

Optimization of Shrink Fitting Process and Its Allowances

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Abstract— Increasing the service life of the extrusion dies is a key issue in the highly competitive tool manufacturing market. After sales feedback data shows that carbide pellet and steel casing assembly die failed before its service life at the customer end and process has registered high level of rejections. In the present dissertation work, causes of decrease in service life of carbide pellet and steel casing assembly die was analysed and rectified through design of experiments (DOE) approach. The experimental results were compared with the finite element analysis. The controllable parameters of shrink fit process such as outer diameter of the pellet, inner diameter of the casing, wall thickness of casing and temperature of casing were identified and the experiments were designed as per Taguchi's method. These parameter levels were optimized to maximize the shear stress between the carbide pellet and steel casing assembly die. The higher shear stress improves the service life of the carbide pellet and steel casing assembly die. The compared experimental results with FEA are showing a deviation of about 5%. By using ID of casing 42.73mm, OD of the pellet 42.91mm, wall thickness 9.185mm and temperature 550°C this set of combination performed beyond its service life and no cracks were developed.

Keywords— Interference, Shrink fitting process, Taguchi method, Shear stress, FEA.

I. INTRODUCTION

Shrink fit used for fastening differs completely from that used for the purpose of producing compressive pre stress; the former joins two parts by friction to prevent movement in the direction of load. Shrink fitting for the purpose of preloading, however, prevents tensile stresses from being set up by internal pressure in the tool or part, mostly of cylindrical shape.

The shrink fitted compound cylinders are used for punching dies at high pressure. Compound cylinders are classified into two types - Thin cylinder & Thick cylinder. For high pressure applications thick cylinders are used. When the magnitude of pressure increases and approaches the yield point of the material used, the thickness of cylinder to resist the load approaches infinity. If internal pressure is equal to the yield strength of the material used, thick cylinder fails. Therefore shrink-fitted compound cylinders are used. Compound cylinders can be used for punching dies at higher pressure closer to the yield stress of the material. Optimally designed compound cylinders have equal maximum hoop stress in both - the inner and outer cylinders. The value of this hoop stress is closer to the value of yield stress of the material used. Such compound cylinders were used in automobile, defensive.

The compound cylinder consists of one inner most cylinder which is covered other cylinder by interference fit. The cylinders are manufactured such as to maintain the required interference. Then the inner cylinder (carbide pellet) is cooled to a very low temperature or the outer cylinder (steel casing) is heated to a high temperature depending on the interference value, and then both the cylinders are assembled together. After attaining normal room temperature, the inner cylinder expands or the outer cylinder shrinks, which keeps both the cylinders together due to the interference. This causes compressive stress in inner cylinder (carbide pellet) and tensile stress in outer cylinder (steel casing). These stresses should be within the elastic limits of the material. When such compound cylinders are subjected to internal pressure, the compressive stress in inner cylinder is relieved first, and then tensile stress is developed. The tensile stress in steel casing is further increased due to internal pressure. Generally the three principal stresses in the cylindrical pressure vessels are – circumferential stress, radial stress and longitudinal stress.

Out of these, the circumferential stress, also known as hoop stress, is maximum and it is the main cause of failure of pressure vessels. In case of open type of cylindrical pressure vessels, the longitudinal stress is absent. When the internal pressure is very high, almost close to its yield point stress, then designing the single cylinder pressure vessels would be very bulky and heavy. Then by using compound cylinders, compact and practicable pressure vessel design can be obtained.

II. PROBLEM DEFINITION

The reason to take up this project is considered with respect to the process improvement by optimize the process parameters

The problems encountered in the present processes are

- Cracks were developed in the steel casing, carbide pellet
- Difficult to assemble the carbide in steel casing in hot condition
- Dies fails before its service period.

III. METHODOLOGY

Organization looks for ways to continuously improve their process, production and quality of the out produced. This requires various techniques and tools to be utilized for reduction of production cost and increase their productivity.

- Study the current process
- Literature review on Shrink fitting
- Problem identification
- Run the components as per the orthogonal array
- Analyse the test run through FEA software
- Subject the components to the testing
- Access the gap between existing and the proposed process
- Define the new process and recommend it as standard for use

IV. PROJECT OBJECTIVES

- To analyze the factors responsible for process variability and defects.
- To optimize the process parameter of the shrink fit to reduce premature failure.
- Comparison of experimental result with the FEA results.

V. ANALYSE

The reason for premature failure of carbide pellet and steel casing were analysed and categorized; design, operator, material, machine

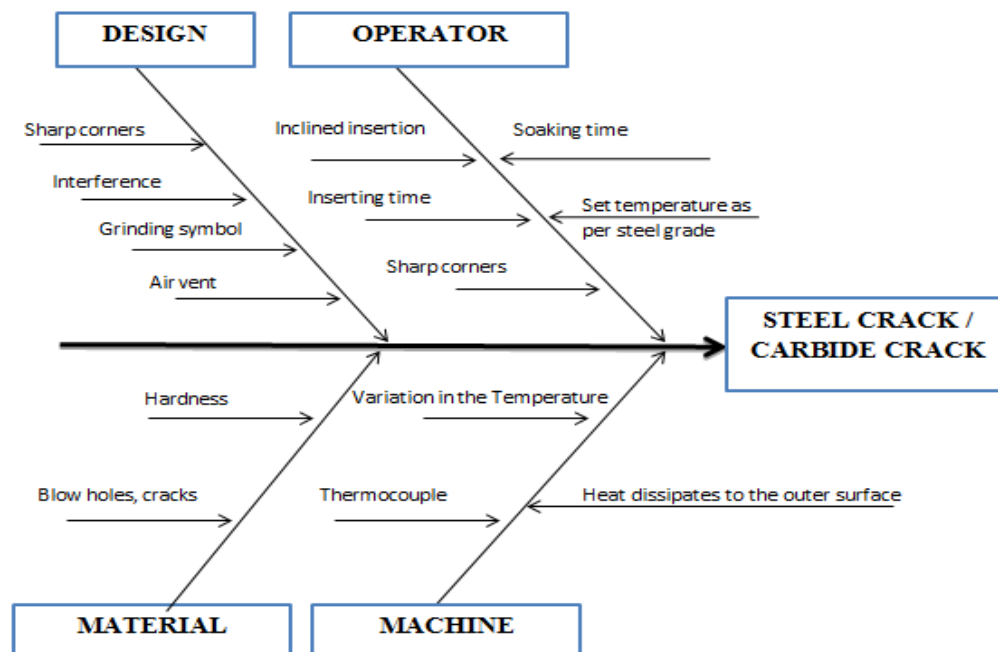


Fig.1 Cause and Effect

The cause and effect diagram showing the main cause for the premature failure is due to interference and shrink fit process temperature. The other parameters are easily rectifiable parameters.

Interference is depends on OD of pellet, and ID of casing. The expansion of the casing during shrink fit process depends on wall thickness and temperature of the casing. As we know poor interference causes insufficient shear strength between pellet and casing assembly. By strengthen the shear strength between pellet and casing the premature failure of the casing dies assembly will be minimized.

Taguchi approach to the parameter

Taguchi's designs aimed to allow greater understanding of variation than did many of the traditional designs. Taguchi contended that conventional sampling is inadequate here as there is no way of obtaining a random sample of future conditions. Taguchi proposed extending each experiment with an orthogonal array should simulate the random environment in which the experiment would function.

Taguchi orthogonal array is designed with three levels of process parameters with the help of software Minitab 14. One way of attaching the shrink fit process is through design of experiments, in order to optimize the process parameters; experimentation is run through the Taguchi method it uses the orthogonal array table which gives fair amount of idea to conduct the experiment.

TABLE I L9 orthogonal array to the design

Trial No	ID of the casing(mm)	OD of the pellet (mm)	Wall thickness of casing(mm)	Temperature (c°)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

TABLE II L9 orthogonal array to the parameters

Trial No	ID of the casing(mm)	OD of the pellet (mm)	Wall thickness of casing(mm)	Temperature (c°)
1	42.65	42.83	9.175	500
2	42.65	42.87	9.180	525
3	42.65	42.91	9.185	550
4	42.69	42.83	9.180	550
5	42.69	42.87	9.185	500
6	42.69	42.91	9.175	525
7	42.73	42.83	9.185	525
8	42.73	42.87	9.175	550
9	42.73	42.91	9.180	500

Experimental Result

The shear strength between pellet and casing is tested by using UTM. The experimentation was carried as per L9 design matrix.

TABLE III Experimental Result

Trial No	ID of the casing(mm)	OD of the pellet (mm)	Wall thickness of casing(mm)	Temperature (c)	Shear strength 1 (Mpa)	Shear strength 2 (Mpa)	Shear strength 3 (Mpa)
1	42.65	42.83	9.175	500	600	610	605
2	42.65	42.87	9.18	525	638	630	620
3	42.65	42.91	9.185	550	658	655	660
4	42.69	42.83	9.18	550	653	640	640
5	42.69	42.87	9.185	500	611	600	595
6	42.69	42.91	9.175	525	638	620	625
7	42.73	42.83	9.185	525	653	640	638
8	42.73	42.87	9.175	550	653	650	655
9	42.73	42.91	9.18	500	611	600	620

Taguchi design using Mini tab

Main effects plot for SN ratios

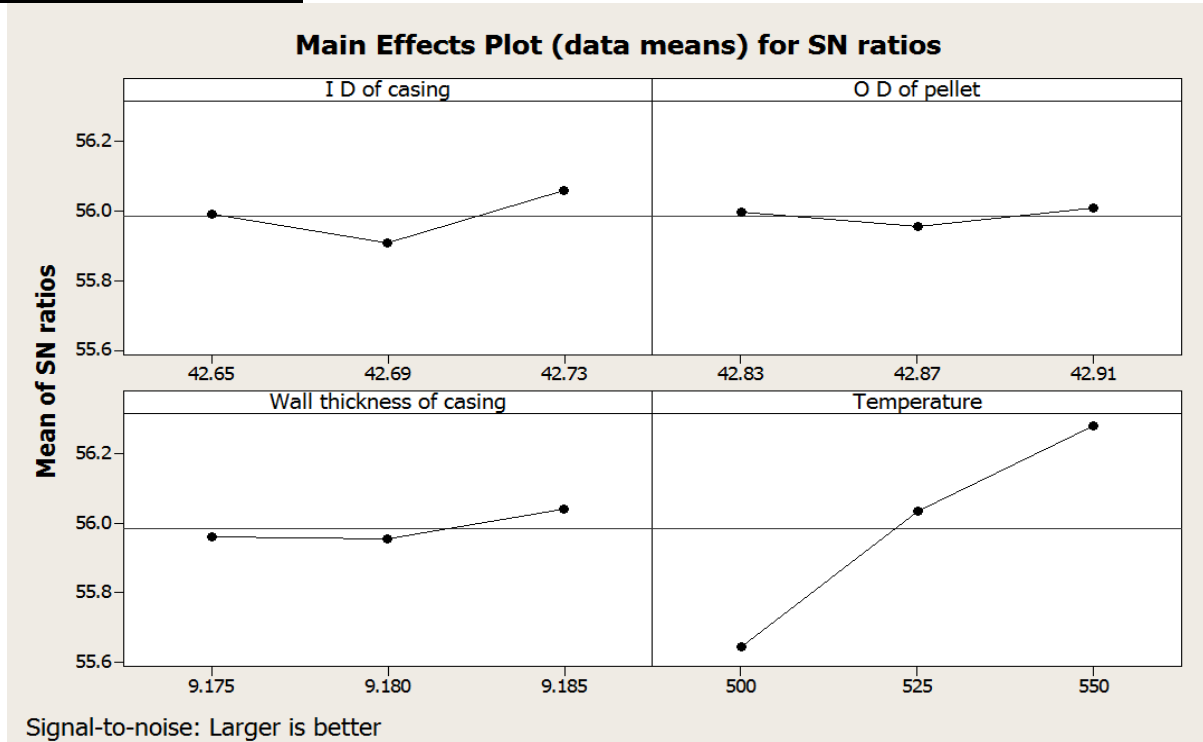


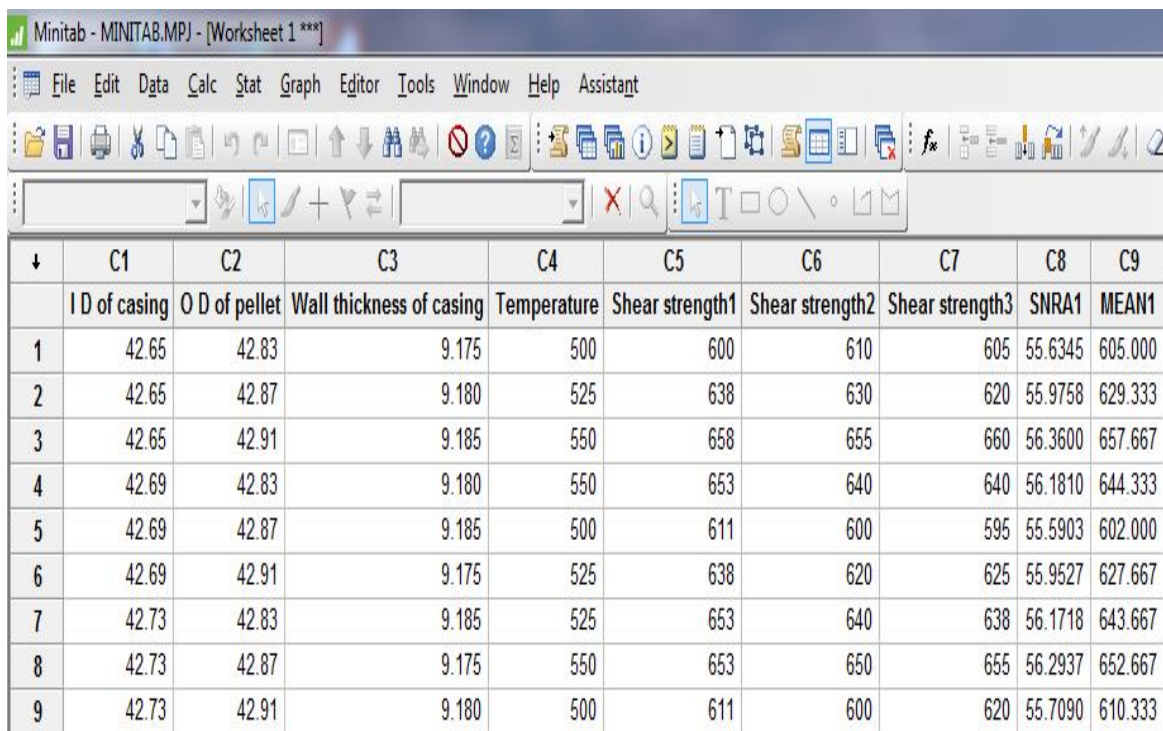
Fig.2

Taguchi Design Using Mini Tab 17

The S/N ratio was calculated for larger the better characteristics of shear strength.

$$S/N \text{ ratio for larger the better} = -10 \log_{10} \left(\frac{1}{n} \sum \frac{1}{y_i^2} \right)$$

Where, n = number of experimental levels



+	C1	C2	C3	C4	C5	C6	C7	C8	C9
	I D of casing	O D of pellet	Wall thickness of casing	Temperature	Shear strength1	Shear strength2	Shear strength3	SNRA1	MEAN1
1	42.65	42.83	9.175	500	600	610	605	55.6345	605.000
2	42.65	42.87	9.180	525	638	630	620	55.9758	629.333
3	42.65	42.91	9.185	550	658	655	660	56.3600	657.667
4	42.69	42.83	9.180	550	653	640	640	56.1810	644.333
5	42.69	42.87	9.185	500	611	600	595	55.5903	602.000
6	42.69	42.91	9.175	525	638	620	625	55.9527	627.667
7	42.73	42.83	9.185	525	653	640	638	56.1718	643.667
8	42.73	42.87	9.175	550	653	650	655	56.2937	652.667
9	42.73	42.91	9.180	500	611	600	620	55.7090	610.333

Fig.3 Confirmation test based on SN ratio

Confirmation Run

With the above four optimized factors i.e. ID of casing = 42.73mm, OD of pellet = 42.91mm, Wall thickness of casing = 9.185mm and Temperature = 550° c a confirmation run was carried out which gave the following result.

TABLE IV Result of confirmation run

Trial No	ID of the casing(mm)	OD of the pellet (mm)	Wall thickness of casing(mm)	Temp (c°)	Shear stress (Mpa)	Shear stress (Mpa)	Shear stress (Mpa)	Average Shear stress (Mpa)
1	42.73	42.91	9.185	550	659	655	660	658

Analysis of Shear Stress on Shrink Fit Components Using FEA

Finite element analysis was carried as per the L9 orthogonal array, the analysis was carried out using Ansys software. The models were developed as per the dimensions and thermal load applied during the analysis, the shear strength between the pellet and casing interface noted from the solved FEA model. The results are shown below,

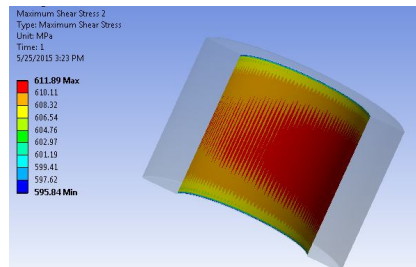


Fig.4 FEA Shear Stress for Trial No1

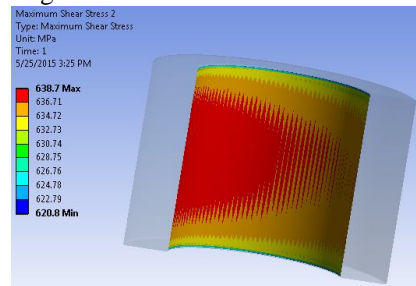


Fig.5FE A Shear Stress for Trial No2

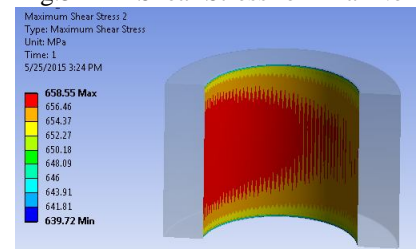


Fig. 6 FEA Shear Stress for Trial No 3

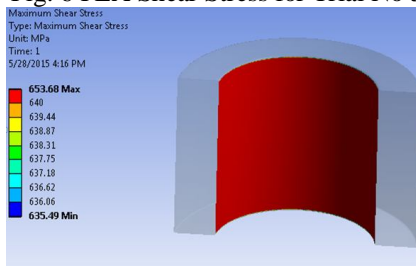


Fig.7FEA Shear Stress for Trial No 4

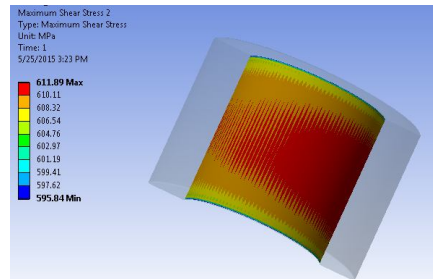


Fig..8 FEA Shear Stress for Trial No 5

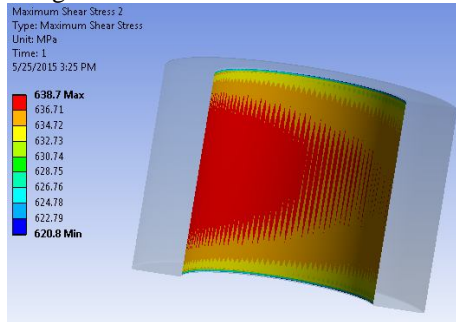


Fig.8 FEA Shear Stress for Trial No 6

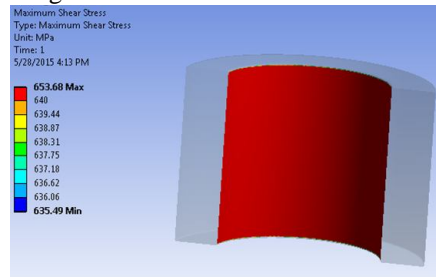


Fig.9 FEA Shear Stress for Trial No 7

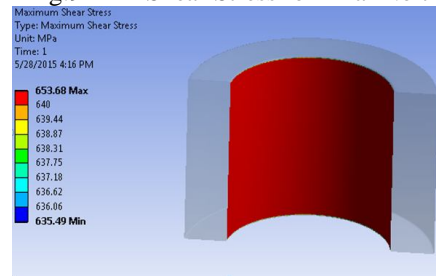


Fig.10 FEA Shear Stress for Trial No 8

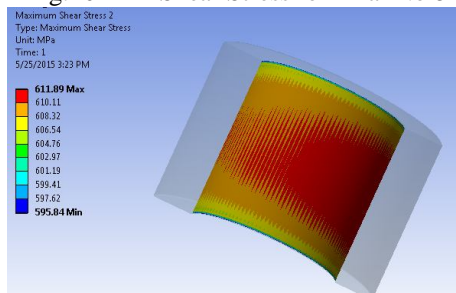


Fig.11 FEA Shear Stress for Trial No 9

VI RESULTS

TABLE V Comparison of experimental v/s FEA results

Trial no	Average experimental shear stress(Mpa)	FEA Shear stress (Mpa)	Deviation in %
1	605	611.89	1.13
2	629.3333	638.7	1.48
3	657.6667	658.55	0.13
4	644.3333	653.68	1.45
5	602	611.89	1.642
6	627.6667	638.7	1.79
7	643.6667	653.68	1.55
8	652.6667	653.68	0.156
9	610.3333	611.89	0.255

Compared Experimental results and FEA results shows a maximum deviation of 1.79 %.

TABLE VI Allowance for the Shrink fit

Sl no	Particulars	Results
1	ID of the casing(mm)	42.73
2	OD of the pellet (mm)	42.91
3	Wall thickness of casing(mm)	9.185
4	Temp (°C)	550

Interference allowance is obtained by the difference of ID of the casing and OD of the pellet, i.e. 0.18mm. With ID of casing 42.73mm, OD of the pellet 42.91mm, wall thickness 9.185mm and temperature 550°C this set of combination performed beyond its service life and no cracks were developed.

VII CONCLUSIONS

Shrink fit process was analyzed for premature failure of pellet and casing die assembly. From the analysis, it is found that insufficient shear stress between the pellet and casing die assembly. The experimentation was carried out as per Taguchi's L9 orthogonal array approach by identifying the controllable parameters and their levels. The optimum levels were identified i.e. ID of casing 42.73mm, OD of the pellet 42.91mm, wall thickness 9.185mm and temperature 550 °c. The shear strength between the pellet and casing interface was tested for the optimal parameter level is found to be 658Mpa (average). The interference between pellet and casing is 0.18mm. Compared Experimental results and FEA results shows a maximum deviation of 1.79 % and it lies within the acceptance level.

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