REPORT

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Optimization of friction welding process to eliminate forking in Engine valves

Periyasamy P[1], **Elaiyaraja K**[2], **Kavitha K**[3]

[1]Head of the Department, Department of Prod. Engg., St.Peter's University, Avadi, Chennai, India; Email: p.periyasamy@gmail.com
[2]ME CAD CAM, Department of Prod. Engg., St.Peter's University, Avadi, Chennai, India; Email: k.elaiyaraja@rane.co.in
[3]Assistant professor, Department of Mathematics, Velammal Institute of Technology, Panchetti, Thiruvallur District, India; Email: kavibiet@gmail.com

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ABSTRACT
Optimization of friction welding process to eliminate valve forking which is resulting in valve breakage in bend test followed by friction welding process and in engine as well. In Engine valve austenitic material and martensitic stainless steel material will be welded through friction welding process to reduce cost and improve temperature gradient. Friction welding defects includes forking will result in valve breakage in the application. Experiments are conducted using Taguchi method to eliminate forking and arrive at empirical relationship between upset force and friction force the parameters of friction welding process.

Keywords: Friction welding, process optimization, forking, bend test

1. INTRODUCTION

Requirement of friction welding process

Rotary friction welding is one; in which one component is rotated against the others. It is the most commonly used of the processes for engine valve manufacturing. It is used to join dissimilar material. In the process, heat is generated by conversion of mechanical energy into thermal energy at the interface of the work pieces during rotation under pressure. In the process, heat is generated by conversion of mechanical energy into thermal energy at the interface of the work pieces during rotation under pressure.

In friction welding the Austenitic stainless steel will be welded against martensitic material. Austenitic material will be used as the head material in the valve stem material will be martensitic due to cost and temperature gradient as well.

2. EXPERIMENTAL

2.1. Understanding of forking

While welding dissimilar material such as austenitic and martensitic material the austenitic material will be tend to penetrate into the martensitic material. The penetration will be beyond the weld line which will be lowering the strength of the weld. The weld strength will be measured through tensile strength measurement. The forking is shown in Fig 1 and the fine microstructure without forking is shown in Fig 2.

2.2. Machine specifications

The machine consists of two important portions; one is stem collet & head collet clamping mechanism. The stem collet clamping mechanism will be attached to the spindle running in 2000 RPM. The machine will be programmed to provide three different forces called soft force which will ensure joining of head and stem material, Friction force will ensure friction between head and stem material. Parallel to friction force the spindle will start running to create heat between head and stem. And upset force is the final force which will ensure welding between both the materials. The schematic structure and welding of head and stem is shown in Fig 3 & 4 respectively.

Fig 1 forking

Fig 2 fine microstructure

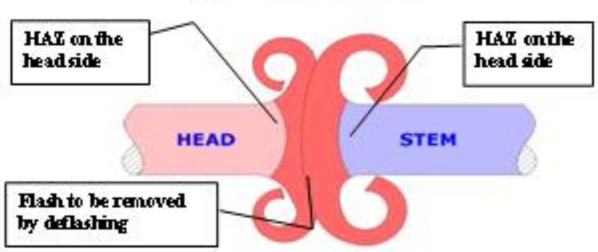

Fig 3 Schematic view of head and stem welding

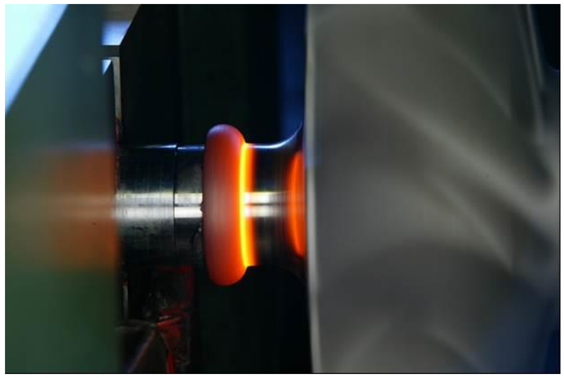

Figure 4 Friction welding of engine valve

2.3. Process flow

The process flow shown in fig , the head material will be upset and forged through electrical upsetting process followed by solution treatment will be done to dilute the carbides in the material and followed by ageing will be done to structure the carbides to form in the grain structure to improve the strength. The friction welding will be done between heat treated head and hardened stem material. The stress relieving will be done to relieve the stress of the welding in the joining portion. The bend test will be done to ensure the welding strength without any joining crack propagation. The process flow of Engine valve is shown in Fig. 5.

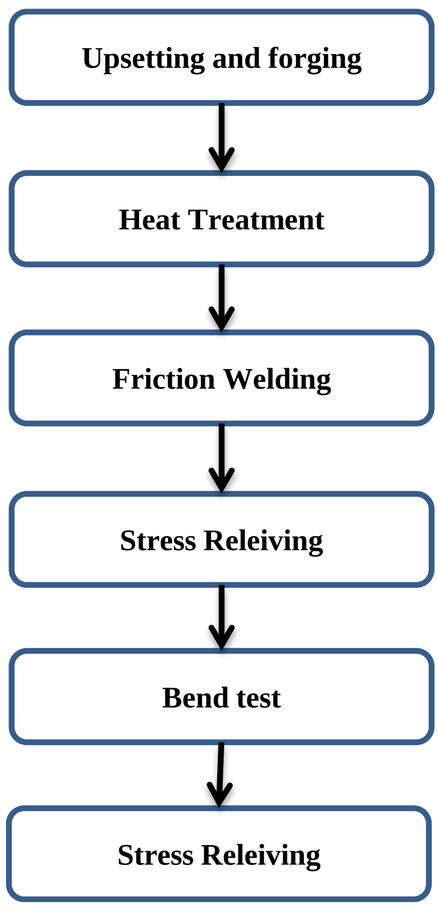

Figure 5 Process flow of engine valve

2.4. Analysis

The fracture or breakage of valve is happening if the valve is not having enough weld strength. The valve with forking will break in bend test. The root cause is identified through funneling approach.

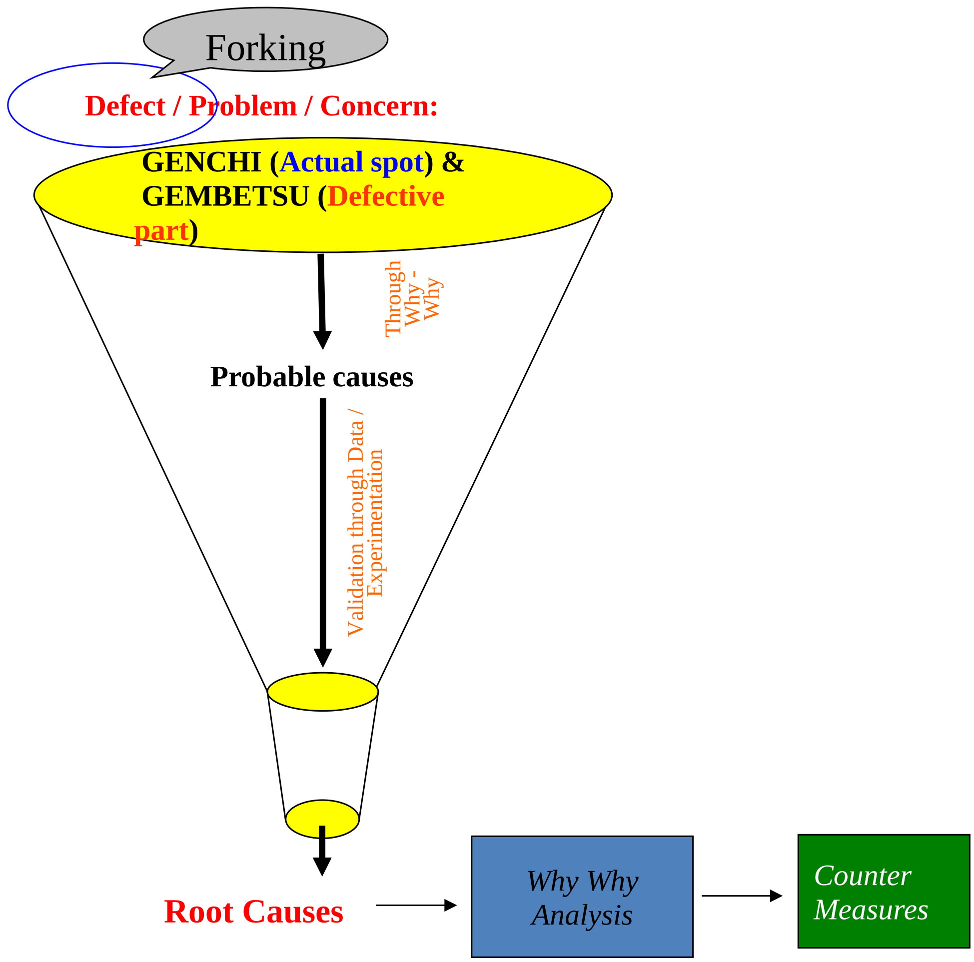

Figure 6 Funneling approach

Followed by funneling approach the ishikawa diagram the causes of forking are identified through 4M approach. The funneling approach is shown in Fig 6 & Ishikawa diagram is shown in Fig 7. The causes are segregated to possible and probable causes and validation done to identify root cause for the problem. The possible cause validation is tabulated in Table 1 and probable cause validation details are tabulated in table 2

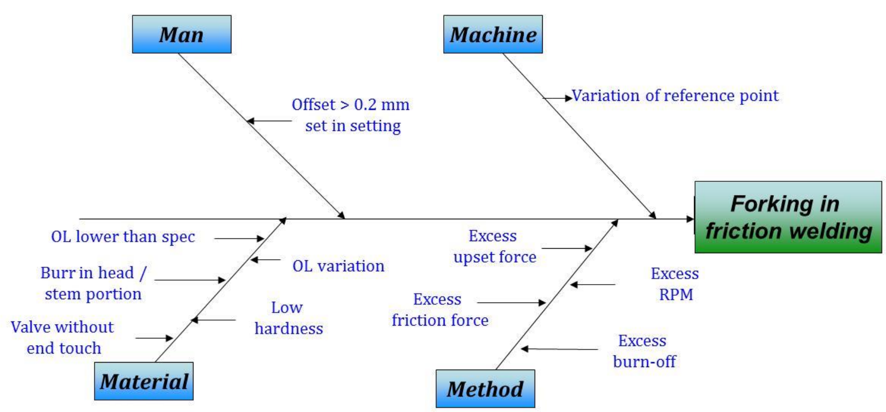

Figure 7 Ishikawa diagram

Table 1 possible cause validation

S.no	Possible Causes	validation
1	OL lower than spec	Detection Poka –yoke available
2	Burr in head/stem portion	100 % visual check
3	Valve without end touch	No forking observed
4	Low hardness	No forking observed
5	Variation of reference point	Repeatability of reference point has been checked and its found ok

Table 2 Probable cause validation

s.no	Probable Causes	Validations	Result
1	Offset >0.2 mm in setting	Valve with offset (0.2 mm) has been checked and found satisfactory	In Significant
2	OL variation(±0.5 mm)	Ol with lower and higher spec has been checked and found satisfactory	In Significant
3	upset force	To be validated by DOE	To be confirmed
4	RPM	To be validated by DOE	
5	friction force	To be validated by DOE	
6	burn-off	To be validated by DOE	

2.5. Experimental design

The experiments are designed to have four factors and two interactions each factors will be having level two levels. Linear graph of the experimental design is shown in fig 8.The experiments are planned through taguchi method and it is falling in L8 Orthogonal array. Factors and levels are tabulated in table 3.

Table 3 Factors and levels

Factors and Level Selection					
S.No	Factors		UOM	Level 1	Level 2
1	Friction force	A	Tone	0.83	0.97
2	Upset force	B	Tone	2.08	2.9
3	Burn off	C	mm	5.3	4
4	RPM	D	RPM	2000	1800
5	AXB				
6	AXD				

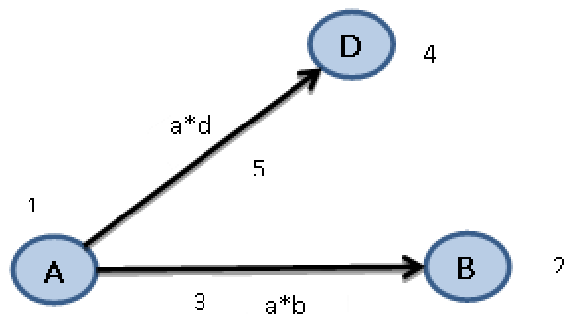

Figure 8 linear graph

2.6. Experimental layout

The experimental layout is tabulated in table 4.The experiment column represents the number of experiments and row represents factor and its respective levels. First experiment will be conducted as given in the corresponding row.

Table 4 Experimental layout

Experimental Layout								
	A	B	C	D	A	B	C	D
Column / Experiment	1	2	6	4	1	2	6	4
1	1	1	1	1	0.83	2.08	5.3	2000
2	2	1	1	1	0.97	2.08	5.3	2000
3	1	2	2	1	0.83	2.9	4	2000
4	2	2	2	1	0.97	2.9	4	2000
5	1	1	2	2	0.83	2.08	4	1800
6	2	1	2	2	0.97	2.08	4	1800
7	1	2	1	2	0.83	2.9	5.3	1800
8	2	2	1	2	0.97	2.9	5.3	1800

3. RESULTS AND DISCUSSION

3.1. ANOVA

The experiments are conducted with the five replicates and each experiment samples are inspected with respected to overall length of valve after friction welding and forking. It is tabulated in table 5. The Anova of the replicates results are calculated and tabulated in table 6.

Table 5 Experiment results

Conducting Experiment						
	REPLICATE					Overall Length
Column / Experiment	1	2	3	4	5	235+/-0.5mm
1	Not ok	Not ok	Not ok	Not ok	Not ok	234.7
2	Not ok	Not ok	Not ok	Not ok	Not ok	234.95
3	Not ok	Not ok	Not ok	Not ok	Not ok	234.08
4	Ok	Ok	Ok	Ok	Ok	235.3
5	Not ok	Not ok	Not ok	Not ok	Not ok	236.2
6	Not ok	Not ok	Not ok	Not ok	Not ok	236.7
7	Not ok	Not ok	Not ok	Not ok	Not ok	233.13
8	Ok	Ok	Ok	Ok	Ok	233.46

Table 6 ANOVA

Source of Variation	Degree of Freedom(DF)	Sum of squares (SS)	Mean Square (MS)	F cal	F Tab	Significant	% Contribution
Factor A	1	2.5	2.5	Infinite	4.17	Y	28.33
Factor B	1	2.5	2.5	Infinite	4.17	Y	26.8
Factor C	1	0	0	0	4.17	N	
Factor D	1	0	0	0	4.17	N	
A*B	1	2.5	2.5	Infinite	4.17	Y	30.3
A*D	1	0	0	0	4.17	N	
Error	33	0	0	0	0		
Total	39	7.5					85.43

4. CONCLUSION

The response graph is drawn with respect to factor A & B which is shown in Fig 9 & 10 respectively. Since it is a quality related issue the graph to be interpreted lower the better. Based on this the factor A & B will be optimum when it is in level 2.And Factor C & D is insignificant any level can be fixed for optimum combination.

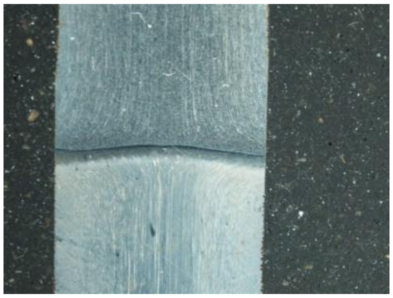

Figure 8 Microstructure of nonforking valve

The empirical relationship is framed between friction and upset force.
Upset force = 3 X Friction force

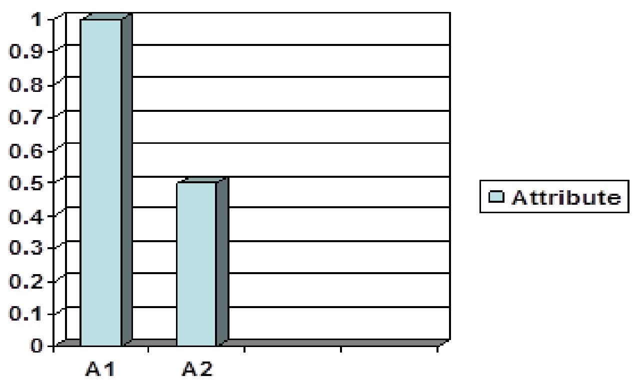

Figure 9 Response graph of Factor A

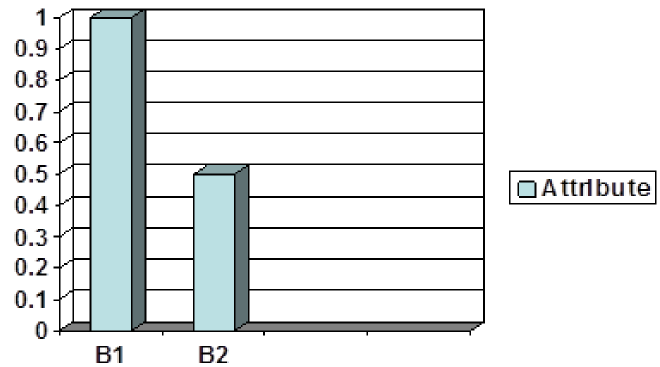

Figure 10 Response graph of Factor B

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