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OPTIMIZATION OF FIELD DATA BASED MODEL FOR FLOW FORMING OPERATION IN BRASS UTENSIL MANUFACTURING

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Abstract

Flow forming is an oldest method of chip less metal forming process for the production of hollow, axially symmetric sheet metal components. In brass utensil manufacturing, most of work is performed manually and repetitive in nature and entire operations are falling under the class of man machine systems. This research identified most influenced input variables like work piece parameter, tooling parameter, process parameter, machine parameter and extraneous factor on flow forming operation in brass utensil manufacturing. Also certain response variables viz. accuracy, surface finishing and cycle time has measured which decides quality, performance of flow forming operation. The mathematical model developed for the phenomenon represents the interaction of various independent variables by applying theories of experimentation. An attempt is made to optimize the process response variables by use of statistical tools are to be applied for field data based model.

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1. Introduction

Flow forming is an oldest method of chip less metal forming process for the production of hollow, axially symmetric sheet metal components [10]. Flow forming was employed mainly to produce domestic products such as saucepans and cooking pots on a simple lathe like machine where repeatability in dimensional accuracy is not very critical; but now a day's components of different cross sectional profiles like cylindrical, conical, elliptical, oval, etc. are manufactured by metal forming processes [2]. Research in metal forming has offers remarkable utilization of metal, high strength, excellent surface finish and close dimensional accuracy within the reasonable economics.

2. Methodology

In brass utensil manufacturing, most of work is performed manually and repetitive in nature by unskilled workers with help of different tools and semi-automatic machine. The method adopted for flow forming operation is not scientific approach and entire operations are falling under the class of man machine systems.

2.1 Identification of Variables

Firstly, we identified most significant input variables (X) concern with work piece parameter, tooling parameter, process parameter, machine parameter, extraneous factors and response variables (Y) viz. accuracy, surface finishing and cycle time has measured which decides quality, performance of flow forming operation in brass utensil manufacturing.

2.2 Reduction of Variables using Dimensional Analysis

Deducing the dimensional equation for a phenomenon reduces the number of independent variables in the experiments. This is achieved by applying Buckingham's Π theorem when number of variables is large.

Table1. List of Independent Π Terms of Flow Forming Operation.

SN.	Description of Π terms	Π terms
01	Π term for anthropometric data of operator	Π_1

02	Π term for specification of work piece	Π_2
03	Π term for specification of tool	Π_3
04	Π term for specification of work station	Π_4
05	Π term for process	Π_5
06	Π term for humidity	Π_6

Table 2. List of Dependent Π Terms of Flow Forming Operation.

SN.	Description of Π terms	Π terms
01	Π term for surface finish	Π_7
02	Π term for accuracy	Π_8
03	Π term for cycle time	Π_9

2.3 Development of Model for Flow Forming Operation in Brass Utensil Manufacturing

The data of independent and dependent parameters of the system has been collected during the field study of this work to correlate various Π terms involved in this man-machine system quantitatively in form of mathematical model as a design tool for such a work station.

2.3.1 Development of Model for Dependent $\Pi_7, \Pi_8, \Pi_9,$ Term

For the dependent Π term $\Pi_7,$ we have

$$\Pi_7 = f(\Pi_1, \Pi_2, \Pi_3, \Pi_4, \Pi_5, \Pi_6)$$

$$\Pi_7 = K_1^*(\Pi_1)^{a1} * (\Pi_2)^{b1} * (\Pi_3)^{a1} * (\Pi_4)^{d1} * (\Pi_5)^{e1} * (\Pi_6)^{f1}$$

$$Log\Pi_7 = \log K_1 + a_1 * \log(\Pi_1) + b_1 * \log(\Pi_2) + c_1 * \log(\Pi_3) + d_1 * \log(\Pi_4) + e_1 * \log(\Pi_5) + f_1 * \log(\Pi_6)$$

then the equation can be written as

$$Z_1 = K_1' + a_1 * A + b_1 * B + c_1 * C + d_1 * D + e_1 * E + f_1 * F$$

Value of a_1, b_1, c_1, d_1, e_1 can determine by using MAT lab.

$$P1 = inv(M1) * N1$$

Antilog $K_1', a_1, b_1, c_1, d_1, e_1$ and f_1 will give the solution for the equation.

$$\Pi_7 = 1.0000 * (\Pi_1)^{1.6412} * (\Pi_2)^{-0.0831} * (\Pi_3)^{14.7290} * (\Pi_4)^{-15.1816} *$$

$$(\Pi_5)^{-0.0291} * (\Pi_6)^{-0.0780}$$

Above same method is repeated to compute the model for Π_8, Π_9 term

$$\Pi_8 = 1.000 * (\Pi_1)^{-0.1386} * (\Pi_2)^{0.0023} * (\Pi_3)^{-1.6975} * (\Pi_4)^{2.8019} *$$

$$(\Pi_5)^{0.0048} * (\Pi_6)^{0.0277}$$

$$\Pi_9 = 1.000 * (\Pi_1)^{0.4016} * (\Pi_2)^{0.0035} * (\Pi_3)^{1.4092} * (\Pi_4)^{-0.8729} *$$

$$(\Pi_5)^{0.0207} * (\Pi_6)^{0.0378}$$

Thus we have formulated three models corresponding to the three dependent Π terms from the set of observed data for flow forming operation.

3. Optimization of Models for Flow Forming Operation

The objective of this work is to find out best set of independent variables which gives maximization/minimization of the objective function. To optimized linear function; we used the linear programming technique.

Let the model for Π_7 is

$$\Pi_7 = 1.0000 * (\Pi_1)^{1.6412} * (\Pi_2)^{-0.0831} * (\Pi_3)^{14.7290} * (\Pi_4)^{-15.1816} *$$

$$(\Pi_5)^{-0.0291} * (\Pi_6)^{-0.0780}$$

$$Z7 = 1.0000 + 1.6412 * X_1 - 0.0831 X_2 + 14.7290 X_3 - 15.1816 X_4 -$$

$$0.0291 X_5 - 0.0780 X_6$$

Subjected to the following constraints

$$1 * X_1 + 0 * X_2 + 0 * X_3 + 0 * X_4 + 0 * X_5 + 0 * X_6 \leq -0.29050$$

$$1 * X_1 + 0 * X_2 + 0 * X_3 + 0 * X_4 + 0 * X_5 + 0 * X_6 \geq -0.3197$$

$$0 * X_1 + 1 * X_2 + 0 * X_3 + 0 * X_4 + 0 * X_5 + 0 * X_6 \leq 0.02664$$

$$0 * X_1 + 1 * X_2 + 0 * X_3 + 0 * X_4 + 0 * X_5 + 0 * X_6 \geq -0.2745$$

$$0 * X_1 + 0 * X_2 + 1 * X_3 + 0 * X_4 + 0 * X_5 + 0 * X_6 \leq -0.2293$$

$$0 * X_1 + 0 * X_2 + 1 * X_3 + 0 * X_4 + 0 * X_5 + 0 * X_6 \geq -0.2396$$

$$0 * X_1 + 0 * X_2 + 0 * X_3 + 1 * X_4 + 0 * X_5 + 0 * X_6 \leq -0.1515$$

$$0 * X_1 + 0 * X_2 + 0 * X_3 + 1 * X_4 + 0 * X_5 + 0 * X_6 \geq -0.1515$$

$$0 * X_1 + 0 * X_2 + 0 * X_3 + 0 * X_4 + 1 * X_5 + 0 * X_6 \leq -0.15495$$

$$0 * X_1 + 0 * X_2 + 0 * X_3 + 0 * X_4 + 1 * X_5 + 0 * X_6 \geq -0.6031$$

$$0 * X_1 + 0 * X_2 + 0 * X_3 + 0 * X_4 + 0 * X_5 + 1 * X_6 \leq -0.4437$$

$$0 * X_1 + 0 * X_2 + 0 * X_3 + 0 * X_4 + 0 * X_5 + 1 * X_6 \geq -0.6576$$

After solving the above problem by using the MS solver we get

$$X_1 = -0.3197,\ X_2 = 0.02664,\ X_3 = -0.2396,\ X_4 = -0.1515,\ X_5 = 0.15495,$$

$$X_6 = -0.4437 \text{ and } Z_7 = -1.62595.$$

By taking antilog of above values; we get optimum values of Π terms.

$$\Pi_7 \text{ min} = 0.02366,\ \Pi_1 = 0.4787,\ \Pi_2 = 1.06325,\ \Pi_3 = 0.5759,\ \Pi_4 = 0.5759,$$

$$\Pi_5 = 1.4287,\ \Pi_6 = 0.36$$

Similar procedure is adopted to optimize the models for Π_8 and Π_9.

$$\Pi_8 \text{ max} = 1.00036,\ \Pi_1 = 0.4790,\ \Pi_2 = 1.06325,\ \Pi_3 = 0.5759,\ \Pi_4 = 0.7055,$$

$$\Pi_5 = 1.4287,\ \Pi_6 = 0.36.$$

$$\Pi_8 \text{ min} = 0.4330,\ \Pi_1 = 0.4790,\ \Pi_2 = 0.5315,\ \Pi_3 = 0.5759,\ \Pi_4 = 0.7055,$$

$$\Pi_5 = 0.2494,\ \Pi_6 = 0.22$$

Table 3. Optimized value of models.

Model	Π_7 min for surface roughness	Π_8 max for accuracy	Π_9 min for cycle time
Optimized value	0.02366	1.00036	0.433
Π_1	0.4787	0.479	0.479
Π_2	1.06325	1.06325	0.5315
Π_3	0.5759	0.5759	0.5759
Π_4	0.7055	0.7055	0.7055
Π_5	1.4287	1.4287	0.2494
Π_6	0.36	0.36	0.22

Table 4. Estimated limiting values of response variables of flow forming.

Max. and Min. value of response variables	Surface roughness (SRa) μm	Accuracy(Dpi) cm	Cycle time (Tc) sec
Minimum	0.19082	26.8546	52.6746
Maximum	0.35028	28.8969	57.3048

4. Discussions

From table 3, after optimization of the models for flow forming operation in brass utensil manufacturing, optimized value for Π_7 min for surface roughness, Π_8 max for accuracy, $\Pi_9$min for cycle time are found to be 0.02366, 1.00036, 0.433 respectively. Also limiting values of response variables of flow forming for minimum surface roughness, maximum accuracy and minimum cycle time are estimated to be 0.19082 μm, 28.8969 cm and 52.6746 sec respectively.

Conclusions

The mathematical models developed for the phenomenon represents interaction of various independent variables. Deviation of the values obtained from mathematical model from actual experimental values of dependent parameters shows closeness of the mathematical model with real life process. After optimization of models for flow forming operation in brass utensil manufacturing, response models are very useful to measure quality of product. Also it reduces fatigue by controlling humidity and time required for operation. Hence it improves the productivity flow forming operation.

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