Enhancement of Air-Fuel Mixture in I.C Engine

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Abstract— The IC engine is an internal combustion engine consisting of 4 strokes – suction, compression, power and exhaust, each taking the crank revolution of 180˚. The work throws light on enhancing turbulent inside the combustion chamber by creating swirl and tumble in the inlet flow of charge. The geometry of valve face and valve head is modified to increase swirl inside the combustion chamber before power stroke takes place. The modification is done without disturbing the properties of conventional valves. The SOLID EDGE V19 software is used to design the member and assemble and ANSYS V15.0 Fluent is used to analyze the assembly. The software's are used to design and analyze the work since fabricating in real time and analyzing physically will lead to consumption of time, raw material and capital.

Key words: Engine Valve, Swirl, Tumble, Solid Edge, Ansys Fluent

I. INTRODUCTION

In an IC Engine at the beginning of suction stroke, the inlet valve of cylinder opens due to pressure difference. Air fuel mixture (in case of SI engine) or air (in case of CI Engine) is sucked into the cylinder through this intake valve from inlet manifold. Inlet manifold contains carburetor for mixing of air and fuel in case of SI Engines. Once the air or air fuel mixture is completely sucked into the cylinder whose piston has reached BDC, the inlet valve closes and compression stroke begins. As piston reaches TDC spark is ignited in the mixture (SI Engines require external sparking arrangement whereas in CI Engine auto ignition takes place on injection of fuel) this marks the beginning of power stroke. Once again as the piston reaches BDC and exhaust stroke begins. During exhaust stroke, the exhaust valve is opened and the burnt mixture is rejected to exhaust manifold. As exhaust stroke is completed, the suction stroke begins once again and cycle continues. The energy supplied to engine in form of chemical energy of fuel is converted into thermal energy.

The in-cylinder charge motion often plays a dominant role in processes of preparation and conveyance of fuel mixture in the engine[1].The in-cylinder flows of internal combustion engine have drawn much attention to automotive researchers and scientist in the present times. An optimal combustion process within an engine block is central to the performance of many motorized vehicles [2].The swirl flow has been proven to reduce particulate matter (PM) emissions from the engine and much research on swirl flow has been carried out for a long period of time [3]. The swirling flow set up in cylinder during intake can change significantly during compression [4].

Among the many design goals of combustion engine, the mixing process of fuel and oxygen occupies an important place. If a good mixture can be achieved, the resulting combustion is both clean and efficient, with all the fuel burned and minimal exhaust remaining. In turn, the mixing process strongly depends on the inflow of the fuel and air components into the combustion chamber or cylinder. If the inlet flow generates sufficient kinetic energy during this valve cycle, the resulting turbulence distributes fuel and air optimally in the combustion chamber. For common types of engines, near-optimal flow patterns are actually known and include, among others, so-called swirl and tumble motions.

The kinetic energy associated with this motion is used to generate turbulence for mixing of fresh oxygen with evaporated fuel. The more turbulence is generated, the better is the mixture of air and fuel, and thus the more stable the combustion itself. By stable we mean achieving the same conditions for each engine cycle. Ideally, enough turbulent mixing is generated such that 100% of the fuel is burned. The swirl or tumble motion should be maximized to maximize turbulence. From the point of view of the mechanical engineers designing the inlet and exhaust valve, the ideal flow pattern leads to beneficial conditions including: improved mixture preparation, a higher EGR (Exhaust Gas Ratio) which means a decrease in fuel consumption, and lower emissions. However, too much swirl (or tumble) can displace the flame used to ignite the fuel, cause irregular flame propagation, or result in less fuel combustion. As such, the balance must be achieved between generating enough swirl or tumble flow and not displacing the flame used to ignite the flow. A controlled flow motion is used to get stable and reproducible conditions at each engine cycle.

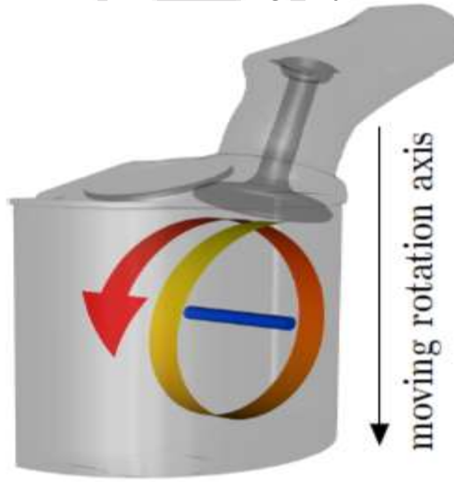

Fig. 1: Swirl Motion

The swirling motion of the flow in the combustion chamber of an engine is shown in Fig.1. Swirl is used to describe circulation about the cylinder axis. The intake ports at the top to provide the tangential component of the flow necessary for swirl.

Some engine components require a tumble motion flow pattern (right) in order to mix fluid with oxygen. Tumble flow circulates around an axis perpendicular to the cylinder axis, orthogonal to swirl flow.

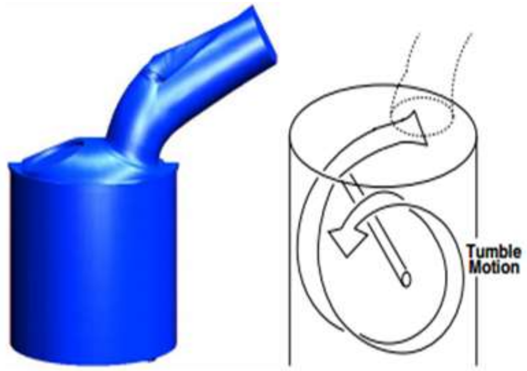

Fig. 2: Tumble motion

II. SWIRL AND TUMBLE COEFFICIENTS

Both swirl and tumble flows are commonly characterized by a dimensionless parameter employed to quantify rotational and angular motion inside the cylinder, which are known as swirl and tumble ratios, respectively. These values are calculated by the effective angular speed of in-cylinder air motion divided by the engine speed. The effective angular speed is the ratio of the angular momentum to the angular inertia of moment. The mass center of the charged in-cylinder air is considered as an origin for the calculation.

The three variables (swirl, sideways tumble, and normal tumble ratio) investigated in this paper are presented in the non-dimensional form by applying the equations as follows:

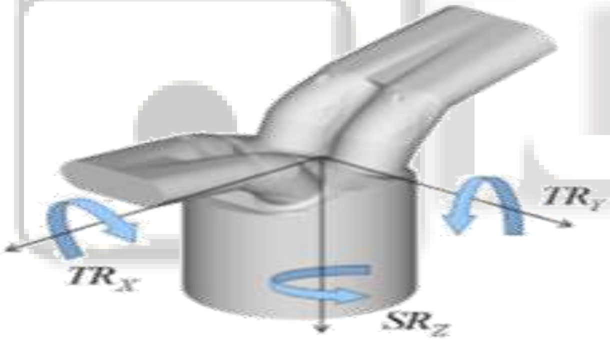

Fig. 3:

$$SR = \frac{60Hz}{2\pi Iz\ \omega}$$

$$TRx = \frac{60Hx}{2\pi Ix\ \omega}$$

$$TRy = \frac{60Hy}{2\pi Iy\ \omega}$$

Where, Hx, Hy and Hz are the angular momentum of the in-cylinder gas about the x-axis, y-axis and z-axis, respectively. Ix, Iy and Iz are the moment of inertia about the x axis, y axis and z axis, respectively. In addition, ω is the crankshaft rotation or engine speed in the unit of rotation/minute.

III. MODIFICATION OF VALVE

A. Type 1: Conventional Valve

The conventional poppet valves are used from long period of time. The changes in material had a great demand based on the application where the temperature is very high. The typical poppet valve terminologies are shown below. The conventional valves have been also focused to increase heat resistance and do its function efficiently without leakage.

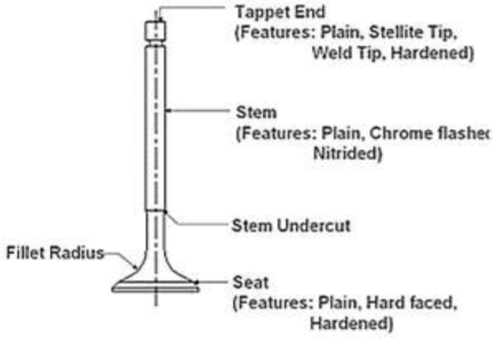

Fig. 3: Terminology of valve

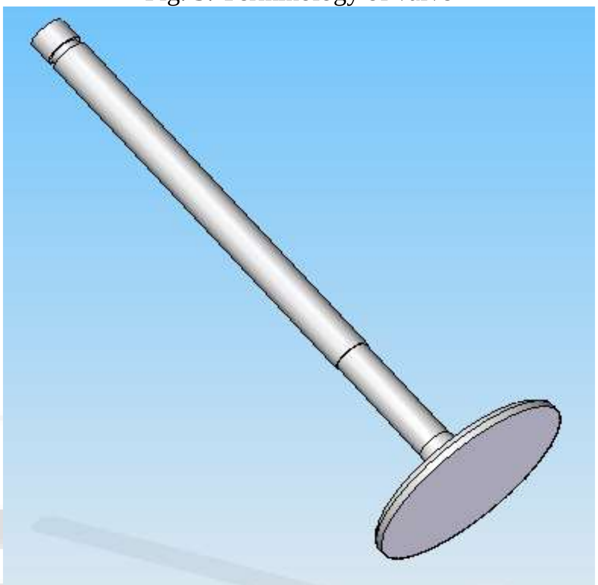
Fig. 4: Solid Edge image of conventional valve

1) *Motion of Charge Mixture*

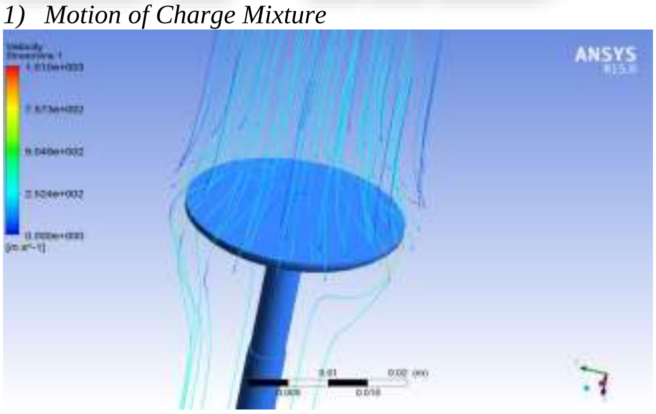

Fig. 5: The flow of charge on valve face during compression stroke

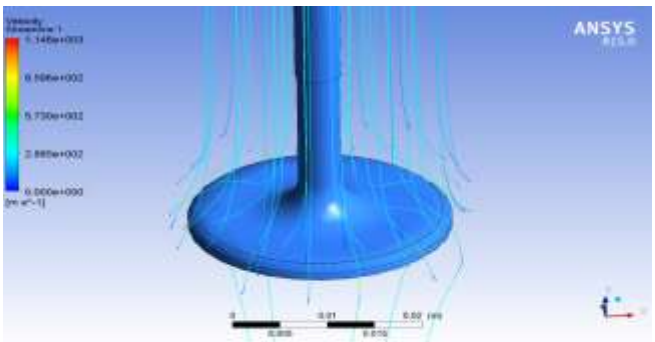

Fig. 6: The flow of charge entering during suction stroke

The motion charge entering the combustion chamber places an important role. The motion should be such that air and fuel should be thoroughly mixed to reduce the fuel consumption and increase efficiency. The typical conventional valves have very less to contribute towards generating turbulence. The analysis below assures that the conventional valve has very less swirl and tumble.

2) Analysis for Deformation And Stress

The conventional valve of titanium material is examined for diameter 28mm and length 81.18mm.The titanium material is selected as properties of it, which offer great heat resistance and deformation is less.

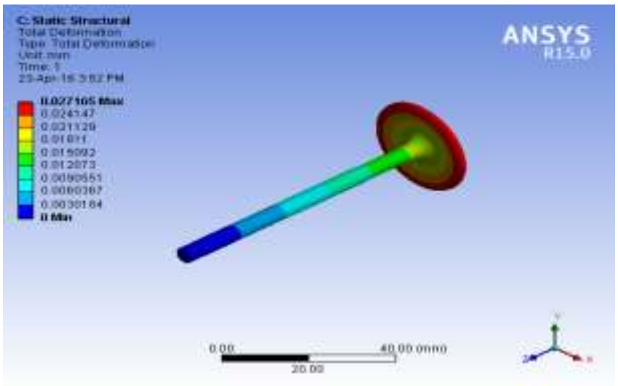

Fig. 7: Conventional valve deformation 0.027165mm

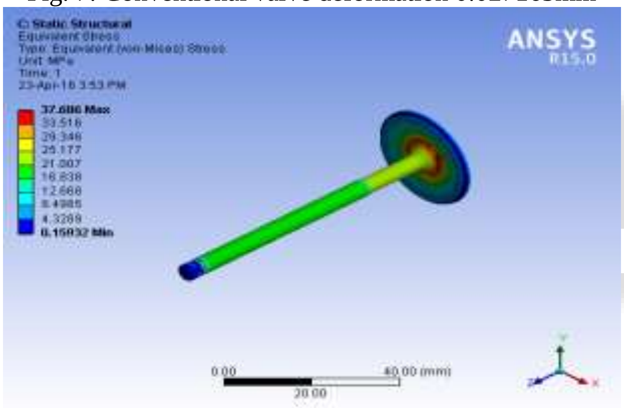

Fig. 8: The conventional valve stress is 37.686MPa

B. Type 2: Face Modification

The face of the valve is modified to 'W' shape to create swirl in the charge when the piston compresses the charge volume during compression stroke. This technique can be adopted in both the inlet and exhaust valve as both are close during the compression stroke. The charge should be mixed before combustion as to decrease fuel consumption to attain increased power.

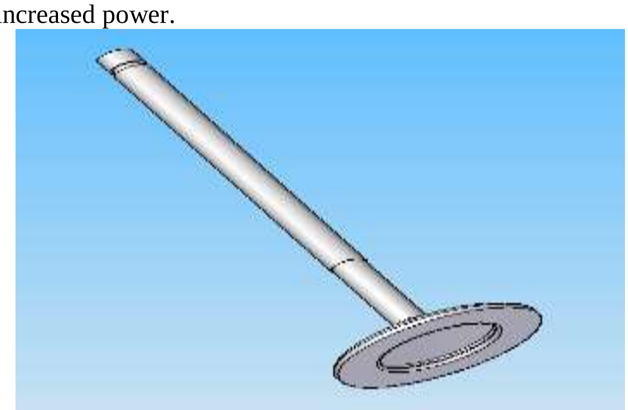

Fig. 9: Face modified valve

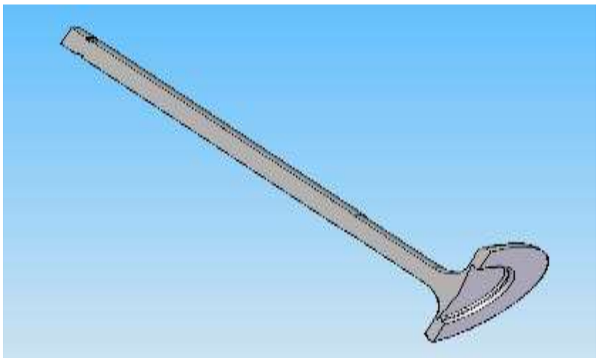

Fig. 10: Inner groves of face

1) Motion of Charge Mixture

The valve face is modified to create a swirl motion in the charge during compression stroke. The return path of charge particle taking a circular cycle initiating turbulence as shown in Fig 11. The return path of no charge particle is laminar, indicating the effect of introducing the 'W' shape in valve face.

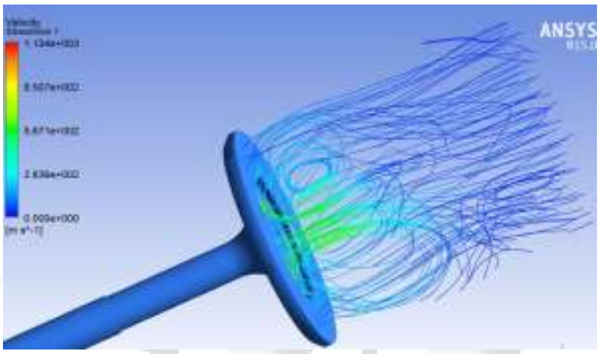

Fig. 11: Charge particle in swirl motion during compression stroke

2) Analysis for Deformation And Stress

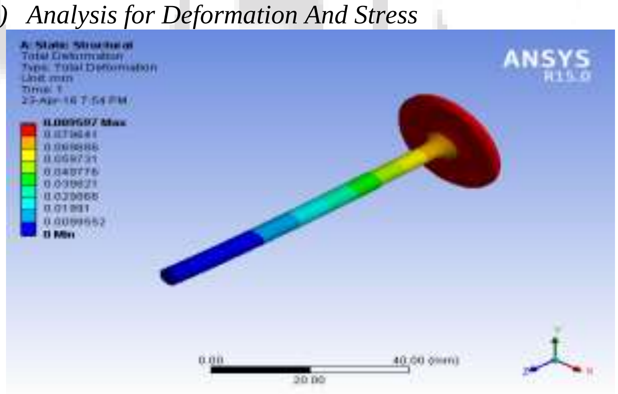

Fig. 12: Deformation (0.089597mm) of face modified valve in different position

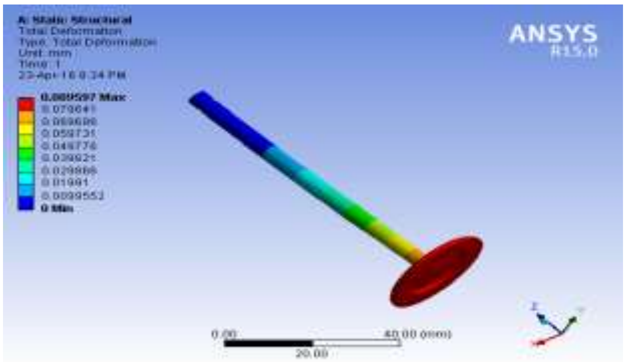

Fig. 13: Deformation (0.089597mm) of face modified valve in different position

The 'W' shape face valve is tested for deformation and stress. The deformation and stress change by negligible amount. The valve will exhibit same properties in case of deformation and stress without leading it to failure due to the modification.

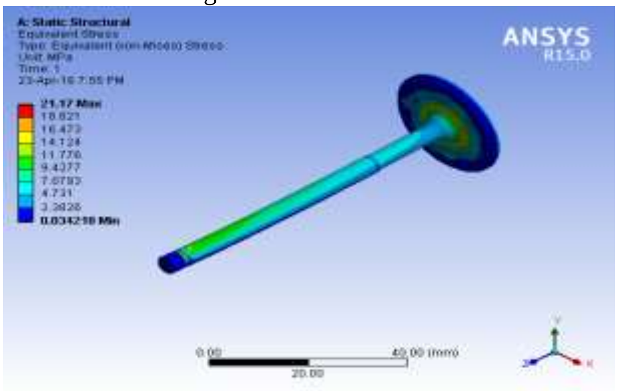

Fig. 14: Stress (21.17MPa) of face modified valve in different position

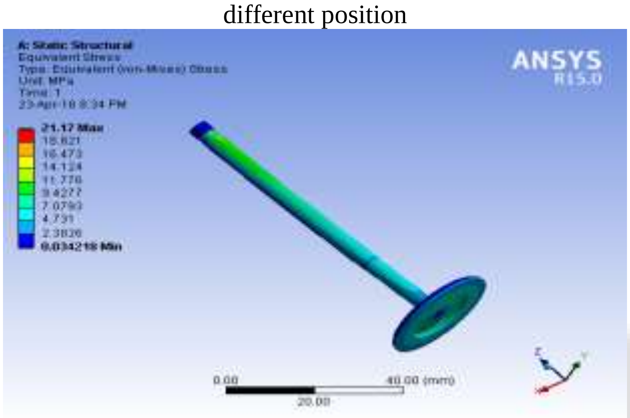

Fig. 15: Stress (21.17MPa) of face modified valve in different position

C. *Type 3: Valve Head Modification*

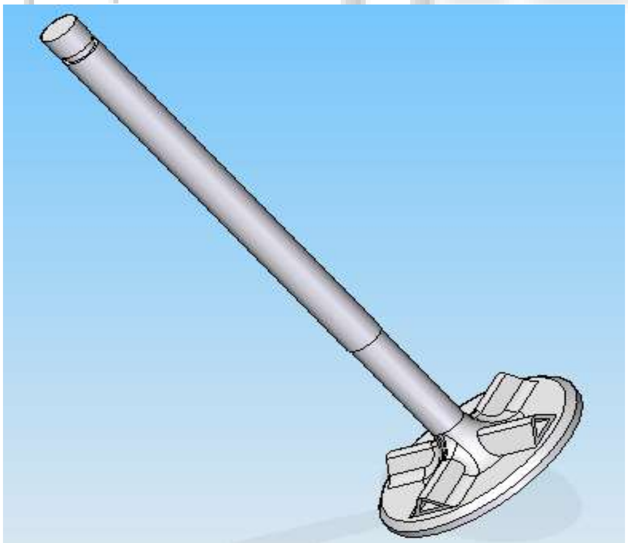

Fig. 16: Design of valve head modification

The valve head is redesign to increase turbulence in the charge entering the combustion chamber. This modification is done to the valve with modified face 'W' shape. This modification can be only in inlet valve. The hollow mountains are made on the valve head and chamfer is given at edges to attain directional flow.

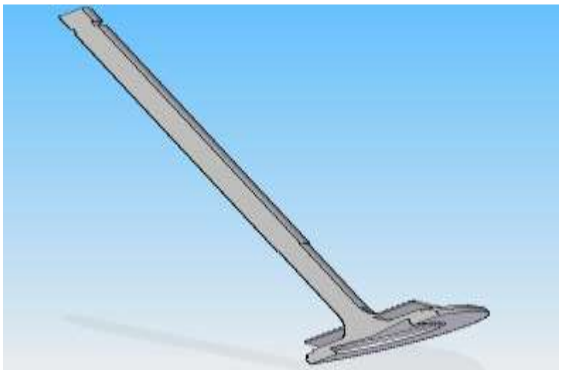

Fig. 17: Cut section of valve head modification

1) *Motion of Charge Mixture*

The figure below shows how the charge particle lines get disturbed when it reaches the valve head. The modification allows the generation of turbulence in the suction as well as in compression stroke. The modification increases masses by negligible amount but improve the mixing.

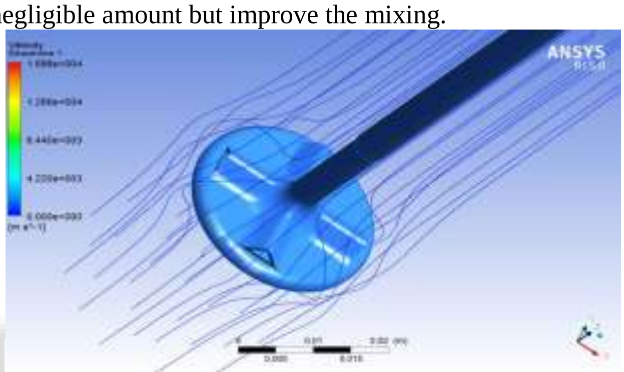

Fig. 18: The motion of charge flow around the valve in suction stroke

2) *Analysis for Deformation and Stress*

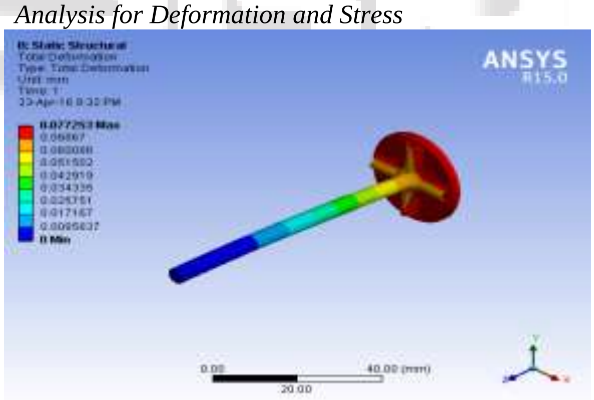

Fig. 18: Deformation (0.07725mm) of face modified valve in different position

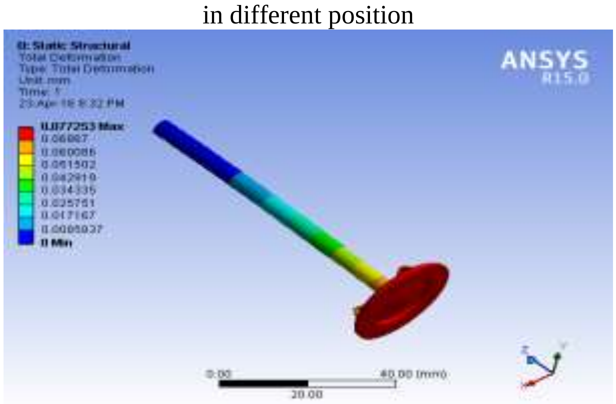

Fig. 19: Deformation (0.07725mm) of face modified valve in different position

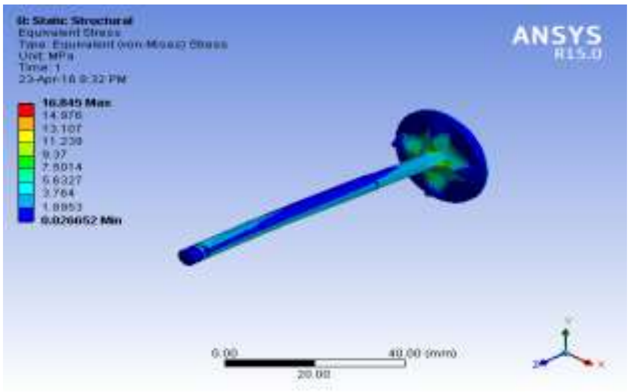

Fig. 20: Stress (16.845MPa) of face modified valve in different position

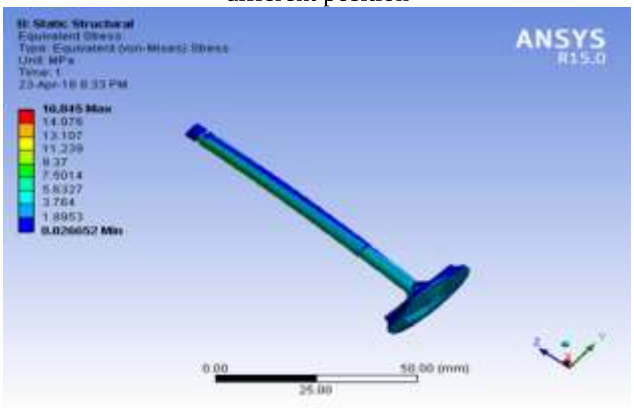

Fig. 21: Stress (16.845MPa) of face modified valve in different position

FACE	MASS
Plane face	1.2451e-002 kg
'W' inner grove on face	1.1169e-002 kg
Valve head+ grove on face	1.1966e-002 kg

Table 1: Mass comparison

FACE	Stress	Deformation
Plane face	37.686MPa	0.027165 mm
'W' inner grove on face	21.17MPa	0.089597 mm
Valve head+ grove on face	16.845MPa	0.077253 mm

Table 2: Stress and deformation comparison

IV. RESULTS & CONCLUSION

The main motto of modification is to increase air-fuel mixture inside the combustion chamber before spark plug ignites the mixture. The modified valves are compared with the conventional valve to check for deformation, stress and the motion of flow. The modification does not disturb the values of stress and deformation of a conventional valve but creates a drastic disturbance in the motion around the valve feeding the rich composition of air and fuel mixture to the engine. The table 1 and table 2 shows the mass, stress and deformation comparison and claims there is negligible change in the values.

- The face modified valve can be used as both inlet and outlet to as during compression stroke both the valves are close.
- The 'W' shape allows squish motion to take place when the charge enters the groove.
- The change face geometry does not affect the compression ratio.
- The valve with head and face modified can used as only inlet valve as it welcome the charge during suction stroke developing turbulence.
- The mass of head modified valve is comparatively same to the conventional valve.
- The analyses strongly suggest that face modified valve is best exhaust valve whereas the face and head modified valve are best inlet valves.
- The modified valves contribute to generate good turbulence and help to improve fuel efficiency by reducing fuel consumption.

REFERENCE

[1] Large Eddy Simulation of the Flow and Mixing Field in an Internal Combustion Engine, Dmitry Goryntsev, Darmstadt, October 2007

[2] C. Garth, R. S. Laramee, X. Tricoche, J. Schneider, and H. Hagen. Extraction and visualization of swirl and tumble motion from engine simulation data- available at http://www.vrvis.at/scivis/laramee/MotionExtracted/.J

[3] D. E. Winterbone; J. H. Horlock and Rowland S. Benson, "The thermodynamics and gas dynamics of internal-combustion engines", Oxford: Clarendon Press, 1982, ISBN 0-19-856210-1.

[4] 8. Heywood. John B., Internal Combustion Engine Fundamentals, New York: McGraw-Hill Book Company, 1988.

[5] Abhilash M Bharadwa "Study of Swirl and Tumble Motion using CFD" International Journal on Theoretical and Applied Research in Mechanical Engineering (IJTARME). ISSN : 2319 – 3182, Volume-2, Issue-1, 2013

[6] Pavan Chandra P V "Design and Analysis of the Effect of a Modified Valve with Helical Guideways on Combustion Performance of an I.C Engine" International Journal of Engineering Research and Applications. ISSN: 2248-9622, Vol. 5, Issue 8.

[7] Dr. Hiregoudar Yerrennagoudaru " Effect of air fuel swirl on four stroke single cylinder diesel engine performance" International Journal of Recent Development in Engineering and Technology. ISSN 2347-6435 (Online) Volume 2, Issue 6.

