ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

Validation of Eatonite Grade Hard Facing Material In place of Satellite Grade for 150cc Engine Exhaust Valve

Ravindra N. Janjal, S.A. Sonawane

Abstract*—Engine exhaust valve seat wear pattern mostly depends on engine conditions, engine RPM, temperature distribution inside the valve head. Engine performance will maximum when valve seat area will not wear while working of engine throughout its life. To reduce valve seat recession and wear, engine manufacturer used hard facing material for valve seat area using TIG welding process. There are number of hard facing material available to improve the valve performance. The objective of this experiment is to optimize the iron base hard facing material in place of cobalt base material. Here experiment have been conducted with two types of exhaust valve having different hard facing material, for cobalt base STELLITE grade-12 and for iron base EATONITE grade-6 material is used. STELLITE grade is regularly using for two wheeler. All other parameters were same for testing. Here intake valve design was same for the both test. But the STELLITE grade material cost is twice more than EATONITE grade material. And we found that iron-base alloy that exhibits the wear-resistance, hot hardness and heat resistance properties of cobalt-and nickel-base alloys. Here we test 150cc engine endurance test with the help of eddy current dynamometer and Engine control system.

Keywords: **Engine Exhaust Valve, Valve Seat, TIG weld, STELLITE Grade-12, EATONITE Grade-6, Hard Facing Material, Engine Test, Eddy Current Dynamometer, Engine Control System.**

I. INTRODUCTION

Engine valve manufacturing organization has a lot of scope for improvement and innovation. For that we have engine testing setup with advanced and precise equipment for metallurgical and chemical composition testing. We observed from our database that generally exhaust valve has weld hard facing material to its seat area for improving the hot hardness, wear resistance and reduce the seat recession problems. There are a number of hard facing materials like STELLITE grade-1, STELLITE grade-6, STELLITE grade-12 and EATONITE. The EATONITE hard facing alloy is developed by Eaton Corporation Ltd. Generally it has been observed that two wheeler manufacturer used only STELLITE grade hard facing alloy for the exhaust valve seat deposit process. But now a day's number of hard facing material has been developed with lowest cost than cobalt base STELLITE material. But engine manufacturer are using only traditional hard facing material. Here we conduct engine test with cobalt base and iron base hard facing material for engine exhaust valve. Inlet valve is not having seat deposit process as it is operate in low temperature. For engine testing we used eddy current dynamometer and engine testing software and control system. The purpose of testing of standard STELLITE grade hard faced valve for comparison of engine performance and product life after endurance testing of the engine with modified EATONITE hard faced exhaust valve. In utility area we have cooling tower to provide cold water for cooling to the dynamometer. Supply air blower to provide fresh atmospheric air to engine test bed as Pulsar engine is air cooled engine, suction air blower provide to take out engine exhaust gases to the environment. Exhaust fan provided to ventilate the test room. For metallurgical testing and chemical analysis we have SEM/EDS and optical microscope. Engine manufacture provides valuable data to test the engine. For validation of both the valve we used new engine to get the accuracy in results. Firstly we test 150cc engine with regular STELLITE grade valve with specified engine testing cycles, after complete the test we took out the valve from engine to analyzed valve seat wear. Then we took new engine and replace its valve with modified EATONITE grade material. And conduct same test with same operating condition and testing cycles. After completion of the second test with EATONITE grade hard facing valve, took out the valve from the engine and again analyzed valve seat wear. We compared both the results with STELLITE and EATONITE grade hard facing material and also compare engine performance. Details study of the experiments as given below.

I. ENGINE SPECIFICATION AND EXHAUST VALVE DESIGN

A. 150cc Engine Specification

Table 1: 150cc Engine Specification

Parameter	Specification
Fuel Type	Petrol
Engine Type	4-Stroke, Air Cooled,
Displacement	150 cc
Max. Power	9.55 kw @8500 rpm
Max. Torque	11.65 Nm @6500
Idle RPM	1300±100
Max. Engine Oil Temp	110°
Tappet clearance : Inlet Exhaust	0.05 0.10

B. Engine Exhaust Valve Design

Both valves has same dimension and heat tr[illegible]ents process as before only hard facing material is different. For test-1 STELLITE seat deposited valve is used and for test-2 EATONITE deposited valve is used.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

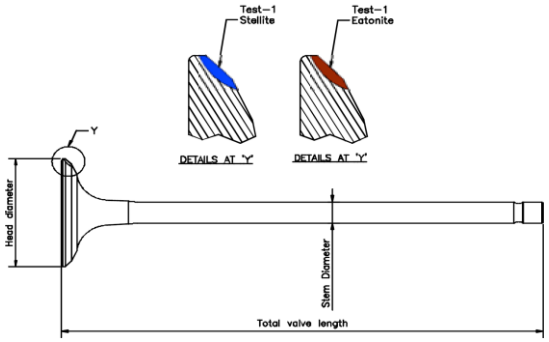


Fig.1: Exhaust Valve with Seat Deposit

II. TEST CYCLES USED TO TEST THE ENGINE

A. Start-Up Test:

Start-up test used to warm-up the new engine. In this test RPM and dynamometer torque are the inputs and power of the engine is the output for compare the performance of engine in the both test. This is four hrs tests to warm-up.

Table 2: Engine Start-Up Test Program for Warm-Up Engine

Sr. no	RPM After transmission	Dyno Torque(Nm)	Measured Power (kW)
1	1420	12.8	
2	1600	14.7	
3	1960	14.5	
4	2320	14.7	
5	2670	13.3	
6	2850	13.2	
7	1420	19.5	
8	1600	18.6	
9	1960	18.1	
10	2320	17.6	
11	2670	16.4	
12	2850	16.2	

B. Performance Test:

Performance test is conduct to measure engine performance against the RPM and throttle. This test has conducted for both the valves and compares the engine parameter like torque and power. This test required 10 to 15 min. Performance test RPM and Throttle has same for both the test. We used auto program through engine testing software to maintained engine test cell temperature and other conditioned.

Table 3: Performance Test Program for Engine Check-Up

	Input values		Measured values	
Sr. no	RPM After transmission	Throttle %	Measured Torque	Measured Power
1	1420	41.49		
2	1600	43.39		
3	1960	48.3		
4	2320	50.95		
5	2670	55.5		
6	2850	57.9		
7	1420	44.95		
8	1600	46.72		
9	1960	47.97		
10	2320	52.73		
11	2670	57.16		
12	2850	59.9		

C. Endurance Test:

After completion of start-up test program and performance test we run the engine for 100 hrs at constant RPM and 47% throttle. This test conducts to ensure the product life and its wear condition after use. We have monitor oil level and its temperature during both the test. After complete 50 hrs of each test we set the tappet end gap as per standard. In 150cc engine we have to set the crankshaft RPM as 2320 after transmission system with 47 percentage of throttle. After completion of both the test we have taken out the engine valve from valve train assembly and study its wear analysis and hardness of the exhaust valve seat.

Table 4: Endurance Test Program for Component Testing

	Input values		Measured values	
Sr. no	RPM After transmission	Throttle %	Measured Torque	Measured Power
1	2320	47		

III. EQUIPMENTS USED FOR TESTING

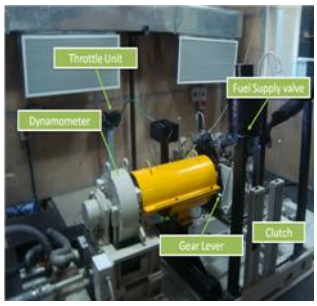


Fig 2: Test Bed Set-Up

Fig 3: Control System

Fig 4: SEM/EDS Used For Analysis

Fig5: Utility Used For Test

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

Table 5: Equipments Used For Engine Test

Equipments	Description
Eddy Current Dynamometer	Model 70 ECA, Maximum Torque 82 Nm, Maximum Power 52 Kw
iASYS Automation System	Orbit-e engine testing software Torque Indication accuracy 0.1% Speed Indication and control accuracy:+/- 1 RPM Capability to run EURO III/ IV, ESC, ELR test cycles. Digital calibration for all inputs, outputs for all modes
Throttle Actuator	Shifting travel: 125 mm Max. actuation force: 200 N (500 N short duration) Max. travel speed: 100 mm in 100 ms Resolution and Repeatability: < 0,05 mm
Inspection Equipments SEM/EDS Roundness tester Profile Projector Stereo Microscope	SEM/EDS used for higher magnification and Chemical analysis. Roundness tester used for measuring seat and stem roundness. Profile Projector used for checking all dimension before and after test. Stereo Microscope used to take close and clear photos.

IV. TEST CYCLES RESULTS FOR STELLITE & EATONITE

A. *Start-up Test Results:*

Table 6: Start-Up Test Results for STELLITE and EATONITE Valve

Sr. No.	INPUT		OUTPUT	
	RPM	Torque	Power	
			STELLITE	EATONITE
1	1420	12.8	2.35	2.7
2	1600	14.7	3.37	3.47
3	1960	14.5	4.18	4.21
4	2320	14.7	5	5.06
5	2670	13.3	5.24	5.27
6	2850	13.2	5.53	5.57
7	1420	19.5	4.01	4.21
8	1600	18.6	4.39	4.34
9	1960	18.1	5.2	5.15
10	2320	17.6	5.92	5.94
11	2670	16.4	6.38	6.39
12	2850	16.2	6.72	3.85

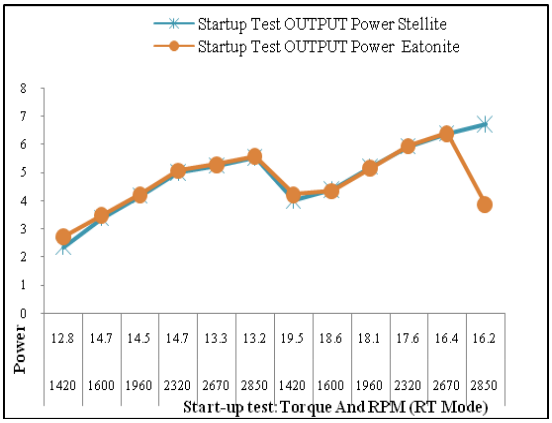


Fig 6: Start-Up Test Comparison Graph

B. *Performance Test Results:*

Table 7: Performance Test Results for STELLITE and EATONITE *Valve*

Sr. No.	INPUT		OUTPUT			
	RPM	Thr ottle	Torque		Power	
			STELLITE	EATONITE	STELLITE	EATONITE
1	1420	40	17.4	19	3.54	3.83
2	1600	41	17.8	19.1	4.06	4.36
3	1960	43	16.6	19.6	4.65	5.47
4	2320	48	16.5	17.7	5.47	5.85
5	2670	51	16.5	20.9	6.28	7.93
6	2850	56	17.7	20.3	7.21	8.24
7	1420	41	20.3	22.6	4.12	4.57
8	1600	45	19.6	23	4.48	5.23
9	1960	47	16.2	19.8	4.55	5.53
10	2320	48	17.7	20	5.87	6.61
11	2670	53	19.4	22.4	7.39	8.52
12	2850	57	19.3	12.8	7.88	5.35

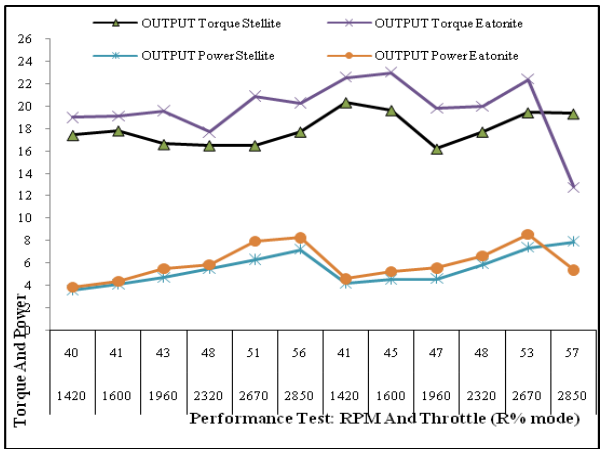


Fig 7: Performance Test Comparison Graph

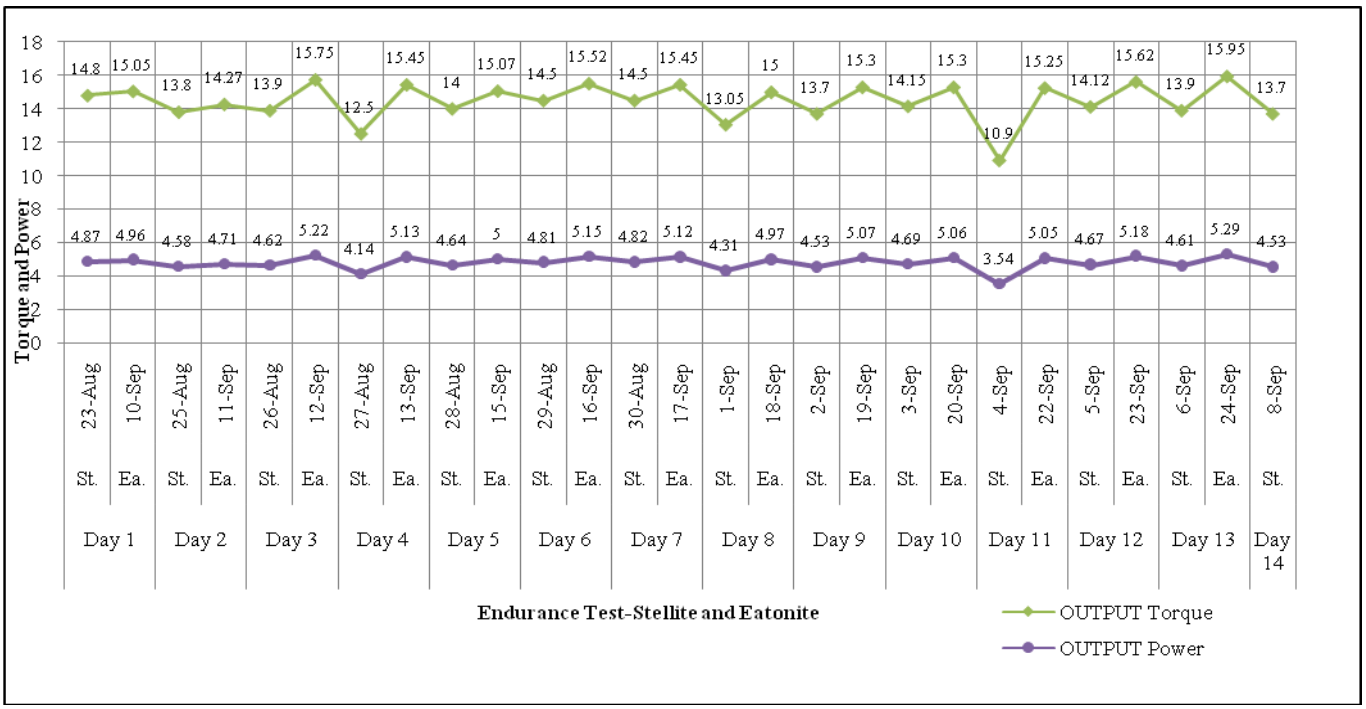
ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

C. Endurance Test Results

Table 8: Endurance Test Results for STELLITE and EATONITE Valve

Sr. No.	Material	INPUT		OUTPUT				
		RPM	Throttle	Torque	Power	Eng.Bdy	Ex.Gs.Temp.	Dyno Hrs.
Day 1	STELLITE	2320	47	14.8	4.87	129.2	406.1	7.57
	EATONITE	2320	47	15.05	4.96	137	379.3	7.22
Day 2	STELLITE	2320	47	13.8	4.58	129.1	412.2	14.29
	EATONITE	2320	47	14.27	4.71	133.4	366.3	14.28
Day 3	STELLITE	2320	47	13.9	4.62	126.2	418.5	21.46
	EATONITE	2320	47	15.75	5.22	138.2	359.6	22.43
Day 4	STELLITE	2320	47	12.5	4.14	125.7	414.4	29.19
	EATONITE	2320	47	15.45	5.13	137.1	365.6	30.26
Day 5	STELLITE	2320	47	14	4.64	127.9	420.9	37.16
	EATONITE	2320	47	15.07	5	131.6	364.5	38.07
Day 6	STELLITE	2320	47	14.5	4.81	128.2	416.2	45.16
	EATONITE	2320	47	15.52	5.15	135.3	329	46.04
Day 7	STELLITE	2320	47	14.5	4.82	126.7	411	52.16
	EATONITE	2320	47	15.45	5.12	131	287.1	50.44
Day 8	STELLITE	2320	47	13.05	4.31	127	410.6	60.09
	EATONITE	2320	47	15	4.97	134	307.4	58.38
Day 9	STELLITE	2320	47	13.7	4.53	127.9	407.2	67.57
	EATONITE	2320	47	15.3	5.07	136.5	298.3	66.36
Day 10	STELLITE	2320	47	14.15	4.69	124	391.7	75.47
	EATONITE	2320	47	15.3	5.06	138.1	293.1	74.33
Day 11	STELLITE	2320	47	10.9	3.54	110.9	296.9	81.14
	EATONITE	2320	47	15.25	5.05	134.8	294.6	82.35
Day 12	STELLITE	2320	47	14.12	4.67	123.1	366.7	89.07
	EATONITE	2320	47	15.62	5.18	137.5	309.4	90.35
Day 13	STELLITE	2320	47	13.9	4.61	123.4	369.4	96.52
	EATONITE	2320	47	15.95	5.29	138.9	297	100.7
Day 14	STELLITE	2320	47	13.7	4.53	126	367.5	100.5

Fig 8 Endurance Test Comparison Graphs



ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

V. DIMENSIONAL REPORT BEFORE AND AFTER TEST OF STELLITE AND EATONITE VALVE.

A. STELLITE Exhaust Valve Dimensional Report:

Table 9 showing dimensional analysis of STELLITE deposited exhaust valve before and after the test. It has observed from dimensional analysis, valve head diameter reduced to 22.36 from 22.45. Seat angle decreased to 44°45' from 45°16'.

Table 9: Satellite Exhaust Valve Dimensional Report

Dimensional Report for STELLITE Deposited Exhaust Valve				
Sr No.	Parameter	Specification	Dimension Before test	Dimension After test
1	Head Dia		22.45	22.36
2	Head Thickness		2.08	2.1
3	Grove Dia		3.76	3.77
4	Seat Hight		1.11	1.09
5	Stem Straightness		0.004	0.005
6	Stem Cylindricity		0.0039	0.0092
7	Stem Dia		4.465	4.455
8	Seat Runout		0.016	0.02
9	Seat Roundness		0.0034	0.0061
10	Seat angle		45° 16'	44° 45'
11	End Runout		12	0.014
12	Overall length		91.09	91.11
13	Datum To End		89.98	90.02
14	Datum To Groove		85.31	85.37
15	Radius Profile		5.82	5.7
16	Radius Angle		10°14'	12°54'
17	Neck Dia		4.78	4.84
18	Neck Angle		2°37'	2°32'
19	Seat Finish		2.2	3.8
20	Stem Finish		1.8	1.6
21	End Finish		2.9	1.3
22	Face Finish		2.7	3.36
23	Radius Finish		1.24	1.52Ra
24	Face Runout		0.09	0.11
25	Second Seat Angle		24°40'	24°42'
26	Head Thickness at Second Seat		3.11	3.07
27	Seat Hardness		38 to 39 HRC	
28	Overall Weight		19.075	19.2881 (With Scale)
				19.19 (without scale)

B. EATONITE Exhaust Valve Dimensional Report:

Table 10 showing dimensional analysis of EATONITE deposited exhaust valve before and after the test. It has observed from dimensional analysis of EATONITE exhaust valve, head diameter value has not changed and seat angle reduced to 44°50' which is 5' less than STELLITE exhaust valve dimensionally EATONITE exhaust valve is more stable than STELLITE exhaust valve.

Table 10: EATONITE Exhaust Valve Dimensional Report

Dimensional Report for EATONITE Deposited Exhaust Valve				
Sr No.	Parameter	Specification	Dimension Before test	Dimension After test
1	Head Dia		22.45	22.46
2	Head Thickness		2.2	1.99
3	Grove Dia		3.83	3.83
4	Seat Hight		0.98	1.00
6	Stem Straightness		0.003	0.002
7	Stem Cylindricity		0.0039	0.0070
8	Stem Dia		4.46	4.460
9	Seat Runout		0.022	0.008
10	Seat Roundness		0.002	0.0056
11	Seat angle		45° 16'	44°50'
12	End Runout		0.015	0.015
13	Overall length		91.15	91.16
14	Datum To End		90.17	90.17
15	Datum To Groove		85.44	85.43
16	Radius Profile		5.88	5.60
17	Radius Angle		09°54'	10°05'
18	Neck Dia		4.72	4.88
19	Neck Angle		3°13'	2°48'
20	Seat Finish		1.1	1.2
21	Stem Finish		2.4	1.7
22	End Finish		1	1.1
23	Face Finish		0.67	0.90
24	Radius Finish		0.72	1.35
25	Face Runout		0.13	0.14
26	Second Seat Angle		25°19'	25°11'
27	Head Thickness at Second Seat		3.14	3.15
28	Seat Hardness		38 to 39 HRC	
29	Overall Weight		19.2839	19.3643 (With Scale)
				19.2977 (without scale)

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

VI. VALVE WEAR AND CHEMICAL ANALYSIS

A. STELLITE valve wear analysis:

STELLITE valve photo after complete all three tests, white calcium scaling found on head side this scaling is due to burn fuel deposition. Visually valve seat area was not wear.

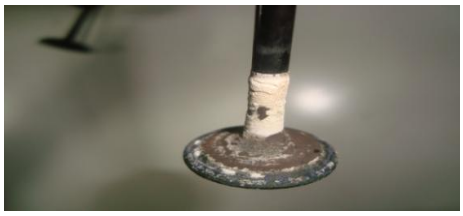


Fig 9: STELLITE Valve After Complete the Test

After removed scale valve seat clearly visible. No wear found along seat angle.

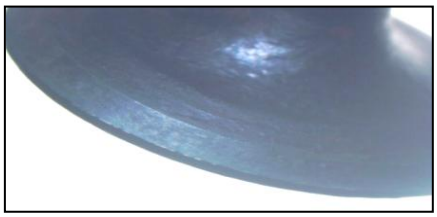


Fig 10: STELLITE Valve Seat after Removed Scale

Fig11: shows seat roundness pattern by using roundness tester found that it is 41 micron. Means valve seat area is not uniform and due to this engine power and torque during endurance test getting low as compared to EATONITE exhaust valve

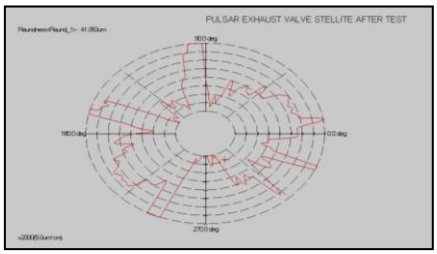


Fig 11: STELLITE Seat Roundness Pattern

B. EATONITE Valve Wear Analysis:

EATONITE valve photo after complete all three tests, here also found white scaling on head of valve. But in EATONITE test white scale was absent on seat angle.

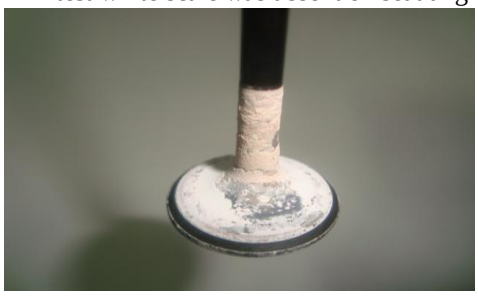


Fig 12: Eatonite Valve After Complete the Test

After removed scale from valve head and neck area, no damage found on valve seat angle.

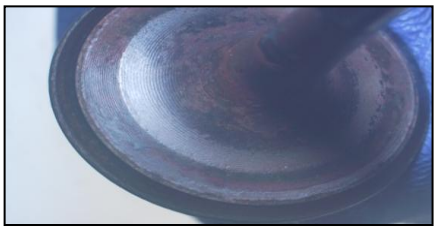


Fig 13: EATONITE Valve Seat after Removed Scale

Fig14: shows seat roundness test by using roundness tester found that it is 3.5 micron. Because of this power and torque graph was higher than STELLITE exhaust valve test.

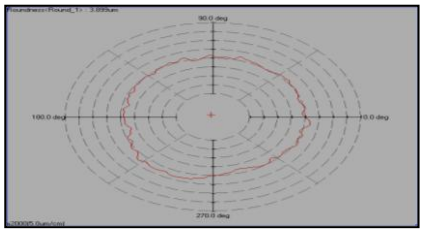


Fig 14: EATONITE Seat Roundness Pattern

C. STELLITE Valve Chemical Analysis:

STELLITE valve SME chemical analysis has conduct for find out deposition on valve head through fuel and other impurities

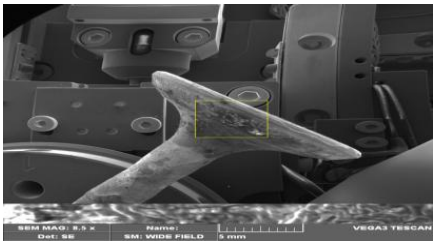


Fig 15: STELLITE Valve for SEM Analysis

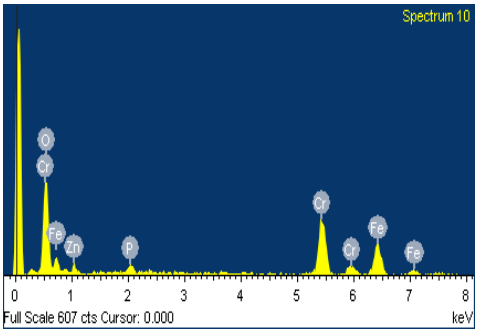


Fig 16: Chemical Composition of STELLITE Valve Seat

Table 11: Chemical Composition of STELLITE Exhaust Valve

Element	Weight%	Atomic%
O	10.46	62.79
P	0.68	2.12
Cr	10.26	18.95
Fe	8.26	14.20
Zn	1.32	1.94
Totals	30.98	

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 2, Issue 4, October 2012

In exhaust valve seat area where no scaling, found maximum percentage of chromium (Cr: 10.26), and Iron (Fe: 8.26) other than oxides. Those elements are the part of STELLITE base material.

D. EATONITE Valve Chemical Analysis:

EATONITE valve SME chemical analysis has conduct for find out deposition on valve head through fuel and other impurities

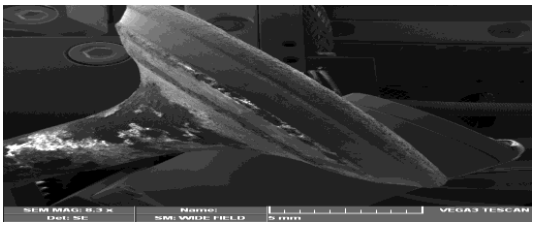


Fig 17: EATONITE Valve for SEM Analysis

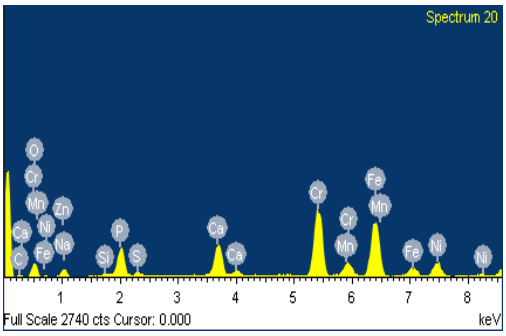


Fig 18: Chemical Composition of EATONITE Valve Seat

Table 12: Chemical Composition of EATONITE Exhaust Valves

Element	Weight%	Atomic%
C	8.39	21.49
O	14.79	28.46
Na	3.61	4.83
Si	0.49	0.53
P	6.71	6.67
S	0.72	0.69
Ca	5.97	4.58
Cr	20.32	12.03
Mn	1.79	1.00
Fe	22.36	12.32
Ni	7.38	3.87
Zn	7.48	3.52
Totals	100.00	100

In EATONITE deposited exhaust valve seat area where no scaling, found that maximum percentage of Iron (Fe: 22.36 & chromium (Cr: 20.32). Whereas Fe is the part of EATONITE material which is iron base material. Cr, Mn, Ni, S, P is part of 21-4N material and presence of this material is showing some seat wear at the seat area. Ca, Zn and C deposited from burn oil and fuel during the test.

VII. CONCLUSION

After complete the experiment of both STELLITE and EATONITE valve, and results came out from test cycles output parameter and wear pattern study of both the valve we conclude that EATONITE can be the alternative for cobalt base STELLITE grade. We found same engine power during startup test of both STELLITE and EATONITE grade seat deposited valve. During performance test of EATONITE valve observed more torque and power than that of STELLITE valve. And 100 hrs. Endurance test, we observed more torque and power for EATONITE valve. Inlet valves observation is same for both the test. EATONITE exhaust valve found uniform ring at seat angle area, where as it not found in STELLITE exhaust valve. Stem wear was same for both the test. During chemical analysis we found calcium deposition on both the exhaust valve. From valve head parameter it has been conclude that thermal deposition was more for STELLITE grade valve. And EATONITE valve seat roundness was also better than that of STELLITE exhaust valve. Here we successfully complete the engine test with existing and modified hard faced valves. And finally conclude that EATONITE hard facing material can used instead of STELLITE material.

REFERENCES

[1] Eaton valve corporation database for EATONITE grade material selection

[2] www.STELLITE.com for Deloro STELLITE material composition.

[3] Durovalve company database for valve hard facing material.

[4] Bajaj auto pulsar manual for operating condition.

[5] R. Lewis and R S Dwyer –Joyce "Automotive engine valve recession.

Author's Profile

Ravindra N. janjal is currently working as Assistant Manager-R&D Department in VARROC group of company, Aurangabad, Maharashtra. VARROC is Global Provider of Automotive Parts. Author is also studding Master of engineering in Production from Govt. College of Engineering, Aurangabad, and Maharashtra.

Prof. S. A. Sonawane is currently working as Assistant Professor-Dept. of Mechanical Engineering, Govt. College of Engineering, Aurangabad, and Maharashtra. He is also a Joint Controller of Examination in same Organization. Author is pursuing PhD.