is touched to the side clip stopper for correct pitch. Check the die thoroughly for any loose scrap present in die.
- **Lubrication –** Ensure that the coil is lubricated by Mineral turpentine oil (MTO) while running. Oil-mist unit should be in ON condition.

5. TOOL OBSERVATIONS AND ACTIONS TAKEN FOR RECTIFICATION:

As explained in the methodology, tools were trialed on the press machine to find all defects in the tool. Same procedure was followed for all the tools. Some of the tools were even trialed for 2nd and 3rd time to produce correct components. Before the trial, all the items in SOP for tool setup should be performed. After trial run, the observations noted for all tools are listed below. As per observations and study of all the factors, actions taken are also listed below.

5.1 *Observations and the corresponding corrective actions taken are listed below in tabular form*

1) Observations identified during the trial and the corresponding corrective actions taken for rectification of tool 1 are listed as shown in Table 1. Component produced by progressive tool is moving contact.

Table 1. Observations and corresponding corrective actions for tool no. 1

Sr.No.	Observations	Remarks	Action taken
1	Components were not falling till 7 shots/stack	Angular relief given on the die is not effective.	Component Relief increased by 0.2mm
2	Strip jammed.	Due to half piercing of one Hole.	Guide plate relieved by 0.4mm after embossing station.
3	Strip jammed.	Strip bulging of 1mm is taking place due to embossing and blanking collectively	Piercing slug relief changed from taper to step relief
4	7 Pilots broken	Due to strip jamming, misfeed occurred	Damaged pilots replaced and tool was ran with misfeed sensor

2) Observations identified during the trial and the corresponding corrective actions taken for rectification of tool 2 are listed as shown in Table 2. Component produced by progressive tool is trip plate.

Table 2. Observations and corresponding corrective actions for tool no. 2

Sr.No.	Observations	Remarks	Action taken
1	Misfeed sensor activates after 140 degree in every stroke.	Spring very sensitive	Misfeed pilot spring changed, hard spring used
2	Hole near bend line is elongated	Very near to bend line	Piercing punch diameter is increased by 0.05mm
3	Micro slug at cut off station	-	New cut-off punch made
4	U-bend dimension deviated	Resizing station not effective	Shims of defined size added to resizing mechanism

3) Observations identified during the trial and the corresponding corrective actions taken for rectification of tool 3 are listed as shown in Table 3. Component produced by progressive tool is latch link.

Table 3. Observations and corresponding corrective actions for tool no. 3

Sr.No.	Observations	Remarks	Action taken
1	No mis-feed sensor	No provision for mechanism of mis-feed sensor	Provision of mis-feed mechanism made
2	Piercing slug at first station coming up	Slug gets stuck to strip	New coil with correct hardness was used
3	U-bend dimension is deviated	Resizing in left side not performing	Re-striking punch changed from line contact to surface contact.
4	Cut-off punch broken	Due to high friction and heat	Punch was replaced by new PVD(AlCrN) coated punch

5.2 *Generic Cause and effect diagram*

With the help of observations taken during working of all tools, detailed cause and effect diagram has been constructed. This cause and effect diagram shows all the possible causes for defects and improper working of progressive tool used for manufacturing sheet metal components for MCCB. By referring this cause and effect diagram, problems related to progressive tool can be resolved easily. Detailed cause and effect diagram is shown in Figure 1

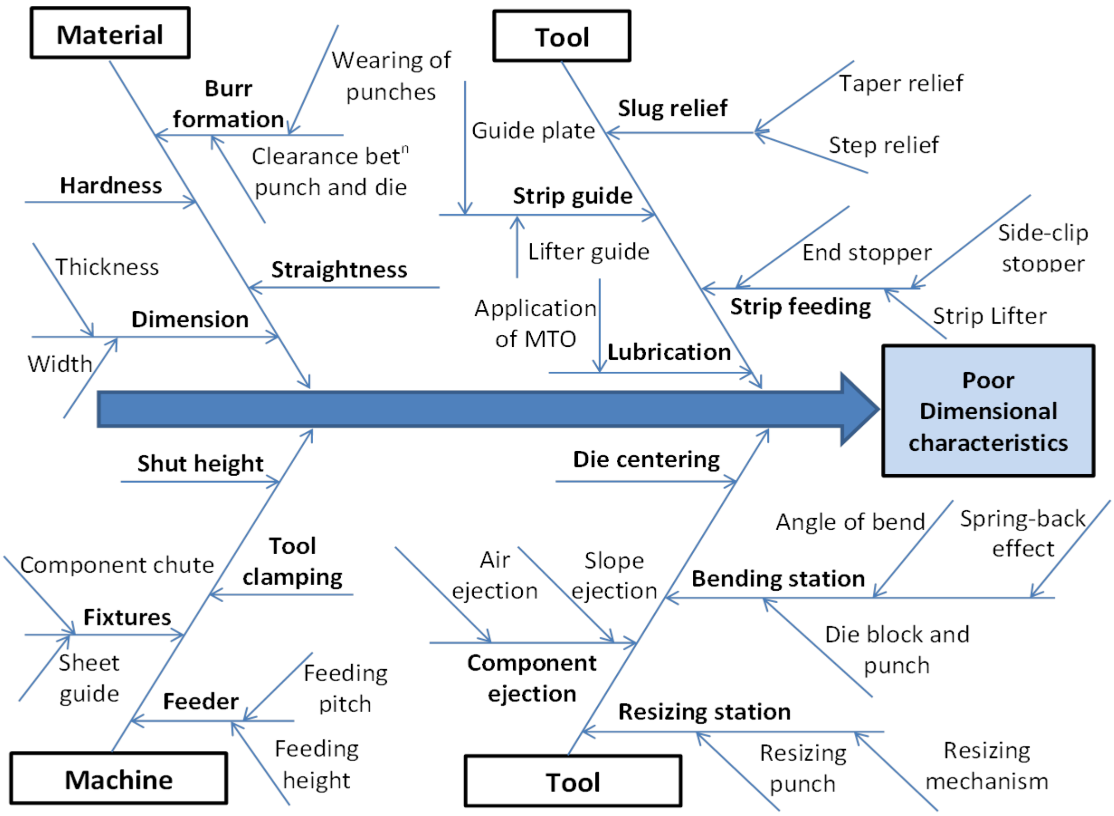

Figure 1. Genericcause and effect diagram of progressive tools for producing MCCB press component

6. VALIDATION OF RECTIFIED TOOLS

After rectification of the tool, it is trialed again to ensure that all the defects are eliminated. When it is ensured that all the defects are eliminated, some samples of components are checked for dimensional specification. If both, running of tool and dimensions checked are satisfactory, then more number of components are produced. Those components are then inspected for validation of rectified tool. Sample size of 30 numbers [Momtgomery 2009] are selected from the lot and inspected for CTQ (Critical to Quality) dimensions. The reading of CTQ dimensions for 30 samples are noted and C_p& C_{pk} value is calculated in Minitab Software. If the C_{pk} value for all CTQ dimensions comes above 1.33 (4 sigma) [Momtgomery 2009], then the components produced are under dimensional tolerance. Same procedure is followed for all the tools. Results of C_p& C_{pk} value are: C_{pk} value for hole with diameter 2.1 mm of tool 1 is **1.4**. C_{pk} value of U-bend dimension 11.2 mm of tool 2 is **1.41**. C_{pk} value of U-bend dimension 20 mm of tool 3 is **1.56.**

7. CONCLUSION

For solving problems related to sheet metal forming, detailed study of design, components and the working of progressive tool is essential. Factors affecting functioning of the tool, also plays important role in correct dimensional specifications. Fishbone diagram helps in identifying the significant causes of defects affecting the working of tool. Detailed Fishbone diagram is made by combining the defects occurred in all tools. 3 numbers of progressive tools were trialled and successfully modified to produce MCCB components with correct dimensional specifications. All the tools were validated by calculating C_p & C_{pk} value for CTQ (Critical To Quality) dimensions. C_{pk} value for CTQ dimensions are obtained above 1.33 (4 sigma) for all components. Same procedure can be followed to identify the possible defects and for the rectification of progressive tools used in the future to produce sheet metal components. By referring to the detailed fishbone diagram, significant defects of other progressive tool can be identified effortlessly.

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A case study of productivity improvement of grinding process in a rubber roller manufacturing industry

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ABSTRACT: In this paper, grinding process of rubber roller manufacturing is selected and work study principles are applied for productivity improvement. The activities of worker are captured and arranged as per the sequential order. The various flow process charts for man, machine, and material are drawn and time study is performed. Alternate grinding cycle is proposed and modified based on the results of analysis of time study and process chart. With the modified process there is a productivity improvement of 50%.

Key words: Productivity improvement; Rubber roller grinding; Work study; Method study; Time Study

I. INTRODUCTION

Productivity is one of the major factors that enable the manufacturing firm or organization to compete in the global market. Throughout the history of manufacturing, there has been a constant effort to improve the utilization of resources. Productivity studies aim at identifying how efficiently the resources in the system are used in producing desired production. In general terms, productivity can be defined as the ratio of output produced to input resources utilized in the production. [Talib 2010]

To enhance the productivity, work study and time study are the most important principles. [Barnes 1980] Time taken for process elements is one of the most important factors for improving productivity. [Kanawaty 1992] Through time study, positive changes that occur in organization can be observed. [Pratiban]

An essential component for the textile and paper industries i.e. rubber roller is shown in Figure 1. The preliminary observations of existing process of the rubber roller manufacturing show ample scope for improvement.

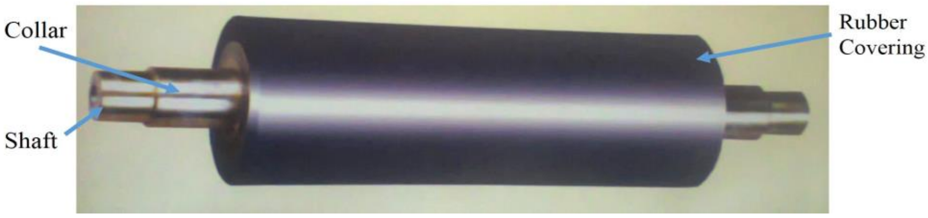

Figure 1. Rubber roller

1.1 Problem definition and research aim

It is intended to carry out a research to enhance productivity of rubber roller manufacturing industry through elimination of non-value adding processes and/or through implementation of enhanced manufacturing process.

2. METHODOLOGY

1) Observe and describe the small process elements of each major process and its sub steps and perform time study i.e. time taken for each element.
2) Analyze the results of time study in order to identify non-productive, excess time consuming, or unnecessary steps i.e. non-value adding and redundant activities.
3) Modify or eliminate the activities so as to reduce process time and enhance the productivity.

3. GRINDING PROCESS

Grinding is a process of rubber roller, in which material is removed and applied finishing on rubber covered on outer periphery of metal core using grinding wheel face on center type cylindrical grinder machine shown in Figure 2.

3.1. Process description

1) Threaded rubber roller is brought on the machine by crane operator by wrapped belt in middle.
2) Head stock and tail stock are set to accommodate the roller between them as shown in Figure 2.
3) Roller center and machine bed center are aligned and roller is fixed between them accordingly.
4) Cloth wrapping is removed from roll and collected in nearby tin.
5) Through-ness of roll and grinding wheel cutting length are adjusted through stopper provided on the ways of the grinding machine.
6) The roller is ground with a grinding wheel in a face grinding mode as shown in Figure 3. Rubber roller camber is set and required depth of cut and feed are given.
7) As cut completes, powder is applied on both sides and center and diameter is measured accordingly.
8) Hardness is verified at different ends.
9) Paper and cotton tape is wrapped on finished rubber roller by helper.
10) Roller is unloaded from the machine and kept at designated area.
11) Machine is cleaned by the operator.

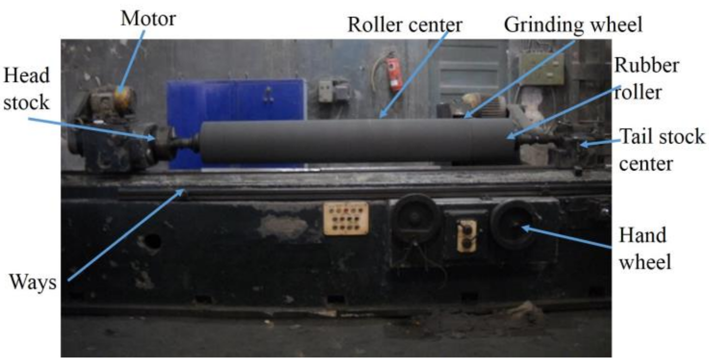

Figure 2. Roller held between head stock and tail stock on a grinding machine

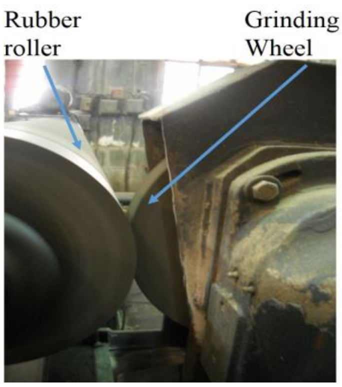

Figure 3. Face grinding of rubber roller on grinding machine

The study of roller grinding process has been carried out by application of method study and the process is divided in to small process activities. The detailed process flow charts (man, machine and material) consisting of total 132 activities have been drawn for the analysis purpose. However, due to the limitation of the number of pages for this research, only process flow charts (man, machine and material) of grinding cycle has been shown in Table 1.

Table 1. Process flow chart for man, machine and material of a rubber roller grinding cycle

Sr. No	Operator	Man						Machine						Material						Remarks
		Symbol						Symbol						Symbol						
		○	⇨	D	□	▽	◙	○	⇨	D	□	▽	◙	○	⇨	D	□	▽	◙	
1	In case of camber roll, goes behind the machine and provides camber by properly setting the knob provided.	●						●								●				
2	Turns on the Camber lever at the front of the machine.	●						●								●				
3	Brings in the grinding wheel and applies depth of cut by rotating the handwheel. At the same instant, provides feed to the machine table by moving lever in on position.	●						●						●						Feed in the grinding machine is hydraulically operated hence feed is automatic and varies with the material and size of roll and the depth of cut. The lathe bed moves horizontally as grinding wheel grinds the roll.
4	Cut running			●				●						●						
5	As cut completes, slows down machine by turning lever in off position.	●						●									●			Grinding cut is applied from left side of roll to right side of roll i.e. bed moves from right to left. The next cut continues from the place the previous cut ends.
6	Goes to fetch powder from machine table.		●							●						●				If powder gets used up, fetches new from near entrance. This process is done during the ongoing grinding cut.
7	Takes powder in paper and applies at both sides and center.	●						●											●	No powder is applied in case of ebonite rolls.
8	Goes to keep powder back at the machine table.		●							●						●				Stops the machine after application of powder.
9	Brings back the Micrometer for measuring diameter.		●							●						●				
10	Measures the diameter at sides and center.				●					●				●						If diameter is larger than required, applies another cut and follows previous grinding steps again.

4. ANALYSIS

The total activities for the grinding process are 132 as summarized in Table 2. The activity of grinding cycle is repeated 8 to 9 times with depth of cut 0.05 mm each time to achieve the final dimension of the roller. The Table 3 shows various activities to be performed in one grinding cycle.

Table 2. Summary of grinding process chart

Summary of grinding process chart				
Activity	*Symbol*	*Man*	*Machine*	*Material*
Operation	○	85	67	38
Inspection	D	12	0	12
Transportation	□	11	30	3
Delay	⇨	21	42	68
Storage	▽	0	0	0
Operation and Inspection	◙	3	0	11
Total Number of activities for one grinding process		132	132	132

Table 3. Activities for one cycle of grinding

Activities for one cycle of grinding				
Activity	*Symbol*	*Man*	*Machine*	*Material*
Operation	○	9	6	3
Inspection	D	1	0	1
Transportation	□	0	0	0
Delay	⇨	1	6	6
Storage	▽	0	0	0
Operation and Inspection	◙	0	0	1
Total Number of activities for one grinding cycle		11	11	11

The total time to grind 9 rollers for completing 132 activities is shown in Figure 4. The maximum and minimum times for grinding rubber roller are 125 minutes and 57.23 minutes, respectively. Figure 4 shows deviation in process time as 66.77 minutes. Hence, the deviation in process time needs to be minimized through improvement.

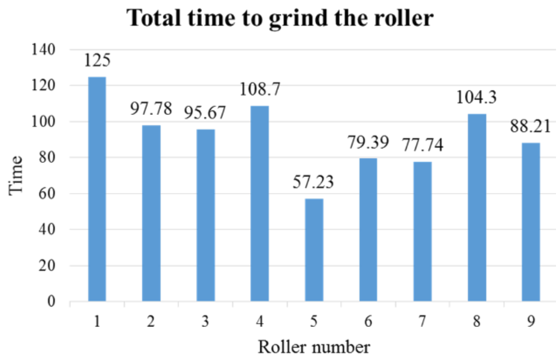

Figure 4. Total time to grind the roller

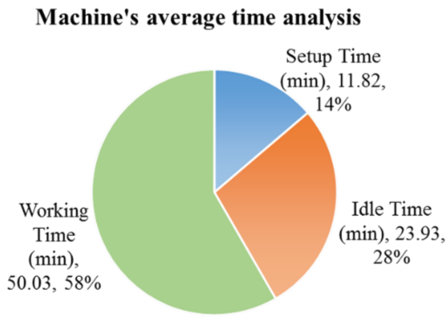

Figure 5. Machine's average time analysis

The time required for different activities like setup time, idle time and working time are shown in Figure 5 through pie-chart. The set-up time, ideal time and the working times are 50.03 min (58%), 23.93 min. (28%), and 11.82 min (14%), respectively. Hence, working and idle times of machine needs to be minimized through improvement.

From the Figure 6, it can be observed that the operation time for grinding varies from 52% to 71 % of the total process time. Time study was performed for many rolls but representative data for nine rollers is presented in the graphical form in Figure 6. Moreover, it has been observed that in the current practice, the number of grinding cycles is not based on the material to be removed in fact it is repeated four to eight times without any proper justification (Figure 7).

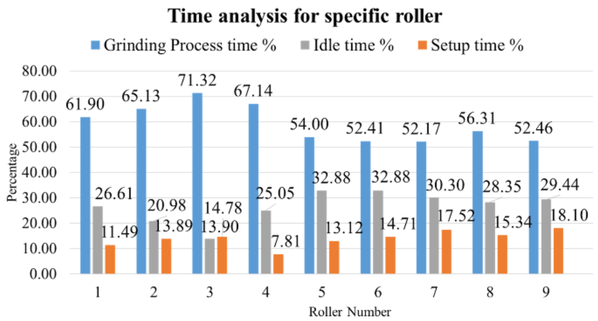

Figure 6. Time analysis for specific roller

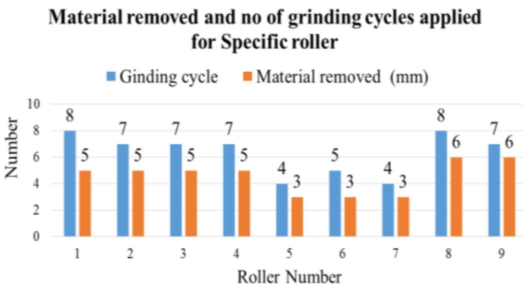

Figure 7. Material removed and number of grinding cycles applied for specific roller

5. RESULTS

5.1. Implementation of grinding process

It is decided to reduce grinding process time by reducing number of cycles by increasing depth of cut. It has been proposed to finish grinding operation in three cycles namely rough cut, semi finish cut and final cut. Rough cut makes the roller cylindrical where depth of cut is selected up to 2 mm. Semi finish cut is taken as 1-2 mm as per the extra material left after rough cut. Final cut brings the roller to the desired dimensions and 0.5-0.7 mm depth of cut is taken. Several rollers over 10 days have been ground with the proposed grinding process. The quality of the rollers is found to be accepted. Hence, proposed process can be implemented. The proposed process reduces the grinding time. The grinding time for 60 rolls over the 10 days span has been shown in Figure 8.

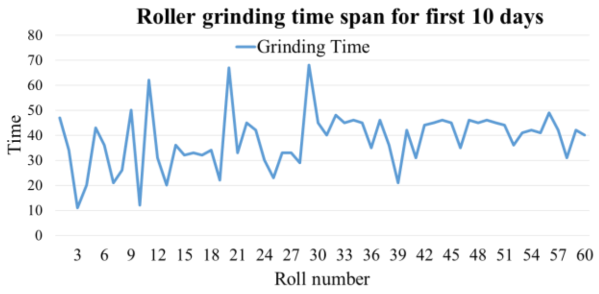

Figure 8. Roller grinding time span for first 10 days

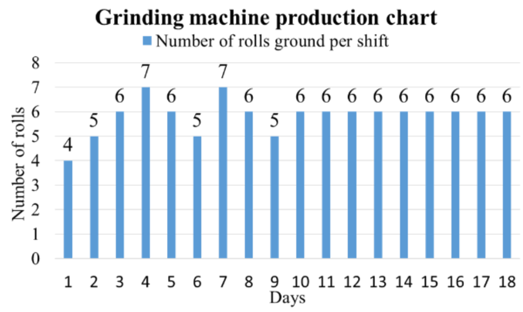

Figure 9. Grinding machine production of one shift for first 18 days

Reasons for peak value for roller grinding time span for first 10 days presented in Figure 8 are as below:-

a) Roller no. 8: Many cotton tape marks were there on the roll so cannot be decided to take depth of cut.
b) Roller no. 11: Camber was increased after third grinding cycle so one more grinding cycle was taken to achieve required value of camber.
c) Roller no. 20, 29: Had excessive rubber material, which was 10 mm more than the required size.

Grinding machine production of one shift for first 18 days is shown in Figure 9. It can be observed from the figure that proposed process on grinding machine increases the production gradually and become constant after 10 days. Therefore the average number of rollers produced per shift is 6 and the total number of activities decreased to 77 from 132. While conducting experiments, no defects have been observed in rolls. Hence, it is proposed that an alternative grinding process is advantageous and production per shift on grinding machine is improved by 50%.

6. CONCLUSION

Method study was carried out at rubber roller grinding machine. The flow process chart (man, machine and material) have been drawn and re-arrangement of activities are proposed. Time study was performed. Based on these, alternate grinding process had been proposed and the total grinding cycles were reduced from 8 to 9 grinding cycles to 3 grinding cycles i.e. rough cut, semi finish cut and final cut. Production is increased from 4 rollers per shift to 6 rollers per shift. Considering 1.5 shift per day, improvement in productivity is 3 rollers per day i.e. 50%. By implementing the improved alternates grinding process, it was estimated that per day saving is rupees 11,000 and the annual saving is around rupees 30 lakhs per year.

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Study on tensile and dry sliding wear behavior of epoxy based fiber reinforced composites

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ABSTRACT: Composite materials have been the dominant emerging materials because of their low density, unlimited availability, good mechanical performance, and problem free disposal. Natural fibers offer a real alternative to the technical reinforcing fibers presently available. In this study, sisal/glass fiber reinforced epoxy composites are prepared and their tensile strength and dry sliding wear behavior of composites are evaluated.The results show that pure glass specimen has been a maximum tensile strength compared to pure sisal and other hybrid laminates. Taking hybrid specimen into account the specimen 60% sisal 40% glass shows maximum tensile strength than laminate 40% sisal 60% glass. The sisal fiber when hybridized with glass fiber provides very good tensile strength. For dry slide wear, the frictional property of hybrid specimens is high with a highest loss in weight indicating the average loss compared to dry slide wear of pure sisal and pure glass specimens which had lower weight loss.

1. INTRODUCTION

Materials are probably more deep rooted in our world than most of us realize, i.e. in transportation, housing, clothing, communication, food production, etc., virtually every segment of our daily lives are influenced by the materials. The development and advancement of societies have been tied to the ability to produce and manipulate materials to fulfill their needs. The discipline of material science involves investigating the relationship that exists between the structure and properties of materials. The structure of materials usually relates to the arrangement of its internal components. Solid materials have been classified into three basic classifications, viz., metals, ceramic and polymers. This classification is primarily based on chemical makeup and atomic structure, most material fall into these categories. In addition to these three, other groups of important engineering materials are composite, semiconductor and biomaterials. Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics, and polymeric materials. These can be combined in composite materials to produce unique characteristics. A composite material is defined as any substance which is made by physically combining two or more materials differing in composition or form to produce a multiphase material which possesses superior properties that are not obtainable with any of the constituent materials acting alone. These constituents remain bonded together but retain their identity and properties. The composite material consists of matrix and reinforcement, matrix is a resin and reinforcement are a fiber the reinforcing material is usually stiffer, stronger than the matrix and there has to be a good adhesion between the components.

2. EXPERIMENTAL

2.1Materials

In the present investigation Sisal fiber (Agave Sisalana), Glass fiber (woven mat form) Sisal fibers were obtained from Dharmapuri District, Tamilnadu, Chennai, India. The Glass-Fiber Reinforced Polymers (GFRPs) used for the fabrication is of a bidirectional mat having 360gs M/s supplied by Suntech fiber Ltd. Bangalore.Commercially available epoxy (LY-556) and hardener (HY-951) supplied by M/s zenith industrial suppliers, Bangalore.

2.2 Preparation of Composite Specimen

The fabrication of sisal/glass-epoxy hybrid composite materials is carried out through the hand lay-up technique. For the sample preparation, the first and foremost step is the arrangement of the tile mold which have smoothed and cleaned surfaces. Cover release sheet on an open mould. After that, the Glass fiber and sisal fiber mats were cut into the dimension of 250x250. A measured amount of epoxy is taken for a different volume fraction of fiber and mixed with the hardener in the ratio of 10:1. The mixture was stirred properly for uniform mixing. Care was taken to avoid the formation of bubbles. A bottom tile piece is placed on the table on the top of that Mylar sheet is placed. A well-mixed resin is poured on the Mylar sheet and spread all over the sheet. After that, a sisal mat is placed on the top of the resin. Again, a resin is poured on the top of the mat. A known amount of resin is poured every time. Care should be taken so that the mats do not slide after placing. Again glass mat is placed on the top of the sisal mat and again resin is poured. The same procedure is repeated until required thickness of the laminate is obtained. After the fabrication, a released sheet is placed to cover matrix and care should be taken to avoid the formation of bubbles then another granite plate should be placed on that to apply a load (40-50 Kg) on the matrix. The composite sheet takes 24 hours for curing in room temperature. After that, laminate is removed from the tile pieces and are then cut into the required dimensions depending on the standards.Five types of specimens are fabricated by adding different layers of sisal and glass fibers in different compositions. Table 1 shows different laminates with different combinations.

Table 1. Laminate description

Laminate	Combinations Sisal(S)		Glass(G)		Series	Thickness (mm)	Laminate Weight (g)	Epoxy Weight (g)	Hardener Weight (g)
	layers	%	layers	%					
L1	4	100	-	-	SSSS	3.9	366	380	38
L2	-	-	5	100	GGGGG	3.8	305	200	20
L3	2	40	3	60	GSGSG	3.4	206	360	36
L4	4	65	2	35	SSGGSS	3.0	217	225	22.5
L5	3	60	2	40	SGSGS	3.2	239	225	22.5

3. RESULT AND DISCUSSION

3.1*Tensile Properties*

Tests were carried out according to ASTM standards, for tensile test the Sample was cut into the required dimension.The test was conducted on polymer testing UTM and the obtained results are tabulated below. The results show the tensile stress of sisal/glass and its hybrid composites. The laminate L4 which has 65% of sisal fiber and 35% of glass fiber has tensile stress of 297.97 N/mm² which is less compared to laminates L2,L3 and L5 which has 100% glass fiber and 60% sisal fiber, 40% glass fiber and 40%sisal, 60% glass fiber respectively. The specimen L2 has maximum tensile stress i.e. 462 N/ mm² and L3 has a tensile stress of 309.4N/mm² and L5 has a tensile stress of 330N/mm². The Specimen L1 is made up of 100% sisal fiber which has least Tensile stress i.e. 174.2 N/mm². The specimen L1 has least ultimate tensile strength i.e. 174.254 N/mm² whereas specimen L2 has maximum UTS i.e. 462.002 but among hybrids L3 has least UTS and L5 have maximum UTS which is shown in the table 5.1.1 .The tensile strain on specimen L1, L2, L3, L4 and L5 is 0.0614, 0.0801, 0.07829, 0.07124, 0.07114 respectively. The specimen L2 has a maximum strain and specimen L1 has a minimum strain.The tensile yield strength of L1, L2, L3, L4, and L5 are 147.54 N/mm², 259.26 N/mm², 211.7 N/mm², 208.18 N/mm² and 198.21N/mm² respectively. The peak load of L1, L2, L3, L4, and L5 are 6327.007N, 26334.003N, 17635.398N, 16984.181N, 16875.424N respectively. The tensile modulus of L1, L2, L3, L4, and L5 are 1639.12N/mm²,5761.32 N/mm², 3951.88 N/mm², 208.18 N/mm², 4004.21N/mm². Table 2 shows tensile test specimens results and Fig.1 shows Stress vs. strain graphs of different laminates.

Fig.1 Tensile testing specimens after testing.

Table 2. Tensile test results

Laminates	Stress (N/mm²)	Strain	Modulus (N/mm²)	Yield strength (N/mm²)	Peak load (N)	UTS (N/mm²)
L1	174.2	0.0614	1639.12	147.54	6327.007	174.254
L2	462	0.08019	5761.32	259.26	26334.003	462.002
L3	309.4	0.07829	3951.88	211.7	17635.398	309.398
L4	297.97	0.07124	208.18	208.18	16984.181	297.988
L5	330	0.07114	4004.21	198.21	16875.424	330.532

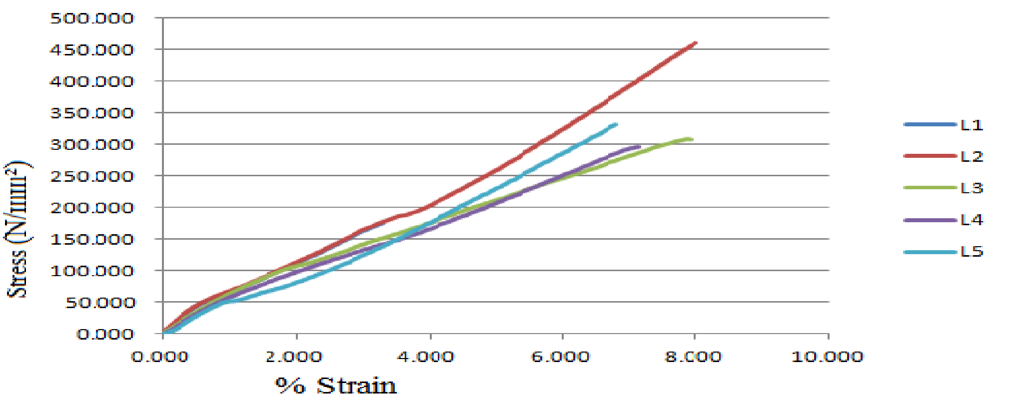

Fig.2 Stress vs. strain graphs of different laminates (Tensile test).

3.2 *Dry Sliding Behavior of Epoxy Based Fiber Reinforced Composites*

The sample 1 contains of sisal and its weight 4.82048g initially, after the test its weight 4.81552g with net weight loss of 0.00496g. Sample 2 contains glass fiber of weight 4.53845g will lose its component of weight 0.00287g after the test. Similarly after the test, combination of sisal/glass (each of 50%) specimen of weight 4.57726g after the test its weight 4.57176g specimen lose its weight by 0.0055g. From the results, combination of sisal/glass fiber specimen can wear most whereas pure glass fiber wouldwear least. Table 3 shows test parameters for varying test loads and Table 4 shows dry sliding wear test results of samples.

Table 3. Test parameters for varying load test

Load	4kg at 300 rpm
Test duration	30 minutes, Mass measured after every test
Wear track dia	80mm
Test condition	Lubricant condition & at Ambient temperature.
Environment	Open to atmosphere, Humidity = 51.5%Rh, temperature = ambient room temperature.
Test was done by	Same operators complete testing for all specimens on the same test rig.

Fig.3 Dry sliding wear test specimens.

Table 4. Dry sliding wear test result

Test No	Sample	Initial weight (g)	Final weight (g)	Weight loss (g)
1	Sisal	4.82048	4.81552	0.00496
		4.81049	4.80568	0.00481
		4.79220	4.78721	0.00499
2	Glass	4.53845	4.53558	0.00287
		4.54915	4.54629	0.00286
		4.53915	4.5364	0.00275
3	Combination (sisal/glass)	4.57726	4.57176	0.0055
		4.56627	4.56087	0.0054
		4.58670	4.5813	0.0054

3.3 Conclusion

The hybrid composites are subjected to mechanical testing such as tensile and also dry sliding wear test. The test result indicates that pure glass specimen has highest tensile strength of 462.002 Mpa compared to pure sisal and other hybrid laminates. Taking hybrid specimen into concentrate the specimen L5 (60% sisal 40% glass) shows maximum tensile strength of 330.532 Mpa than laminate L3 (40% sisal 60% glass) which had more % of glass fiber yielded 309.398 Mpa.Thus it is concluded that sisal when hybridized with glass provides better tensile strength.Testing the specimens for dry slide wear, the frictional property of hybrid specimens is high with highest loss in weight indicating the average loss of .00543g compared to dry slide wear of pure sisal and pure glass specimens which had lower weight loss.

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Study and development of engineering standard for press working of stainless steel components used in switchgear

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ABSTRACT: Sheet metal forming is the widely used in manufacturing process now a day in many company because of its easy and mass production method. In switchgear (circuit breaker) many sheet metal components are used. They are produced by forming operations in mechanical or hydraulic press machine. Due to incorrect forming method or process parameters there are problems like heavy burr, spring-back, wrong dimension and deformation in components which lead to part rejection. Due to them there is waste of time and resources. Cause and effect analysis has been carried out to tackle the problem of resetting and de-latching of MCCB and have been presented in this paper work. The component namely bracket have been found dimensionally and surface finish wise inaccurate. Which in turn cause the functional problems in MCCB. One additional shaving operation has been suggested to make the bracket dimensionally accurate. Triangular media have been proposed for deburring operation to remove the burrs. The modifications helped to reduce rejection of parts and make the MCCB functionally correct.
Keywords: Sheet metal forming, Burr, Spring-back

1 INTRODUCTION

A circuit breaker is a manually or automatically operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current low. It can be manually opened and closed, as well as automatically opened to protect conductor or equipment from damage caused by excessive temperature from over current in the event of short circuit. For that important consideration to above said event is the breaking and making time which is customarily design for few milliseconds to avoid prolonged arcing and pre-arcing time that overheats and thus melts moving and fixed contacts. Breaker is operated by spring operated mechanism which supplies required mechanical energy to it. Drive is the heart of the circuit breaker. If it fails, breaker cannot perform its intended function and even if there is a delay in providing energy within few milliseconds breaker fails to perform its intended function. That is why drive has to be precise to give adequate energy at all time through its life cycle.

1.1 *Need of standardization*

L & T EBG, Vadodara is a leading manufacturer of MCCB and ACB. They cover almost 63% market of MCCB in India. In MCCB many sheet metal components are used, which is made in press shop of L&T EBG. They make this component in thousands of numbers, but due to some problem the component are rejected due to damage, burr problem, and Spring Back effect. The paper is about developing the standard procedure for the production of component of switchgear namely bracket.

2 STANDARDIZATION OF PRUCEDURE FOR COMPONENTS USE IN SWITCHGEAR

There are many components used in switchgear assembly. The switchgear may not function properly if the components going in assembly are not dimensionally correct as per the design. Few of the switchgear have been found functionally faulty and few components have been found to be dimensionally in correct. Hence its causes have been studied and remedies have been suggested to rectify the same. Procedure for components like bracket have been standardized and presented in following section.

2.1 *Process standardization for Bracket*

Bracket (CM 72008) as shown in figure 1, is a component used in DN250 MCCB. Material used in this component is AISI TYPE GRADE 304 stainless steel of 1 mm thickness. This component is assembled with the drive shaft of MCCB. The mechanical properties are listed in Table 1.

Figure 1: Bracket (CM 72008)

Table 1: Mechanical properties of AISI 304 stainless steel

Grade	**304**
Tensile strength (Mpa)	520
Compression strength (Mpa)	210
Hardness Rockwell B	90

2.1.1 *Problems found in DN250 MCCB*

The MCCB DN250 has encountered problem of resetting and De-latching. The assembly with shaft is shown Figure 2. The probable causes have been studied and presented as cause and effect diagram in Figure 3

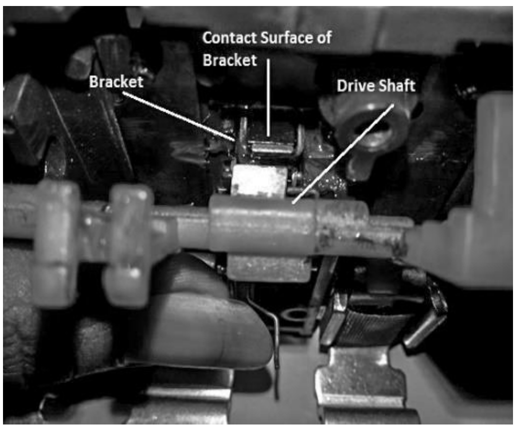


Figure 2: Assembly with drive shaft

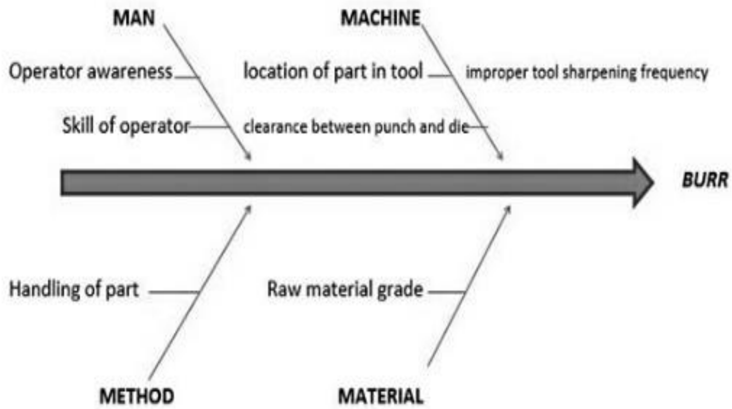


Figure 3: Cause and effect diagram for burr

2.1.2 *Dimensional and quality requirements for bracket*

- The center of shaft to contact edge dimension as shown in fig. 4 should be 10.02 to 10.10 mm
- Surface roughness (Ra) at contact edge should be less than 0.8 micron (μm)
- Edge should be burr free and
- Taper of edge should be ≤ 0.2 mm

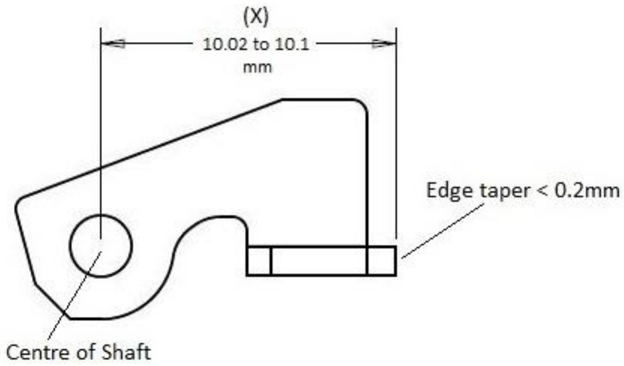


Figure 4: 2D view of Bracket

2.1.3 *Manufacturing process for bracket*

This component is produced in progressive die. First two operations, bending and shaving are performed at vendor's place. After bending and shaving operation, second shaving operation is performed at company. Following steps are observed to produce it within prescribed dimensions.

1. Metal forming
2. Shaving operation
3. Deburring

2.1.4 *Quality of the bracket*

2.1.4.1 *Dimensional accuracy of bracket with existing tool set up*

More than thousand component were produced and the shaft center to edge distance was measured for every component. Typical measurement for a few components are presented in Table 2. The results are also presented as a process control chart. It has been observed that the dimensions (X) is out of the accepted range and process is also consistency out of control. Moreover it gives idea that if the component input dimension to the shaving operation is controlled by 0.1 mm, the final dimension would be under specific dimension.

Component		
Sr. No	Before shaving	After shaving
1	10.27	10.11
2	10.32	10.15
3	10.25	10.1
4	10.33	10.14
5	10.3	10.12
6	10.27	10.12
7	10.32	10.15
8	10.26	10.09
9	10.31	10.13
10	10.36	10.16
11	10.28	10.11
12	10.34	10.15
13	10.25	10.1
14	10.32	10.15
15	10.27	10.13

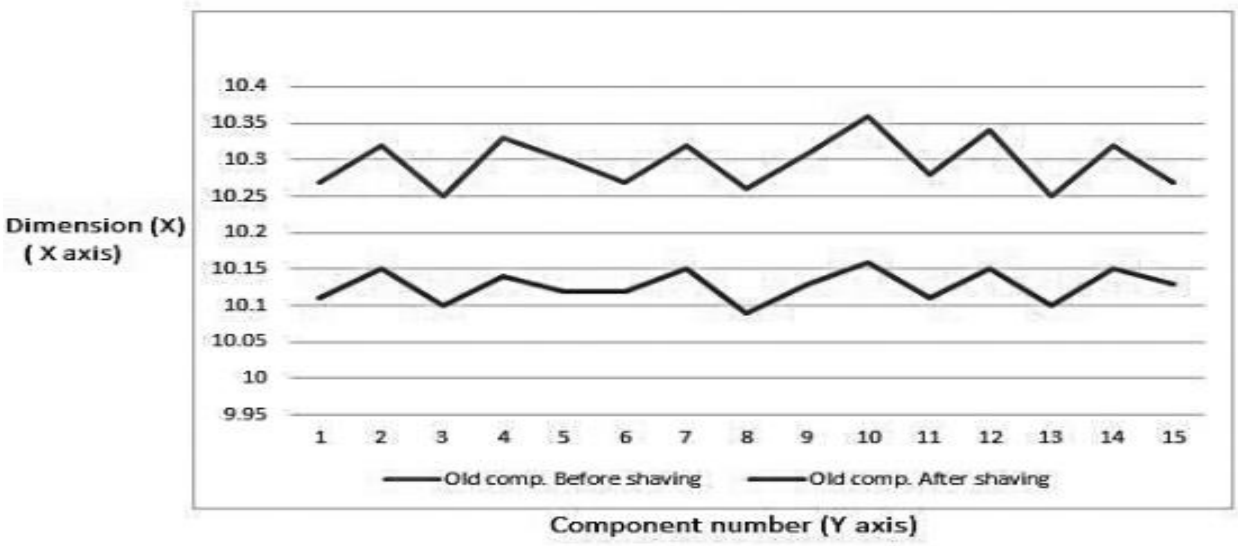


Table 2: Data measured before setting the standard ranges

2.1.4.2 Burrs on the edge

The components were found with excessive burrs as shown in figure 5. The burrs are not acceptable as it causes problem in de-latching.

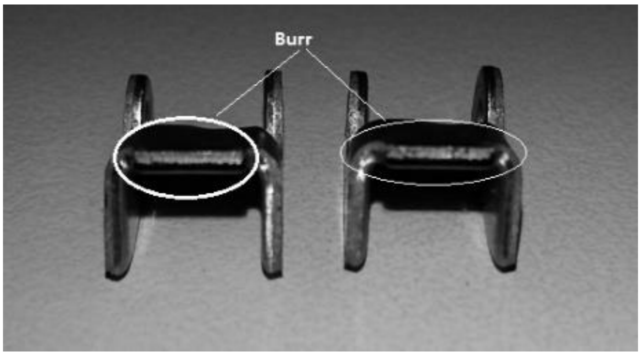


Figure 5: Burrs on Bracket

2.1.4.3 Surface finish at the edge

Surface roughness was measured for each component and was found more than 0.8 microns. The surface appearance is shown in figure 6

Figure 6: Surface roughness of the bracket

3 SUGGESTIONS FOR QUALITY IMPROVEMENT

3.1 *Including one extra shaving operation*

- The shaving operation produces a straight, square edge, generally to approximately 75% of the metal thickness. Two shaves make a better, straighter edge (to approximately 90% of the metal thickness) than does a single shaving operation. [ASM Handbook 2006]
- According to standard we can get better result if we do two time shaving operation. So second shaving operation in process has been added.

3.2 *Setting the standard allowance range before shaving*

- As standard the allowance left for shaving should exceed the die clearance by approximately 0.15 mm [Tekaslan 2008]
- So adding 0.15 lower and upper limit. So that lower range 10.02+0.15= 10.17 mm, and upper range 10.1+0.15=10.25 mm
- So we set the range of input shaving material **10.17 to 10.25** mm.

3.3 *Change deburring media from cylindrical to triangular*

- Triangular deburring media as shown in figure 7 provides shaving edges. Hence better deburring is expected

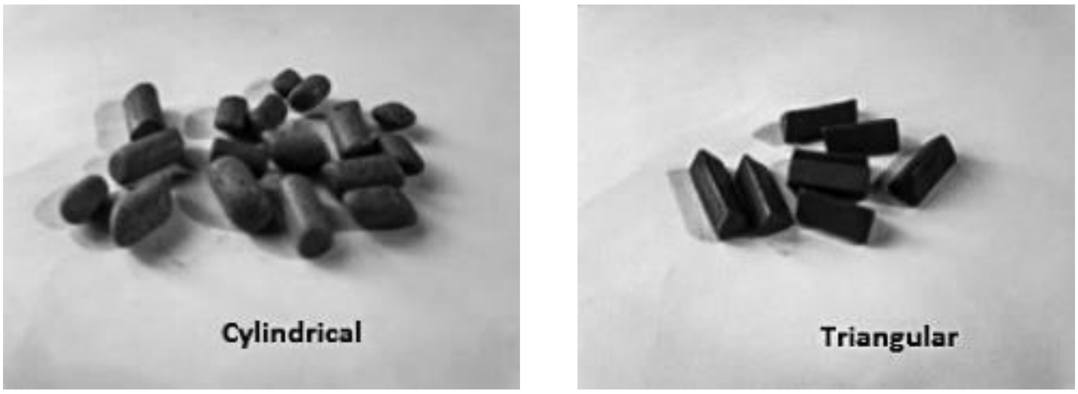


Figure 7: Deburring media.

3.4 *Process standardization*

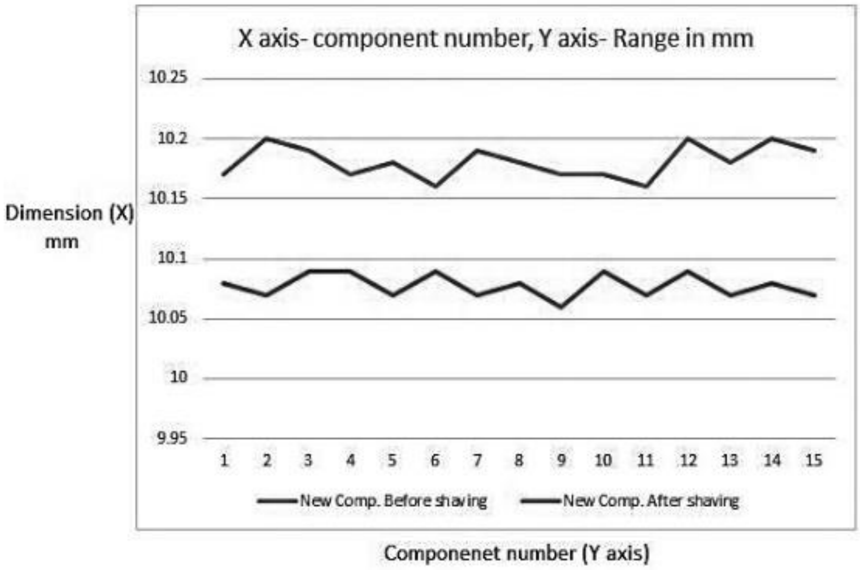
Based on above suggestions the procedure has been standardized as shown in block diagram.

4 RESULTS AND DISCUSSION

4.1 *Dimensional accuracy of bracket*

The components were produced as per the procedure explain in standard. The components were checked for dimensional accuracy and quality. The result are shown in table 3.

Table 3: Data after standardization



Component		
Sr. No	Before shaving	After shaving
1	10.17	10.08
2	10.2	10.07
3	10.19	10.09
4	10.17	10.09
5	10.18	10.07
6	10.16	10.09
7	10.19	10.07
8	10.18	10.08
9	10.17	10.06
10	10.17	10.09
11	10.16	10.07
12	10.2	10.09
13	10.18	10.07
14	10.2	10.08
15	10.19	10.07

The results are also presented as a process control chart. It has been observed that the dimensions (X) is in the accepted range and process is also consistency in control. The dimension of bracket comes in the range of 10.02 to 10.1 mm

After applying the different standard on component (CM 72008) we get the new result which satisfies the need of component. The range of dimension of 10.02 to 10.10 mm achieved by adding second shaving operation. It is also useful to set the clearance between die and punch. And for burr related problem we change the media type from cylindrical to triangular shape so that burr is removed from the edges and good surface finish are achieved. Figure 8 shows the difference between old and new component before and after applying the standard process.

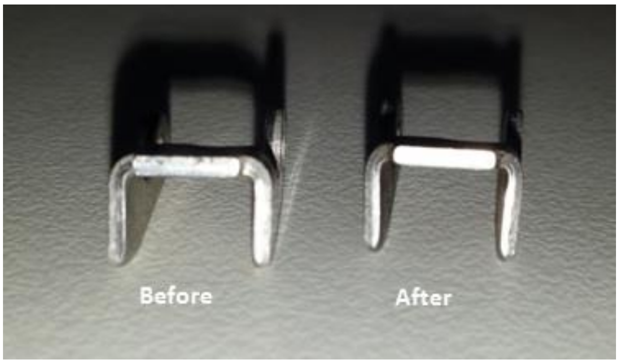


Figure 8: Before and after image of components

5 CONCLUSION

- Caused and effect study has been carried out for the functionally incorrect MCCB.
- A bracket has been found dimensionally inaccurate which causes de-latching and resetting problem in MCCB.
- An additional shaving operation has been proposed to make the bracket dimensionally accurate.
- From process chart it can be inferred that the new process is capable to produce the bracket as per specifications.
- Triangular deburring media has been proposed to eliminate burrs and it has been found promising.

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