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Optimizing influence of process parameters on induction hardening for IC engine valve

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Abstract

Fatigue behavior of induction hardened part is largely dependent on the correct combination of hardening depth and the magnitude. The objective of this work is to optimize the process parameters of the Induction Hardened End of SH-5395 tuff pattern in which experimentations have been conducted, the process parameters of IHE were varied to give a constant hardness penetration depth in both spiral and flat coils.

Keywords: IC engine, valve, hardness penetration depth, spiral coil, flat coil.

Introduction

The experiment investigation showed that the process parameters of Induction Hardened End (IHE) in spiral and flat coils for the Bajaj pulsar valves to a great extent. Induction surface hardened low alloyed medium carbon steel is widely used for critical automotive and machine application such as crank shaft and knuckle joints which require high fatigue resistance. Fatigue behavior of induction hardened parts depends to a great extent on the correct combinations of induction hardened depth and magnitudes, in order to reduce the many cost in terms of material consumptions and elimination of number of processing steps. The effect of induction hardened process parameters should already be considered in the design stage. In recent years number of investigations has been put forward dealing with modeling and simulation of fatigue behavior of different components coupled to the used process parameters for induction hardened valves (Kristofferson & Vomacka*,* 2001). It found an almost linear correlation between log of the heating and log of the bending endurance limit irrespective of the hardness penetration depth of induction hardened steel 37 Cr 4v an increase the endurance limit was observed when decreasing the heating power and consequently increasing the heat time in order to maintain hardness penetration depth constant (Schopfel & Storzel, 1997). The objective of the presented work is to optimize the process parameters of IHE of SH 5395 Tuff, in which process parameters is varied to give a constant penetration depth. These depths were measures in micro hardness survey (HRC).

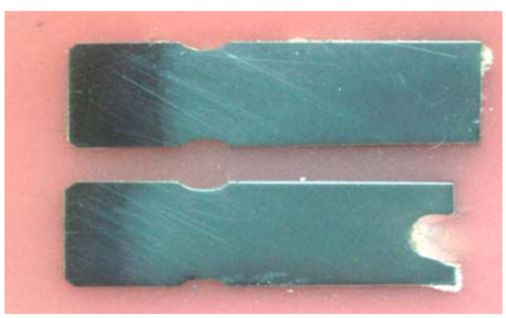
Experimental procedure

The Investigation was performed on the cylindrical samples made of SUH-3 raw material. This chemical composition is indicated in Table 1. Two types samples were prepared namely for spiral and flat coil of the valve length 100 mm and diameter of 4.6 mm prior to induction hardening of end. Material used for Bajaj Pulsar inlet valve is SUH-3 in which Carbon is 0.35 to 0.45%.

Induction hardening

The aim of the satisfactory IHE was to vary the process parameters of available generator (25 KW & 150 KHz) to give an effective hardness zone of 1-2.5 mm from tappet end with surface hardness (56 HRC minimum). Fig.1 shows the hardening occurred on tappet end, First the inductor was three turn spiral coil distance of 4.0 mm and Meta Quench (Super C-11) used as a quench media. The quench was applied immediately after the power had been turned off. The chuck rotated during induction hardening. No tempering was applied. Table 2 shows the selected Induction hardened end parameters that gives the desired surface hardness and effective hardness penetration depth. Similarly, when the inductor is changed to single turned flat coil, the following process parameters given in Table 3 are used.

Fig. 1. Typical structure of heat affected zone in IC engine valve



Result and discussion

Valve stem hardening after nitriding, 56 HRC at end 0.5 mm in spiral coil is difficult to achieve, whereas in single turn flat coil, as the heat is applied from bottom of the valves, hardness 56 HRC minimum at the tappet end is easily achieved, shown in Table 4.

Table1. Chemical composition of material

Element	C	Si	Mn	S	P	Ni	Cr	Mo	Fe
Specification %	0.35 0.45	1.80 2.50	0.60 Max	0.030 Max	0.030 Max	0.60 Max	10.00 12.00	0.70 1.30	Balance
Observation % valve 1	0.41	1.93	0.21	0.018	0.006	0.31	10.41	0.74	85.91
Observation % valve 2	0.40	1.92	0.23	0.023	0.009	0.29	10.34	0.73	85.86

Table 2. Spiral coil process parameters

Material	Power (KW)	Heat time (Sec)	Cooling media	Hardness in HRC
SUH - 3	7.00	2.50	C - 11	54,53
SUH - 3	7.50	2.00	C - 11	52,54
SUH - 3	8.00	1.80	C - 11	53,54
SUH - 3	8.50	1.80	C - 11	55,56
SUH - 3	9.00	2.00	C - 11	54,55
SUH - 3	9.50	1.80	C - 11	51,54

End hardness test record (trial)

Pattern No.:SH-5395 TUF		Date: 30/4/2009	
Material :SUH-3		Specification:	Min 55 HRC (79 HRA)
Sr. No.	Hardness In HRA	Sr. No.	Hardness in HRA
1	79	23	78
2	79	24	78
3	78	25	78
4	79	26	79
5	80	27	78
6	79	28	78
7	78	29	78
8	78	30	78
9	79	31	79
10	78	32	78
11	78	33	80
12	78	34	78
13	78	35	78
14	79	36	79
15	79	37	78
16	79	38	78
17	80	39	78
18	79	40	80
19	79	41	78
20	79	42	78
21	80	43	78
22	79	44	78

Table 3. Flat Coil process parameters

Material	Power (KW)	Heat time (Sec)	Cooling media	Hardness in HRC
SUH - 3	7.00	2.50	C - 11	57,58
SUH - 3	7.50	2.00	C - 11	56,57
SUH - 3	8.00	1.80	C - 11	56,57
SUH - 3	8.50	1.80	C - 11	57,57
SUH - 3	9.00	2.00	C - 11	58,57
SUH - 3	9.50	1.80	C - 11	58,58

End Hardness test record (trial)

Pattern No.:		SH-5395 TUF		Date:	20/4/2009		
Material		SUH-3	Observation in HRA	Specification		Min 55 HRC (78 HRA)	
Sr. No.	Observation in HRA	Sr.No.		Sr. No.	Observation in HRA	Sr.No	Observation in HRA
1	82	14	83	27	78	40	79
2	80	15	80	28	81	41	81
3	81	16	79	29	84	42	84
4	79	17	82	30	84	43	81
5	80	18	80	31	81	44	81
6	79	19	78	32	79	45	81
7	85	20	82	33	81	46	81
8	82	21	83	34	82	47	79
9	79	22	82	35	79	48	83
10	79	23	85	36	79	49	79
11	79	24	81	37	78	50	82
12	78	25	80	38	79		
13	79	26	81	39	83		

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Fig. 2. Hardened end micro structure

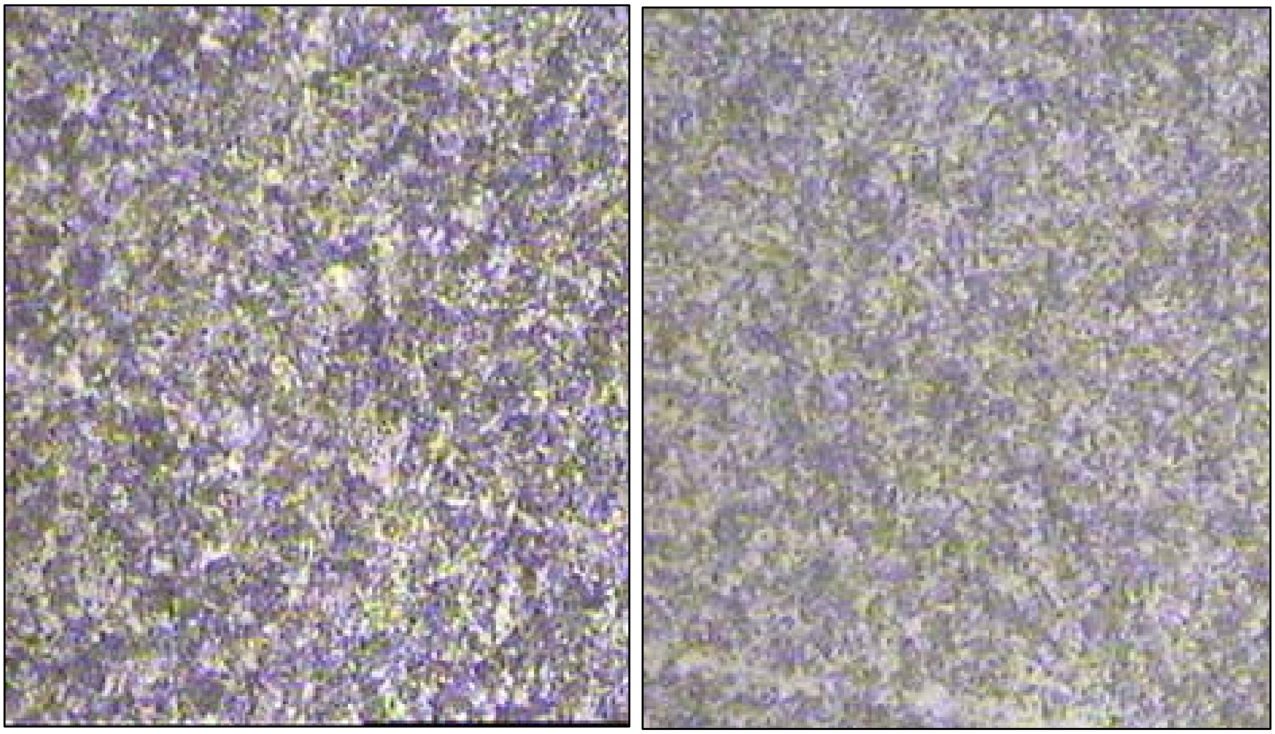

Table 4. End micro hardness survey

Hardness depth in (mm)	Hardness in HRc	
	Valve 1 (Flat coil)	Valve 2 (Spiral coil)
End	57.00	54.00
0.10	57.40	55.30
0.20	57.70	55.10
0.30	57.90	55.00
0.40	56.10	54.70
0.50	55.90	54.60
0.60	55.10	54.30
0.70	55.00	54.20
0.80	53.90	52.90
0.90	53.70	52.40
1.00	53.70	51.30
1.10	53.10	51.20
1.20	52.60	51.00
1.30	52.30	50.20
1.50	52.10	49.90

From the above trial readings, single turn flat coil gives the consistent hardness as per requirement. The investigated induction hardened samples a constant biaxial residual stress state at the surface. The induction hardening gave rise to compressive and tensile normal residual stresses in the hardened zone and outside the zone, respectively. The quenched and tempered starting microstructure revealed a smooth compression/tension at the case depth after induction hardening compared to the normalized microstructure, shown in Fig. 2. This experimental investigation is made for same case depth and the process parameters of induction hardening to see the influence on spiral and flat coil inductors.

References

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