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Experimental Analysis of Valve and Valve Seats Wear in Gases (CNG) Fuelled Engine

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Abstract: *When CNG, LPG, and other gas fuels were used for combustion in vehicles' engines, a large degree of valve seat wear was observed and it was difficult to provide the same wear resistance as that of petrol (gasoline) & Diesel fuel engines. Therefore, valve seat wears in gas fuel engines need to examine. These parts related to the engine valve timing. Now the most of the company in engine manufacturing, found field related problem of valve and valve seat in gas engine. So most observed problem is valve and valve seat wear. In R&D department, durability is one of the ways to find the problem of valve and valve seat before the field related problem will face. In durability, the engine is test at approximately condition that of the vehicle, in engine test bed.*
So this paper gives material as per various parameters like Temperature. Mach inability, weld ability, Cost, availability is studied for valve & valve seat in gas fuel engine
Keywords: *Air fuel mixture, Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), valve, valve seat,*

I. Introduction

In recent years, the measure difficulty facing by automotive division is that, to maintain vehicle BSFC (Average), cost with lower harmful Exhaust gases & for an increase in the use of alternative fuels in view of atmospheric pollution. Compressed natural gas (CNG) & LPG (liquefied petroleum gas) are appropriate fuel in meeting these demands.

Comparing these two gases i.e. CNG & LPG, LPG (C3H8) is highly inflammable & it is heavier than air and on leakage will settle to ground and accumulate in low lying areas. Also the Releases CO2 which is a greenhouse gas but is cleaner when compared to gasoline. CNG (CH4) is lighter than air and hence disperses quickly in the event of spillage & Releases lesser greenhouse gas. Engine valve train mechanism is combination of Camshaft, Roller tappet, Push rod, Rocker arm, Valve & valve seat. This valve seat serves as seals for high-temperature, high-pressure exhaust gas & also does not adverse wear on valve, resulting in compression pressure loss. As conventional gasoline engine is liquid fuel engine, having high load still the wear resistance is low. So when it becomes gases fuel engine the failure of valve & valve seat is very high i.e. very low wear resistance. Also following figure indicates the overall view of valve train mechanism

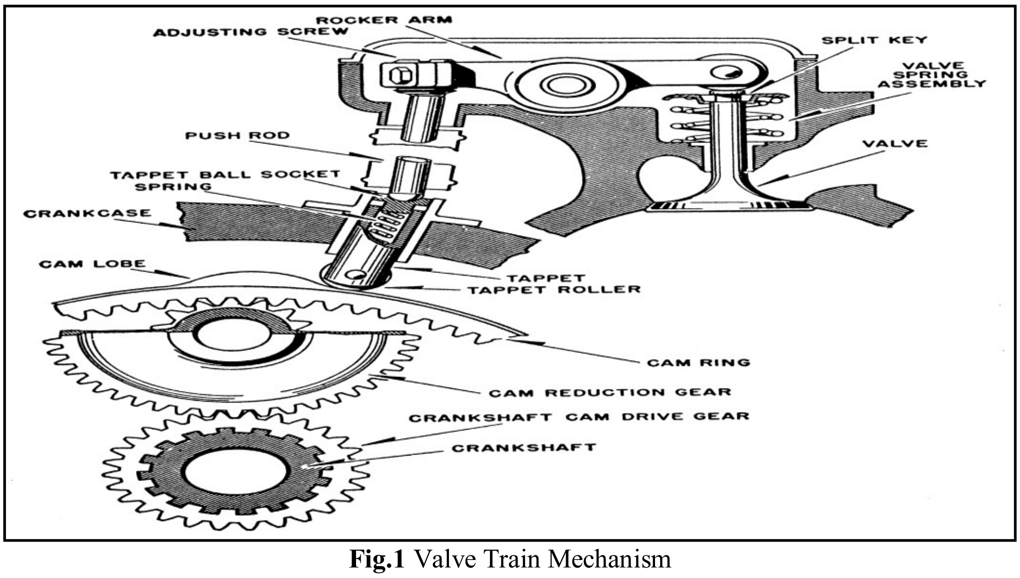


Fig.1 Valve Train Mechanism

II. Experimental setup

1. Introduction

1.1 Role Of Valve & Valve Seat Wear

There are two valves used in engine one is Inlet valve and other is exhaust valve. Basic valve consist of valve stem, head, seat, face, tip, spring keeper retention or groove as shown in figure.

1.1.1 INLET VALVE

Generally in high temperature and high load engine valve and valve seats wear occurs. This wear occurs due the high combustion pressure which gives high temperature causes the valve and valve seats operated in high temperature. This valve is used at suction stroke to suck the air/fuel mixture from inlet manifold.

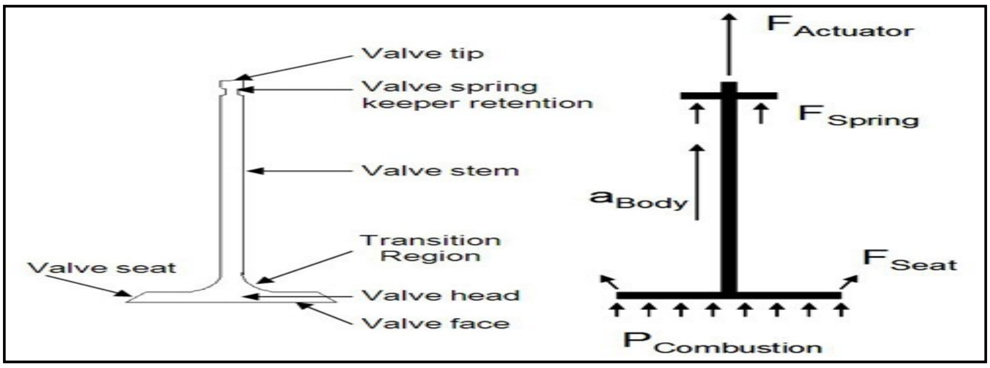


Figure 1.1.1: Valve details

Design of Inlet valve plays an important role in I.C. Engine. Volumetric efficiency, power, torque and BSFC depend on design of valve diameter and valve lift, whereas Design of Valve diameter and lift generally depends on engine size, combustion chamber design.etc. Generally the maximum valve lift is around 12% of engine cylinder bore. The inlet valve generally opens 10-20° before top dead center and closes 20-40° after bottom dead center. Generally Intake valve prefer to bigger than exhaust valve because of following reason.

During the suction stroke, the piston move down, and air fuel mixture enters inside the cylinder barrel with low speed. When piston moves up during the exhaust stroke, the exhaust gas leaves the cylinder barrel with high pressure. The speed with which the exhaust gas leaves the cylinder barrel is very high. Therefore the inlet valve is bigger than exhaust valve. Also other reason is there. Energy is neither created nor destroyed, only changes forms. X amount comes in intake valve. Once ignited, most of the energy is used to push the piston down. The leftover energy (exhaust gases) is expelled out the exhaust valve. Here not creating energy by igniting the mixture, only converting it to heat, basically. Since most of the energy was used in pushing the piston down, there is less that has to go out the exhaust valve compared to what came in. The sum of the energy used to push the piston down and the leftover that has to exit can never be more than the amount of energy that came in.

Due to high temperature in the region of valve and valve seats, the material lose its properties of hardness and continues valve open and close, cause the valve and valve seats wear. In case of gas engine, valve wear is more as compared to gasoline because in case of gasoline engine fluid entering through inlet valve helps to drop down the temperature of valves

1.1.2 Exhaust Valve:

This valve is used to remove the burnt gases from combustion chamber to the environment. Opening angle and closing angle of exhaust valve having important role viewed from the point of performance and fuel consumption. Due to this opening and closing of valves should be optimum in order to get maximum power with less fuel consumption. The exhaust valve generally opens 20-40° before bottom dead center and closes 10-20° after top dead center. Exhaust valve is generally smaller than inlet valve, the reason is explained in already in inlet valve details.

Valve lash of exhaust valve is always more than inlet valve, because exhaust valve temperature is always more than inlet valve so it need more lash to compensate the change in temperature.

1.2 Causes of Valve & Valve Seat Wear

As mentioned above, whenever a gasoline engine is carry forward to Gases engine, many failures may occur. This failure is in term of valve & valve seat wear, valve bend. All this failure is mainly related to valve train mechanism due to high combustion pressure without any lubricant. As in diesel or gasoline engine fuel itself acts as lubricant in combustion chamber. But in Gases fuel engine (CNG) no lubricant liquid as that of above. So the problem of valve & valve seat inserts is occurring. General the wear is mainly depends on the properties of valve & valve seat materials, exhaust temperature & angle between valve & valve seat. As that the material change in valve & valve seat is again cost increasing & desirable up to certain limit. Exhaust temperature can be control by ignition timing but emission as effect on this, so this is also hand bonded job. The most desirable way to come out of this is to having some modification in valve & valve seat & also for materials up to cost limit

III. Setup

Generally in any R&D section, Engine testing should be done by using no. of standard test. Some testing that required to validate the engine for launching in market. Durability test is used. (It is also used for other validation purpose)

1.1 Durability Test

Name itself indicated, this test is on Mix-cycle points. In Mix-cycle test, engine is run on different point, which related to vehicle condition. Before doing the test, initial & final measurement need to done for the comparison of wear. Engine Technical Specifications are given below in table.

Table no. 2.1 Engine specifications

Sr. No.	Parameter	
01	No. of cylinders	01
02	Engine Capacity, cc	592-630
03	Type of cooling	Water cooled
04	Fuel type	CNG
05	Power, hp	10-12 @ 3100-2900 rpm
06	Torque, N-m	32-37

2.2 Test Bed

The engine is tested on Eddy current dynamometer. A dynamometer is a device for measuring force, moment of force (torque), or power of engine. Figure itself shows eddy current dynamometer. Eddy current (EC) dynamometers are currently the most common absorbers used in modern chassis dyno.

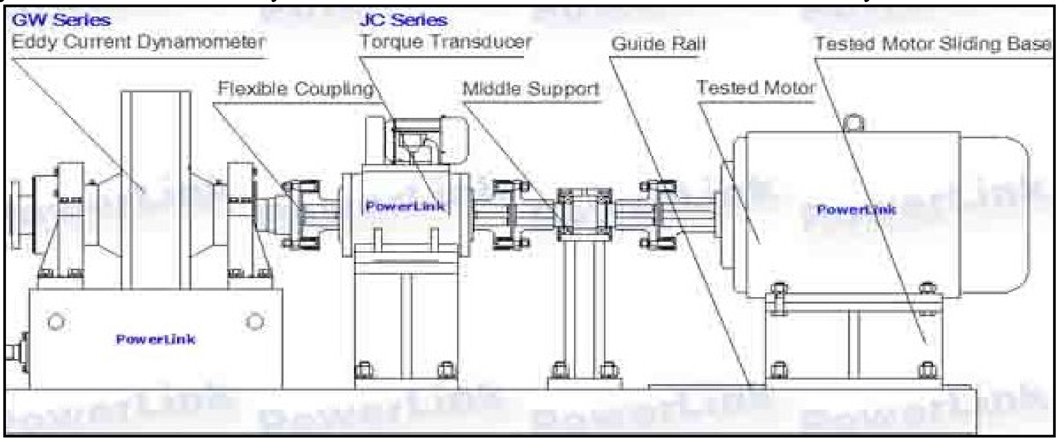


Fig. 2.2.1 Eddy Current Dynometer

The EC Absorbers provide a quick load change rate for rapid load settling. Most are air cooled, but some are designed to require external water cooling systems.

Eddy current dynamometers require an electrically conductive core, shaft, or disc moving across a magnetic field to produce resistance to movement. Iron is a common material, but copper, aluminum, and other conductive materials are also usable.

As shown in fig, to the left of this dyno, engine is connected to dyno by using propeller shaft. When engine reaches to some RPM with some torque, it is going to record by using Tachometer & Torque is recorded by load cell.

2.3 Properties Of Materials For Valve Seat Inserts

Table Number 2.3.1 PL33MV Properties

CHEMISTRY	PL 33MV (OLD ONE)
	C =1.8~2.3%
	Si=1.80~2.1%
	Mn = 0.6Max
	Cr = 33.0~35.0%
	Mo = 2.0~2.5%
	Ni = 0.50% Max
	P= 0.06% Max
	S = 0.04% Max
HARDNESS	37 - 43 HRC
PROPERTIES	Because of very high % of Cr Content oxidation sulphadisation will be minimal. The operating temp can go as high as 1200deg K
APPLICATION	CNG, LPG and HSD Medium to Heavy Duty

Table Number 2.3.2 Stellite 12 Properties

CHEMISTRY	STELLITE12(NEW MODIFIED)
	C =1.3%
	Si=1.0%
	Mn =1.3%
	Cr = 32.0%
	Co = 50.90%
	Ni = 2.0%
	W = 9.5 %
	Iron = 2.05%
HARDNESS	44 HRC (min)

As per properties of PL 33MV, it have higher percentage of Cr, so the Content oxidation sulphadisation will be minimal. The operating temp can go as high as 1200deg K. But it has lower hot hardness as compare to Stellite12. So the withstand properties at higher temp. is quite low. These properties can be increase by using Cobalt base materials.

2.4 Valve & Valve Seat Configuration

General in any engine valve & valve seat angle is 45°. In first test, the valve & valve seat angle is 45°. After getting the problem of valve & valve seat wear the angle change to 30°. Due to which the seat resting area is increased & the wear resistance is also increased. Following fig. shown the exact idea about the same.

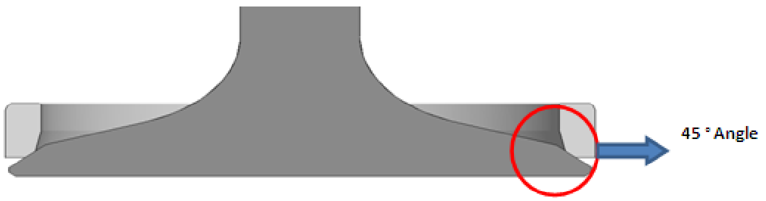


Fig. 2.4.1 Valve & Valve Seat Angle (45°)

As shown in fig. the valve and valve seat angle is 45°. When we compare this fig. with 30° valve & valve seat angle it clearly indicated that, the seat resting face for valve on valve seat is more in 30° angle. So that it can sustain more pressure i.e. load of combustion pressure. Due to increase in sustain load of combustion pressure, the wear resistance properties for valve and valve seat is increased.

In this fig. the angle is 30°, so the seat resting area is more as previously discussed.

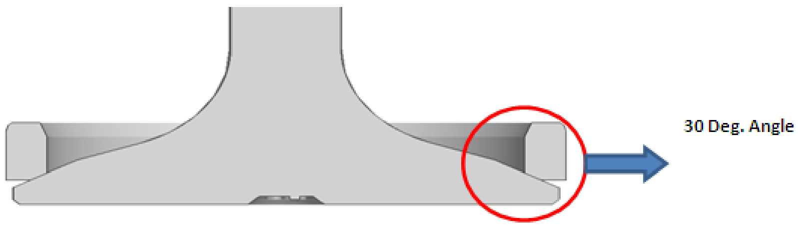


Figure 2.3 Valve & Valve Seat Angle (30°)

IV. Results & Experimental Graph

Here engine is build up with respective valve train component. After that, engine runs for 100 hrs for all four configurations on durability test. The initial & final reading for valve protrusion is taken.

Valve Protrusion
'It is defined as the distance of valve face from combustion chamber face."

As shown in graph, the % of valve & valve seat wear reduction is given. In inlet valve after the both test, wear reduce to ~90-95%. Also in exhaust valve & valve seat the wear reduce to 85-90%.

3.1 Comparison Is Given Below As Per Configurations

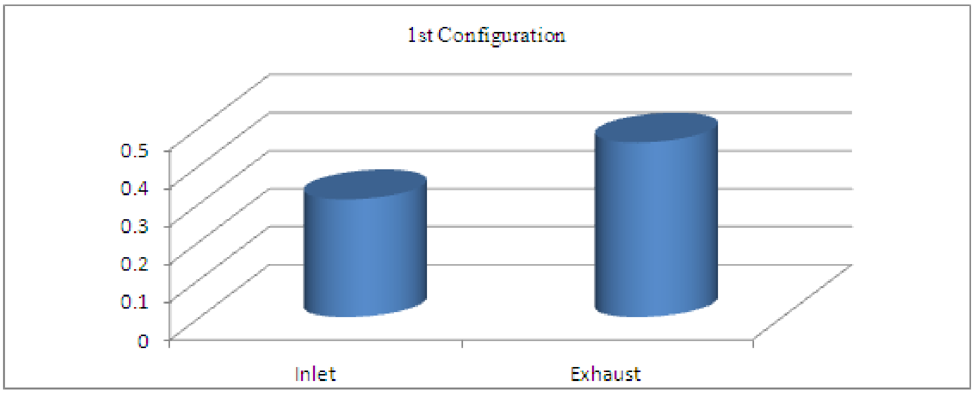
3.1.1: 1st Configuration

Valves (both intake & exhaust) – Bi-metal
Valve Seat Inserts (both intake & exhaust) - Pluco MV-33
Seat angle - 45 deg (for both intake & exhaust)

Table number 3.1.1: 1st Configuration

Durability test with 1st configuration			
Valve	Wear rate (mm) per 100 hrs.	Wear limit (mm) per 100 hrs.	Remark
Inlet	0.31	0.1	NOK
Exhaust	0.46	0.1	NOK

Fig. 3.1.1 Graph 1st configuration



3.1.2: 2nd Configuration

Valves (both intake & exhaust) – Bi-metal with Stellite-12 Coating on seat area
Valve Seat Inserts (both intake & exhaust) – Stellite-12
Seat angle - 45 deg (for both intake & exhaust)

Table number 3.1.2.1: 2nd Configuration

Durability test with 2nd configuration			
Valve	Wear rate (mm) per 100 hrs.	Wear limit (mm) per 100 hrs.	Remark
Inlet	0.05	0.1	OK
Exhaust	0.25	0.1	NOK

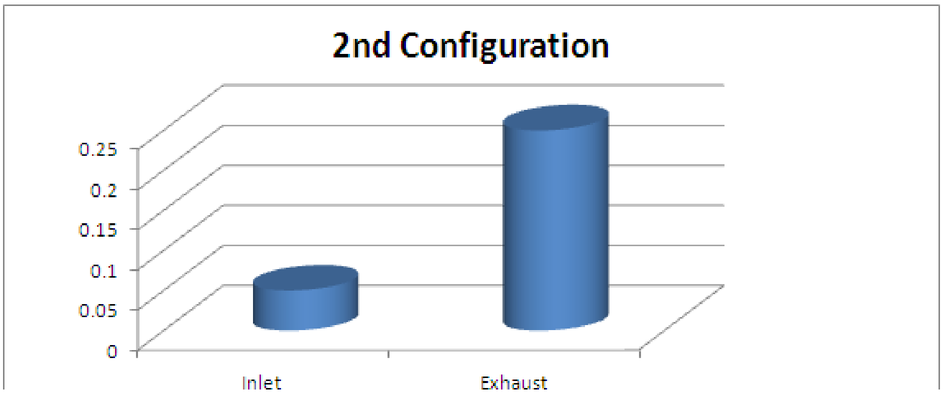


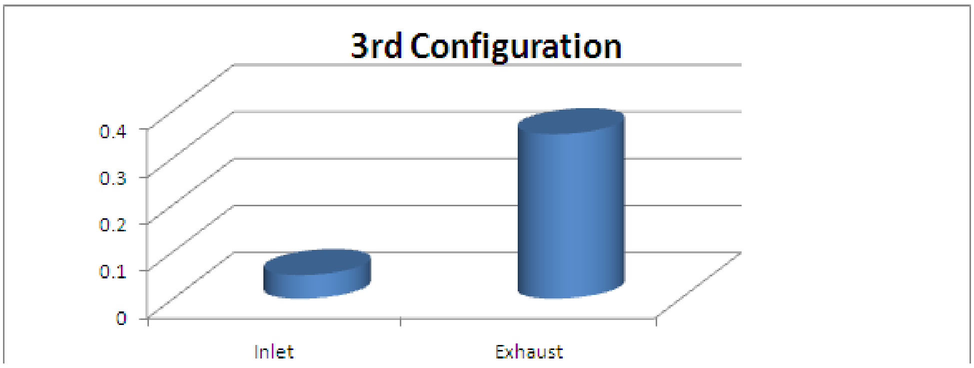
Fig. 3.1.2.1 Graph 2nd configuration.

3.1.3: 3rd Configuration
Valves (both intake & exhaust) – Bi-metal with Stellite-12 Coating on seat area
Valve Seat Inserts (both intake & exhaust) – Stellite-12
Seat angle - 45 deg (for both intake & exhaust)
Seat width increased from 1.2 mm to 2.2 mm

Table number 3.1.3.1: 1st Configuration

Durability test with 3rd configuration			
Valve	Wear rate (mm) per 100 hrs.	Wear limit (mm) per 100 hrs.	Remark
Inlet	0.05	0.1	OK
Exhaust	0.35	0.1	NOK

Fig. 3.1.3.1 Graph 3rd configuration



3.1.4: 4th Configuration
Valves (both Intake & exhaust) – Bi-metal with Stellite 12 coating on seat area.
Valve Seat Inserts (both Intake & exhaust) – Stellite 12
Angle-30 deg (for both Intake & exhaust)

Table number3.1.4.1: 4th Configuration

Durability test with 4th configuration			
Valve	Wear rate (mm) per 100 hrs.	Wear limit (mm) per 100 hrs.	Remark
Inlet	0.04	0.1	OK
Exhaust	0.035	0.1	OK

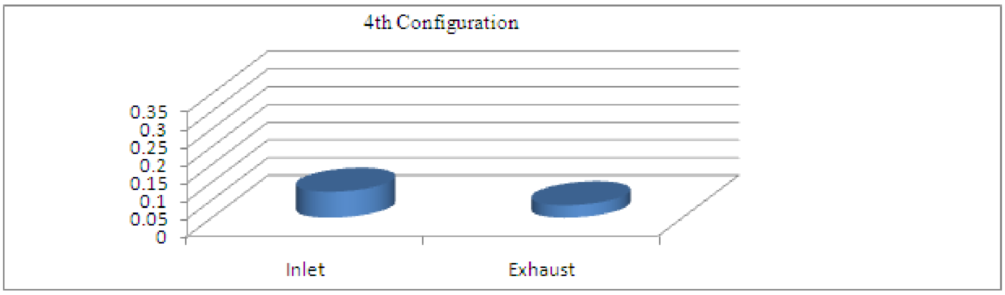


Figure 3.1.4.1 Graph 4th configuration

So from above we can conclude that, valve & valve seat wear can be reduced by using above combination
So finally, compare the first & final configuration with graph.

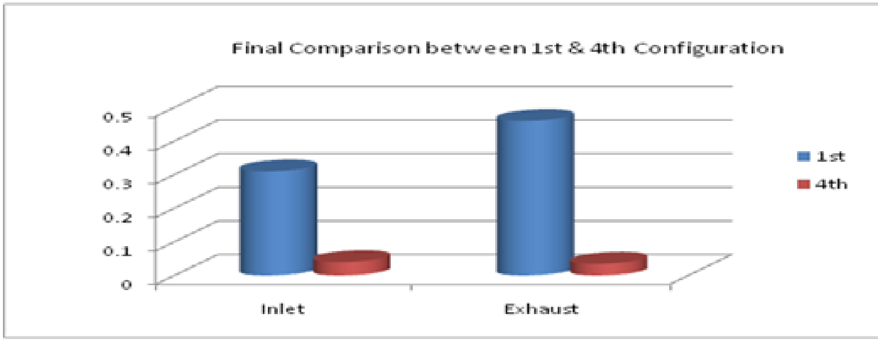


Fig.3.1.1.2 Graph comparison between 1st & 4th configuration

V. Conclusion

1. So, in CNG engines, the mechanism of wear that occurs due to gases.
2. This can be reduced by using proper material & valve & valve seat angle.
3. The material is as per the application & engine estimated cost.
4. The points in which the wear mechanism for CNG
5. Fuel differs from that for gasoline fuel are as follows;

- Combustion temp. is higher than that of gasoline engine due to latent heat of evaporation.
- Due to gas fuel, no gum particle no lubrication.

6. The features of the developed valve seat material are as follows;

- In order to secure wear resistance in the dry environment characteristic of gas fuels, selection of the material should be such that, which can withstand it hot hardness.
- In this, Iron base material is shifted to Cobalt base material.
- Cobalt base materials have high hot hardness.

7. Valve & valve seat angle changes from 45° to 30°, which can give better Side width, so that seat resting area for valve is increased.
8. 7. Due to which, it can sustain the combustion pressure more than that of 45°.
9. So, we suggest you to prefer the Stellite material for valve seat & Valves (both Intake & exhaust) – Bi-metal with Stellite 12 coating on seat area.

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