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OPTIMAL DESIGN OF PREFORM SHAPE IN COLD FORGING PROCESS

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ABSTRACT

In this research, preform shape optimization in forging process of a geometrically complex shape is investigated using the reduced basis technique (RBT) which is coupled by Taguchi design of experiments and finite element method is presented. The RBT is a weighted combination of several trial shapes to find the best combination using the weights for each billet shape as the design variables. A multi-level design process is presented to find suitable basis shapes at each level that can be used in the reduced basis technique. Each level is treated as a separate optimization problem until the required objective is achieved. Flash, i.e. excess material, is a industry requirement. The optimization process is started with simple basis shapes that are defined by their shape co-ordinates.

KEYWORDS: Preform Shape Optimization; Reduced Basis Technique; Taguchi Design Of Experiment Method, Finite Element Method.

In the forging process, an initial block of metal (billet) is compressed between two or more shapes to produce a complex shape. The initial shape of billet is very important in achieving the desired characteristics of the final forged product. Several methods conducted to optimize initial billet shape (Kang et al., 1990).

In this research paper, preform shape optimizatio in cold for An integrated algorithm is presented in this research and it is conducted to preform shape optimization in a sheet metal Explosive deep drawing process of a trapezoidal cup. An innovative, comprehensive way of using an efficient design variables linking method, termed as reduced basis technique (Jabbari et al., 2009; Jabbari et al., 2010). is demonstrated for preform shape optimization. In the reduced basis technique, many initial preform shapes, called basis shapes, are combined linearly by assigning weight factors.

Different resultant shapes can be generated by changing their weight factors. Therefore, the number of design variables required to define the preform shape is reduced to the number of basis shapes. So, the weights assigned for each basis shapes are the design variables and the optimization goal is to find the best possible combination of these weights to minimize underfill value.

PREFORM SHAPE OPTIMIZATION

Although the reduced basis technique is widely used in shape optimization in permanent magnet motors (Hicks et al., 1997; Park et al., 1983). but it is suggested for preform shape optimization in this work. However, it should be adopted for preform shape optimization in forging process.

OPTIMIZATION PROBLEM PROCEDURE

Appropriate starting basis shapes are required to employ the algorithm to find optimumblank shape design. The problem can be solved in multiple levels as shown in Fig. 1 in which the optimization procedure guides the designer progressively in selecting viable basis shapes. In first Level, the basis shapes may not be anywhere near to what they are supposed to be, but by the first set of basis shapes the one can determine a best combination from the first trial shapes.

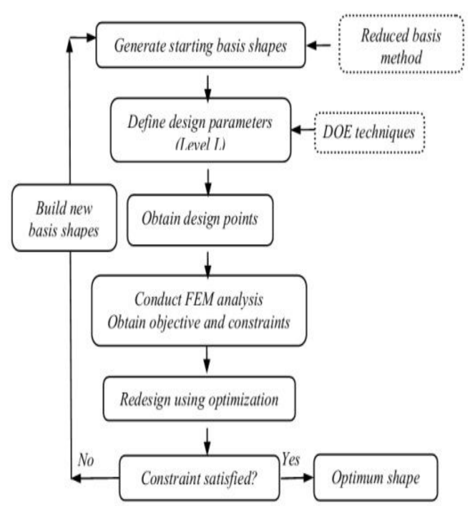

Figure 1. Algorithem of design optimization.

PREFORM SHAPE OTIMIZATION

The preform shape optimization of forging process is demonstrated in this work. The finite element package ABAQUS is used to simulate the process and to calculate the underfill value to conduct DOE. A view of model is shown in *Fig. 2*. Specifications of the investigated billet and the finial shape are presented in *Table 1*.

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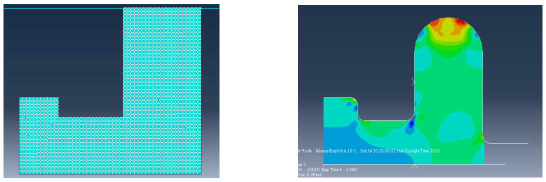


(a) *(b)*

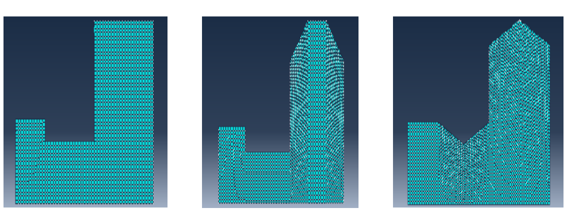
Figure 2. A view of forging process. (a) preform shape, (b) final product

Table 1. Specification of the investigated product

Parameter	Value
Material density	7800
Poisson coeficient	0.3
Young Module	2e11 pa

2-D FEA simulations of the basis shapes are performed in ABAQUS software to find the underfill for preliminary analysis as shown in *Fig. 3*. The underfill of the Basis shapes are 67.923, 45.234 and 23.453 mm, respectively. From this preliminary analysis, it can be said that the Basis 3 is more successful than the other two shapes in reducing the underfill. Therefore, the contribution of Basis 2 must be more than the other basis shapes, which must be recognized by the optimizer. Each Basis shape is defined by one shape variables, (r). These shape variables form the respective Basis vector. These basis vectors is combinedwith the weighting factors, a_1, $a_2$and a_3 that correspond to each basis vector based on the following equation

The proposed technique is applied to three basis vectors and the number of design variables is decreased to three, which are the weights for each basis vector. By changing these weights, it is possible to obtain various resultant blank shapes for the optimizer to find the best combination of these weights.16 DOE points are generated to conduct simulation. All of the resultant shapes are scaled to maintain in a limited area. Simulations are conducted at these DOE points to find the underfill and to build the Taguchi models for optimization. Optimization is performed in QualiTek-4 to minimize the underfill.



B1 **B2** **B3**

Figure 3. The selected basis shapes.

Procedure of ANOVA

A DOE/Taguchi approach is used to study the effects of multiple variables simultaneously. Three factors including Basis shapes weighting factors will be investigated and their optimum values will be specified through ANOVA. Based on known variation of underfill with respect to different factors, each factor is considered to have four levels. Therefore, an M-16 orthogonal array has been selected to run the experiments. *Table 2* shows the weighting factors and their levels and the layout for the selected array is also presented in *Table 3*.

Table 2. Weighting factors and their respective values.

Factor	Level 1	Level 2	Level 3	Level 4
B1	0.65	0.55	0.5	0.4
B2	0.3	0.33	0.35	0.38
B3	0.05	0.12	0.15	0.22

Table 3. A standard M-16 array for three four levels factors.

Trial NO.	B1	B2	B3
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

To obtain the resultans of each experiment, the following equation is used.

$$A[X1] + B[X2] + C[X3] = (A + B + C)[X]$$

Fig. 4 show shape discrettization to create the basis vectors.

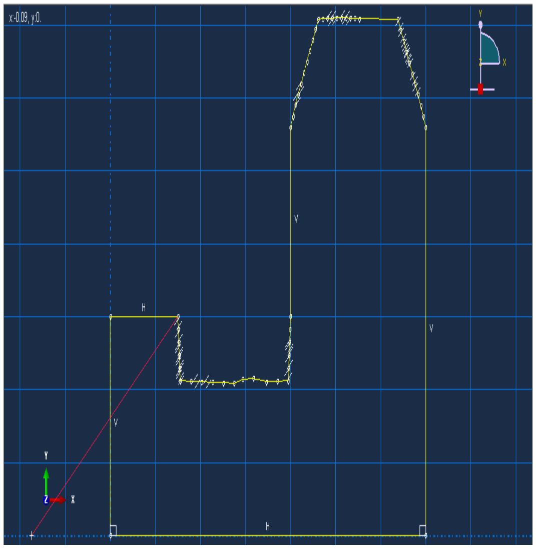


Figure 4. Shape discretization to achive basis vectors.

The experiments are carried out using FEA and the underfill for each experiment is listed in *Table 4*.

Table 4. Underfill values for 16 trials.

Trial NO.	A	B	C	Underfill
1	1	1	1	67.925
2	1	2	2	24.400
3	1	3	3	43.060
4	1	4	4	32.200
5	2	1	2	72.020
6	2	2	1	78.050
7	2	3	4	33.420
8	2	4	3	71.600
9	3	1	3	55.350
10	3	2	4	74.350
11	3	3	1	32.370
12	3	4	2	30.500
13	4	1	4	63.350
14	4	2	3	36.700
15	4	3	2	26.750
16	4	4	1	28.000

Analyzing the Results

Considering underfill as cost function, the results are investigated. The main effects table, which presents the mean value of underfill for each factor at all levels, is shown in *Table 5*.

Table 5. The mean values and optimum conditions.

Level	A	B	C
1	41.9	64.66	51.59
2	63.77	53.35	38.42
3	48.12	33.90	51.68
4	38.70	40.58	50.81
Delta	25.07	30.76	13.26
Rank	2	1	3

As shown in Figure 5, the maximum value of the underfill for three Basis shapes are 67.923, 45.234 and 23.453 mm, which it has been reduced significantly by this method to 0.05 mm.

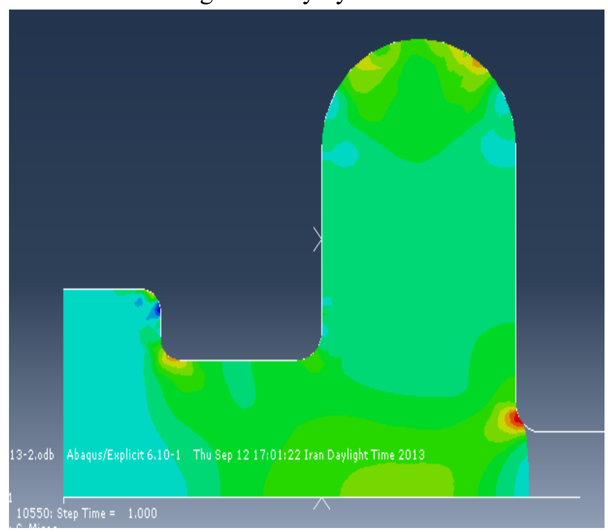


Figure 5. Optimum preform shape.

CONCLUSION

A preform shape optimization method in forging process is presented and investigated in this paper using the reduced basis technique coupled by finite element and design of experiment methods. The reduced basis method aids in the use of the Taguchi design of experiments models foroptimization. Most blank shapes obtained by this method are practical. The presented method has been applied on preform shape optimization steel 1045 as a case study. An optimum preform shape has been achieved by the implemented algorithms, starting from three basis shapes. The underfill value has been reduced significantly (from 67.925 mm to 0.05 m.m) by this optimization method.

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