American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-10, pp-34-39
www.ajer.org
Research Paper Open Access

DEVELOPMENT OF NEW DIE FOR THE FORMING OF IMPELLER VANE AND THE INVESTIGATION OF PROCESS PARAMETERS INFLUENCING ITS PART QUALITY.

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ABSTRACT : *Computer aided analysis provides optimum results to reduce the costly trial and error iterations .The component vane used in the impeller of stainless steel pump is obtained by two forming operations. The required profile is complex with the combination of five radii and is made of Stainless Steel 304. The forming of the partial shape of profile is done using the first die and then it is transferred to the second die to obtain the final shaped component. Thus ,the lead time for the manufacture of vanes was observed to be high. In this work, an effort is made to design a die so that the required profile of component is obtained by a single operation. The die is modeled in PRO-E and analyzed using the DEFORM 3D software to reduce the trail and error iterations after manufacturing the die. Then the die is manufactured, checked whether it confirms to the simulation and spring back is observed which is not considered in simulation. Bio-degradable lubricants selected are sunflower, olive and castor oils. Taguchi L27 orthogonal array is employed to investigate the effect of oils along with load and dwell time as other variables. It is observed that the load, lubricant contributes most for the forming process and next is the Load and castor oil combination that influences the process.*

Keywords - *Impeller Vane, Stainless Steel 304, PRO-E, DEFORM 3D, Bio-degradable lubricants, Taguchi.*

I. INTRODUCTION

Metal forming is a general term for a large group of sheet metal operations that includes drawing, bending and curling operations. In order to plastically deform a metal, a force is applied that must exceed the yield strength of the material. Bending refers to the operation of deforming a flat sheet around a straight axis where the neutral plane lies. Sheet forming processes generally is affected by several factors such as the shape of the die, the initial blank, the material property, friction, lubrication and so on. It is necessary to design forming processes, which can achieve specific product shapes without failures like fracture, wrinkling, surface unevenness and geometrical inaccuracies. Traditionally, the design of sheet metal products and processes is performed to a large extent by a trial-and- error approach .It is therefore unreliable, time and money consuming approach. Finite element analysis (FEA) is ideally suitable for precisely simulating the forming process taking into consideration the elasto- plastic behavior of the material, actual forming conditions such as contact and friction between the tools and the sheet.

In the field of metal forming simulation, because of the increasing people's needs, there are many mature commercial simulation software convenient for researchers using numerical simulation technique to study the industrial process. DEFORM is a finite element process simulation system to be applied for the analysis of metal forming and various forming process in related industries.

II. PROBLEM DEFINITION

In Indian pump industries, different varieties are produced and marketed. In that, phenomenal group of pumps are exported to foreign countries, mainly stainless steel pumps. In these pumps, the impeller vanes are manufactured by forming process. The profile used for these vanes is of complicate design that is combination of five radii. The metal profile used for making impellers is formed by two operations. In the first, the flat metal sheet is formed to semi circular shape (Fig 1), and then the semi circular shaped sheet is formed to required profile (Fig 2). So, efforts are made to manufacture a die that gives the required profile in single operation

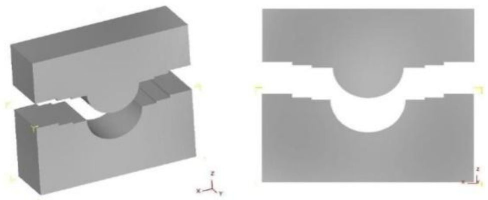

figure-1: First Forming Die.

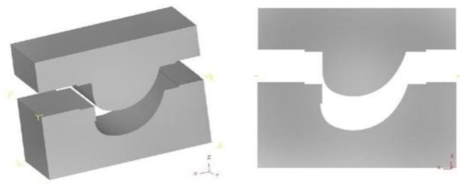

figure-2: Second Forming Die.

III. DESIGN AND MODELING OF NEW DIE

3.1. Freehand Sketching

Several designs are manually sketched and then are modeled in Pro-E. The importance of computer aided analysis is clearly understood in this stage. Here, four designs are sketched. These four designs are modeled and checked for the outcome using DEFORM 3D and fourth design seems to be satisfying. Without FEA simulation, trial and error runs should have been conducted for all the four designs which is time consuming and costly process.

3.2.Finite element model

By means of the CAD software of PRO-E, the finite element models of the forming pair and workpiece is modeled and were set according to their actual dimensions, they could be then used in DEFORM-3D simulation. In order to simplify and reduce the running time during the simulation, the upper and lower anvils were suggested as the rigid ones. Workpiece in Fig-3 is made of Stainless steel grade 304 with thickness of 1.5±0.025 mm and its material properties are mentioned in Table 1.

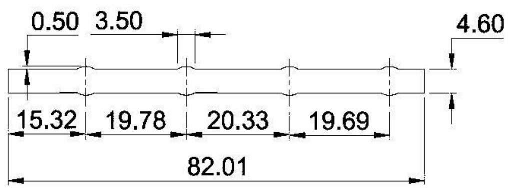

figure-3 : Workpiece

Table 1 Material Properties of SS304

Density	8 gm/cc
Ultimate Tensile strength	505Mpa
Yield Strength	215Mpa
Elastic Modulus	193-200Gpa
Poisson's Ratio	0.29

3.3. Simulation control of the forming process

In the current simulation, the coordinates system was set as that the perpendicular direction as the *z*-axis and the other two as the *x*-axis and *y*-axis, respectively.

(1) During the forming process, the upper die, which is the main module, with a given speed and load moves along the negative *z*-axis, and the workpiece was placed on the still lower die.

(2) Tetrahedral mesh is used to mesh the object and the punch load is given as 1.5 tons.

(3) The friction coefficient between the dies and workpiece is given as 0.12, which is a preset for cold forming dies.

(4) Suitable stopping criterion for the top die is assigned and step increment is assigned.

(5) Simulation is submitted and monitored in frequent intervals.

3.4. Results of DEFORM Simulation

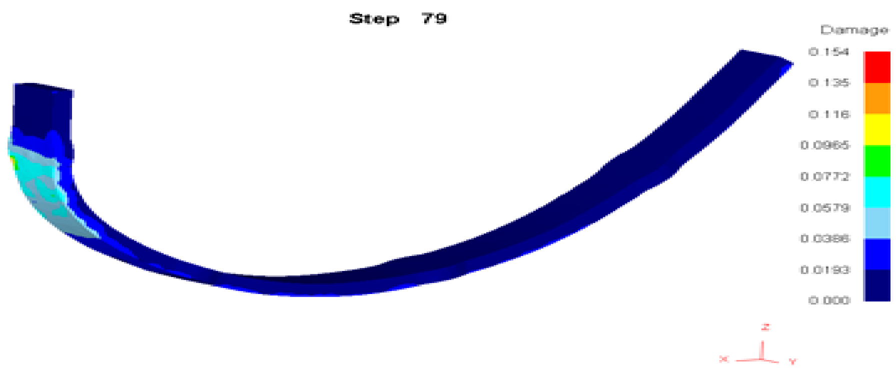

figure 4: Damage in final component

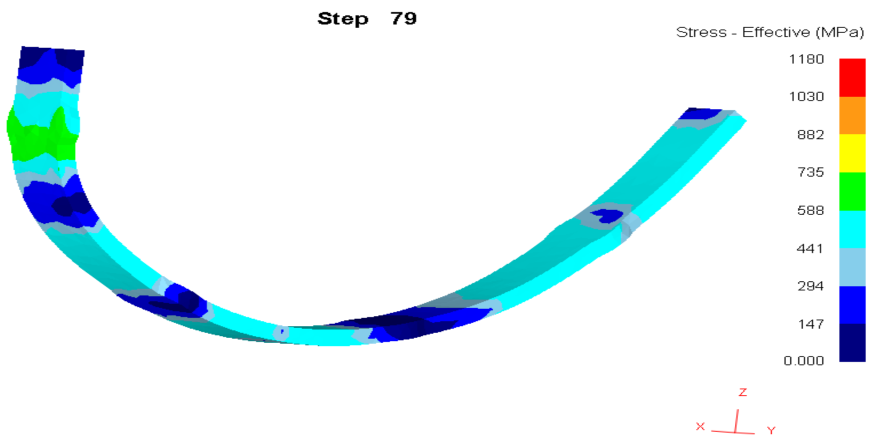

figure 5: Effective stress variations in final component

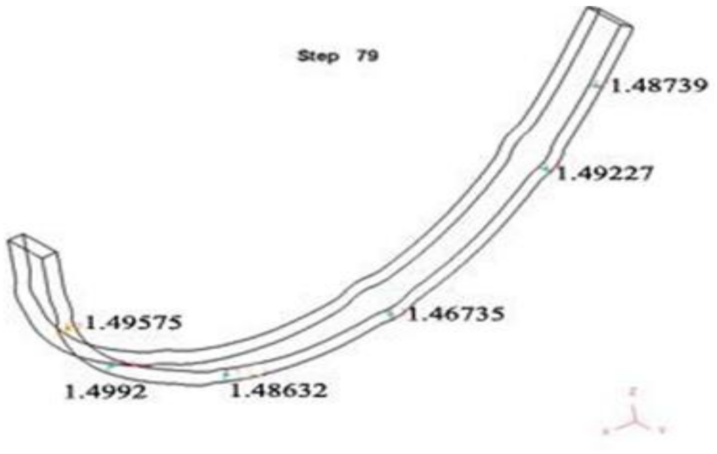

figure 6 : Variation of thickness in final component

Lesser is the damage, lesser is the chances to fracture. Damage in this case is shown in Fig 4.. It is inferred from Fig 5 that slightly higher stresses were seen in the profile indicated by green color. It cannot be eliminated because of the complex shape of the profile .The variation in thickness is indicated in Fig 6 and it is less than the permitted value of 10% change in thickness.

IV. MANUFACTURING OF DIE

The die is made up of tool steel of grade AISI D2. The die is cut form a single block using Wire EDM and the required holes are made for fasteners and threading is done. Then the die is hardened by the method of vacuum hardening. In the method of vacuum heat treatment, the die is heated gradually to 850ºC in three stages of 10 minutes each. Then the die is heated to temperature of 1030ºC where it hardens. Later it is to be tempered in three levels since heat treatment induces small changes in the dimensions of the die. During tempering, it is heated for 200ºC two times for 240minutes and it is heated at 250ºC for 240 minutes which makes the die to obtain its initial dimension and also to obtain the required HRC of 59-60.

V. DESIGN OF EXPERIMENTS

The operating variables selected in this experiment are Punch Load, Dwell Time and Lubricant used. L27 full factorial array is chosen with three operating variables at 3 levels. Punch load ranges are of 1..5, 2 and 2.5Tons. Dwell time varies from 1, 2 and 3 seconds. Due to important health, economic, and environmental issues, significant efforts are being made to develop and implement manufacturing lubricants that come from natural resources. Lubrication is selected based on the previous researches as Sunflower, Olive and Castor oils.

5.1. Experimentation

Die is placed in the hydraulic press as shown in the Fig 7. Different types of oils used are shown in Fig 8.

5.2. Experimental Analysis

Experimental results for the forming process are shown in the Table 2 and the response factor considered is the amount of spring back. The workpiece obtained by experimental process is placed on the ideal shape of the required component that is printed on the graph sheet as shown in Fig 9 and then using bevel protractor, the deviation from actual and the original is observed as shown Fig 10. For the impeller vane, outlet angle is most important than inlet angle. As the variation in inlet angle does not vary significantly, only outlet or exit angle is observed to record the amount of spring back in terms of degrees.

figure 7:Die Fixed in hydraulic press

figure 8- Lubricants

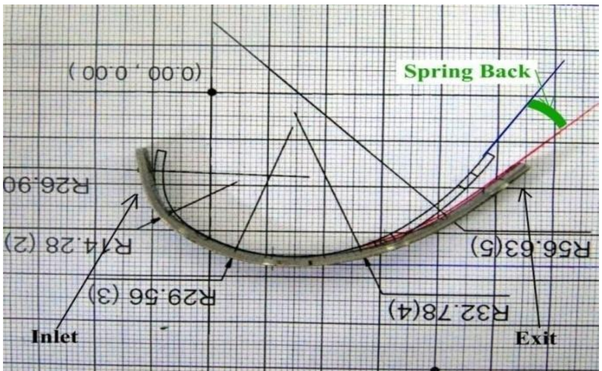

figure 9:Spring back and Inlet and Exit angles of vane

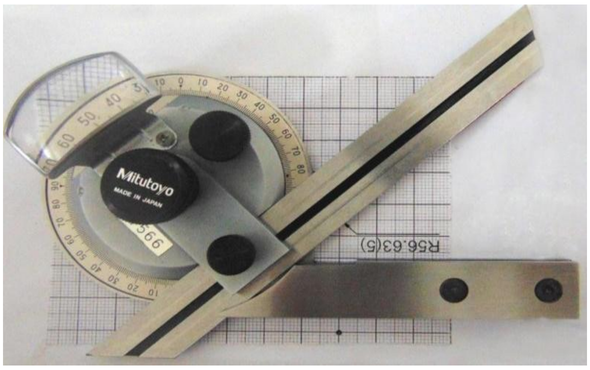

figure 10-Measurement of spring back using bevel protractor

Table 2- Experimental Table

S. No	LOAD	DWELL TIME	LUBRICANT	SPRINGBACK (Degrees)
1	1.5	1	SUNFLOWER	16.5
2	1.5	1	OLIVE	15.99666667
3	1.5	1	CASTOR	14.97
4	1.5	2	SUNFLOWER	15.85666667
5	1.5	2	OLIVE	16.02333333
6	1.5	2	CASTOR	15.16333333
7	1.5	3	SUNFLOWER	17.10666667
8	1.5	3	OLIVE	15.46666667
9	1.5	3	CASTOR	14.52333333

10	2	1	SUNFLOWER	15.85666667
11	2	1	OLIVE	16.72
12	2	1	CASTOR	15.33
13	2	2	SUNFLOWER	15.27333333
14	2	2	OLIVE	16.69333333
15	2	2	CASTOR	15.33
16	2	3	SUNFLOWER	15.69333333

5.3.Calculation of S/N ratio

The S/N ratio using the smaller the better characteristics by Taguchi Method (Minitab Software) is calculated using “equation 1”and shown in Table 3.

$$S/N = -10 * \log (\Sigma (1/Y^2)/n) \ldots\ldots\ldots\ldots (1)$$

Table 3- S/N ratio values

S. No	SPRINGBACK	S/N Ratio
1	16.5	-24.34967888
2	15.99666667	-24.0805899
3	14.97	-23.50443601
4	15.85666667	-24.00423793
5	16.02333333	-24.09505735
6	15.16333333	-23.61589364
7	17.10666667	-24.66330786
8	15.46666667	-23.78793452
9	14.52333333	-23.2413261
10	15.85666667	-24.00423793
11	16.72	-24.46472546
12	15.33	-23.7108431
13	15.27333333	-23.6786766
14	16.69333333	-24.45086131
15	15.33	-23.7108431
16	15.69333333	-23.91430399
17	15.38666667	-23.74289091
18	13.88333333	-22.84987502
19	15.10666667	-23.58337293
20	13.13666667	-22.3697036
21	14.36	- 23.1430888
22	14.72	-23.3581562
23	15.49666667	-23.80476583
24	14.69333333	-23.34240662
25	14.22	-23.05799193
26	14.85666667	-23.43842759

VI. RESULTS AND DISCUSSION

From the experiments it is understood that the amount of spring back is less as the load acting on it increases. Load and Lubrication have more prominent effect on the amount of spring back and Dwell time has least effect on the spring back. Interaction between Load and Lubricant has also major impact on the forming process compared to other interactions. From the plots for S/N ratios, a combination of 2.5 Tons of load, 3 seconds of dwell time and Castor oil as lubricant gives the minimum amount of spring back and hence it is considered as optimum combination.

The results of ANOVA Table 4 that indicate that load is the most significant factor in affecting the spring back, followed by Lubricant used and combination of both also has major influence on spring back. Taguchi uses Signal to Noise (S/N) ratio in order to interpret the trial results data into values for the evaluation of characteristics in the optimum setting analysis. This is because the S/N ratios can reflect both the average and the variations of the quality characteristics. The main effect plot for S/N ratios is plotted between forming parameters and spring back value as shown in Fig 11.

Table 4
ANOVA for S/N ratios for Spring back

Variable	**Level**			**DOF**	**Sum of Squares**	**Mean Sum of Squares**	**F**	**%**
	1	2	3					
Load	1.5	1	Sunflower	2	2.4968	1.2484	10.46	34.613838
Dwell Time	2	2	Olive	2	0.2979	0.149	1.25	4.1298712
Lubricant	2.5	3	Castor	2	1.3343	0.6672	5.59	18.497774
Load*Dwell Time				4	0.5779	0.1445	1.21	8.0115897
Load*Lubricant				4	0.8496	0.2124	1.78	11.778242
Dwell Time*Lubricant				4	0.7022	0.1755	1.47	9.7347954
Residual Error				8	0.9546	0.1193		13.233887
Total				26	7.2133			100

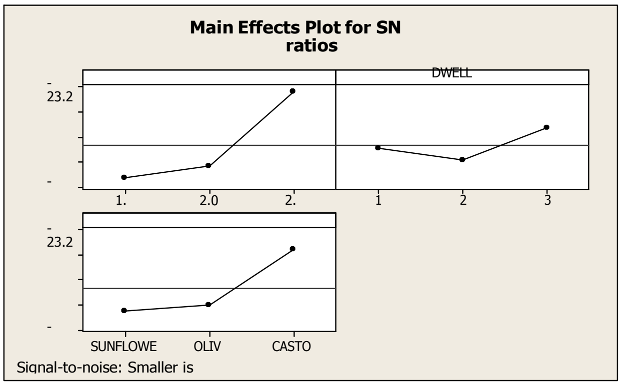

Fig.11 S/N Ratio plots for Spring back

VII. CONCLUSION

1. The simulation and experimental process is found to be in good agreement and required shape of the profile is obtained.
2. Spring back is observe, which is not considered in simulation.
3. The damage seen in simulation can be observed as scratches on the side of the specimen and excessive effective stress seen in simulation is observed as the dent on the side of the workpiece.
4. Punch load and lubricants collectively influence the spring back.

Bio-degradable lubricants can be used effectively as industrial lubricants and castor oil exhibits better lubricant as the extent of damage is very less when this is used as observed by examining the specimens.

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