Some thoughts on Turbulence Generation in a Tumble Head

1. Basics of the Turbulence Cascade Model

Turbulence is created when there is fluid motion. During fluid flow the viscous forces, frictional forces etc. creates small eddies in the moving fluid. These eddies uses some of the energy in the fluid so the fluid will slow down. These eddies breaks down into ever decreasing eddies until they are small enough to dissipate completely at a molecular size. The fluid motion will also eventually stop unless energy is added to maintain the flow.

This breakup or decay of the large eddies created by the bulk fluid flow into ever decreasing eddies until final dissipation of these eddies form the basis of the “Turbulence Cascade Model” used to explain the in-cylinder process of an internal combustion engine.

2. Basics of the Bulk Flow Model

The bulk flow inside the cylinder is caused by the flow in and out of the ports and the piston motion. There are two main types of flow:

a. Swirl – the bulk flow is mostly around the cylinder center line
b. Tumble – the bulk flow is primarily around an axis perpendicular to the cylinder center line.

The discussion here is focused on “Tumble” flow which is the predominant flow in 4 valve heads and two valve hemispheric heads where the inlet and exhaust ports are aligned. In a swirl engine it is easy to maintain the bulk flow to be able to cascade down to the required turbulent intensity at combustion initiation and duration. In a tumble engine it is quite a challenge to maintain the bulk flow to ensure enough turbulent intensity at combustion initiation and duration. If the bulk flow is not maintained and cascades through the turbulence dissipation process before ignition the combustion process becomes very slow and inefficient and required substantial spark advance to produce reasonable power.

3. Tumble Bulk Flow and Turbulence Generation and Dissipation

To generate strong tumble flow in an engine the first requirement is for the inlet port flow into the cylinder to be directed approximately parallel to the exhaust valve head and for the majority of the inlet flow to be over the top of the valve. This generates bulk flow that follows the exhaust valve head, flows down the cylinder on the exhaust valve side, flows over the piston crown in the inlet direction and then up the cylinder wall on the inlet valve side before joining the inlet flow again.

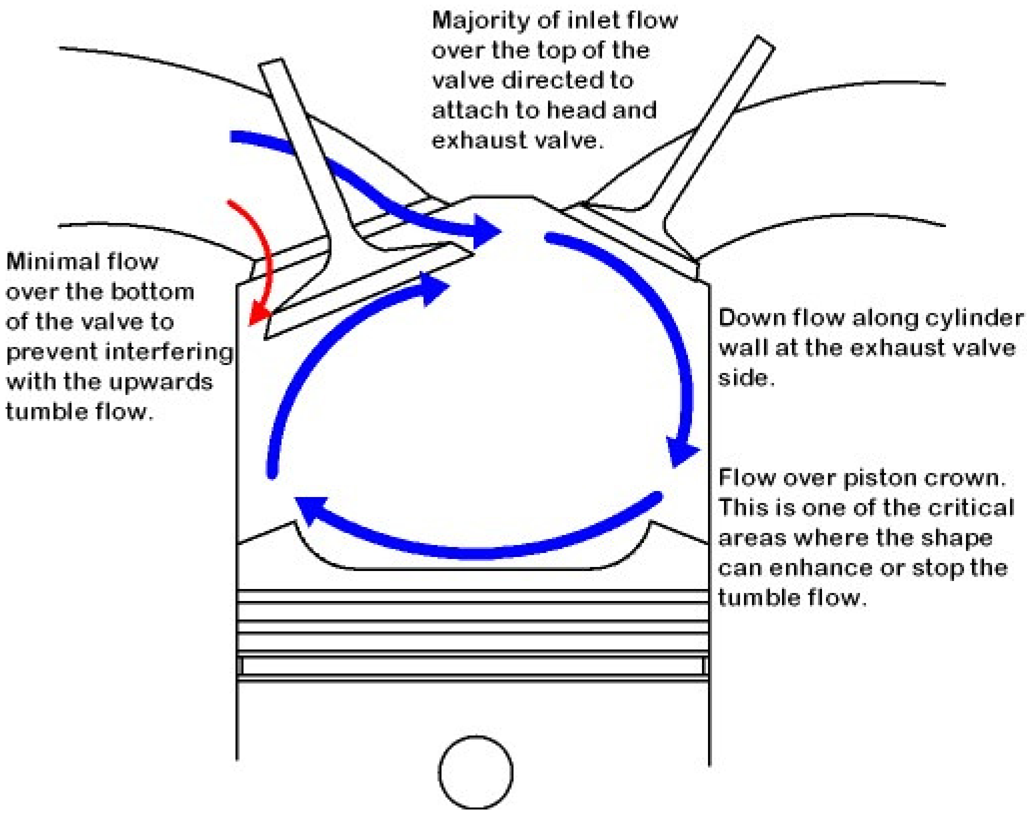

Figure 1: Piston at the bottom of the inlet stroke

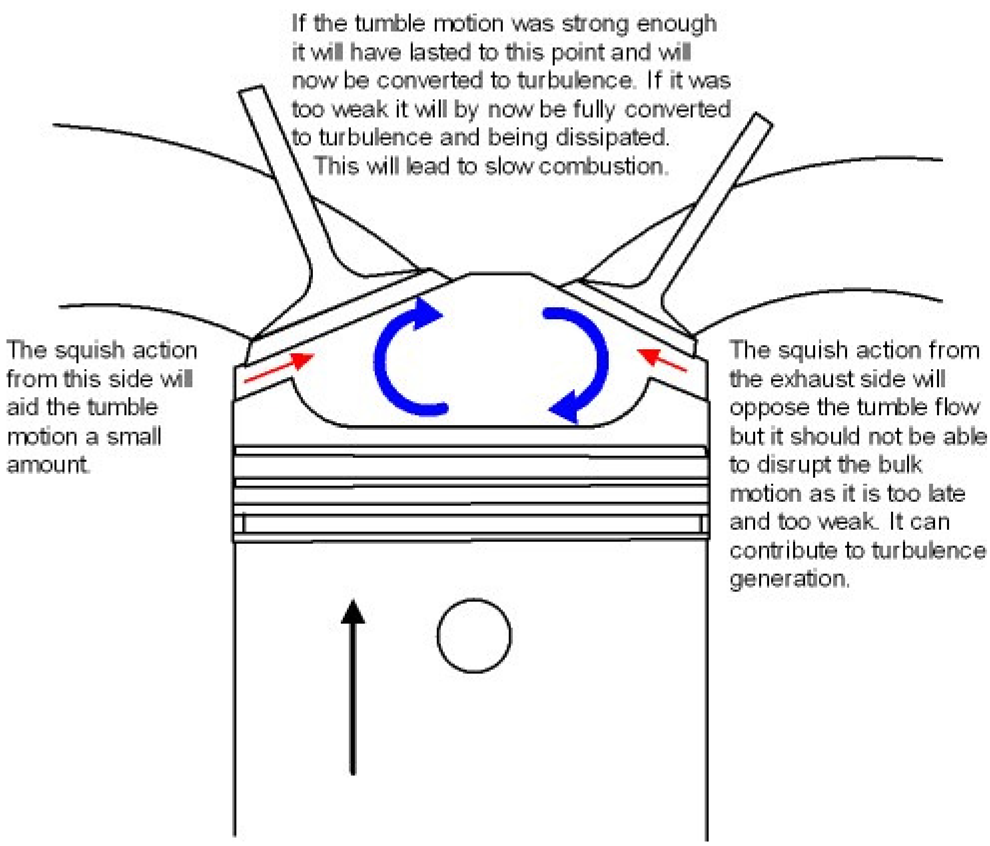

Figure 2: Piston at the point of ignition

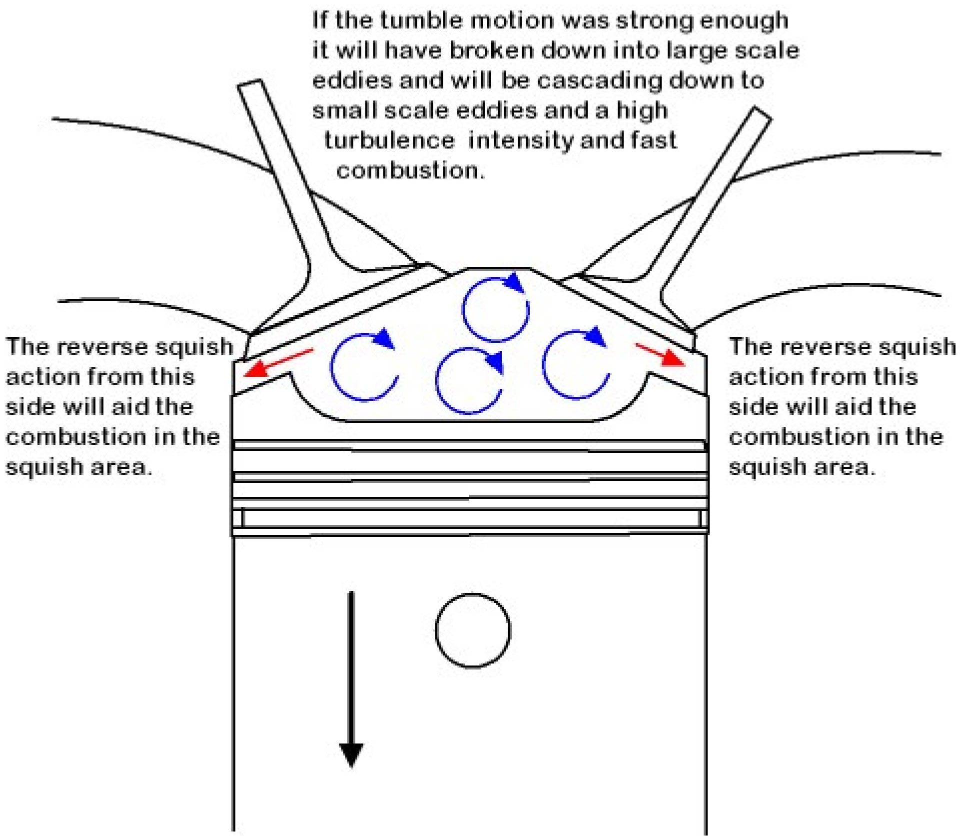

Figure 3: Piston just past TDC during the combustion phase

Some general comments:

a. Using an inlet valve with a smooth transition from the rear of the valve to the seat will promote the flow attachment to the valve and direct the flow more towards the middle of the cylinder which is unwanted. A sharp transition will cause the flow to break away and allow it a more favorable flow direction for tumble bulk flow generation.
b. Blending the inlet valve seat to the combustion chamber wall in the upper part will encourage the flow to attach to the chamber wall which is favorable for tumble flow.
c. It is a challenge to get a high compression ratio without interfering with the tumble flow on a two valve head. The trick is to trade a power loss from low compression for a bigger power gain from enhanced combustion efficiency, combustion rate and less ignition timing.
d. Getting a good squish pad on the inlet side will help in both enhancing the turbulent intensity and increasing compression and end gas quench.
e. An exhaust side squish pad should not interfere with the bulk flow as it is a small amount of flow around TDC.

Some comments on the Mitsubishi Paper:

a. It is difficult to determine from the angled squish results whether the improvement is from the better squish direction, the turbulence enhancement or the major improvement in tumble flow resulting from the better piston shape. Probably from all three but it looks as if the major result is the improvement in bulk tumble flow.

b. It would be interesting to see a full power comparison between the options with timing optimized for each.
c. The simulation that shows reverse squish is a motored simulation and does not include the effect of combustion. Puts a level of doubt on the validity.