A MULTI-CYLINDER 4 STROKE ENGINE SIMULATION SOFTWARE DEVELOPMENT.

G.M SERPILLI-D.DUCA-M.BILANCIA-M.NALDINI Soft-Engine R&D Ancona, Italy

Abstract

This paper introduces the last evolution of 4TBASE 4 stroke engine simulation software for multi-cylinders engine, offering the possibility of ample choice for ducts and cylinders geometry. Besides, special attention has been set on the definition of the flow coefficients, considering especially the formulations, to focus the aspects of the friction losses in the gap valve; moreover it is possible to input the flow coefficients as three-dimensional map with a friendly data input. Then, the software simulation has been validated using twin and four cylinders engine data; the bench data tests are also available for the discussion of the results.

The method of caracteristics

This is a monodimensional method about the study of wave fenomenouses. The hypotesis are:

1. unidirectional motion (that is the transversal dimensions are negligible as regards the longitudinal ones)
2. the fluid can be compressed
3. non-stationary motion
4. conduits at any variable geometry
5. the friction force is not negligible as for the flow
6. heat flow exchange with pipe walls
7. non isoentropic flow.

The last two hypotesis application allow the model very similar to reality, but the computings are more binding. So, in this article will be presented the complete theory, but the computing informatical code will not take the two last hypotesis into consideration.
The pressure waves trajectory is drawn by the diagram of positions.
We consider a perfect gas at p_0, T_0 reference status. We consider also this equation:

$$p v^k = \cos t.$$

that take some isoentropic transformation into consideraiton; later, we insert some necessary corrections.
These two equations settle slack pressure and temperatures depending on the thermo-dynamic and dynamic flow status:

$$p_R = p\left[1+\frac{k-1}{2}\left(\frac{u}{c}\right)^2\right]^{k/(k-1)} \qquad T_R = T\left[1+\frac{k-1}{2}\left(\frac{u}{c}\right)^2\right]$$

The Mach number is the following ratio: M=u/c.
When a limted-amplitude wave spreads through a gas into a pipe (constant diameter), the gas initially is at reference p_0-T_0 status, but immediately begin to move with this velocity:

$$u = \pm\frac{2c_0}{k-1}\left[\left(\frac{p}{p_0}\right)^{(k-1)/2k} - 1\right] \qquad (1)$$

the sign $\pm$ indicates that the wave can move both directions; c_0 is the not-noised sound velocity. So, different points of a wave have different velocities, this fact depends on the factor p/p_0 value
The wave spread velocity is:

$$w = u \pm c$$

the factor c is the actual gas status sound velocity and u is gas velocity. For c and c_0 factors we can say that:

$$c_0 = \sqrt{kRT_0} \;\; ; c = \sqrt{kRT} \;\; \Rightarrow c = c_0\left(\frac{p}{p_0}\right)^{(k-1)/2k} \qquad (2)$$

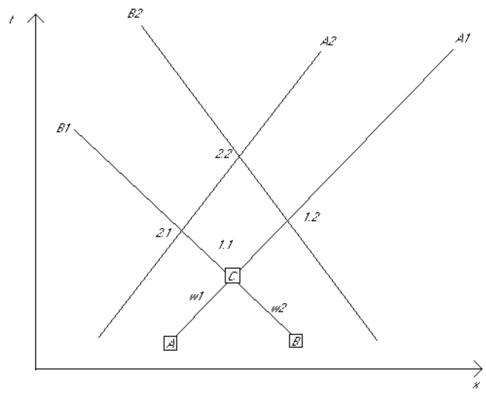

Fig. 1 *charcteristic diagrams*

Refering to the figure 2, we consider the A2 trajectory of an isoled wave point moving with w_{A2} velocity in a static gas. We can say that :

$$w_{A2} = u_{A2} + c_0 \quad \text{e} \quad u_{A2} = \frac{2c_0}{k-1}\left[\left(\frac{p_{A2}}{p_0}\right)^{(k-1)/2k} - 1\right]$$

If another wave starts to move in the contrary direction, following the B2 trajectory, the two particles meet in the 1.1 point. In the 1.1 point, the resulting velocity is the sum of both particles velocities, for these values of gas velocities. So, for the 1.1 point, the velocity is:

$$u = -\frac{2c_0}{k-1}\left[\left(\frac{p}{p_0}\right)^{(k-1)/2k} - 1\right] + u_{A2} \Rightarrow u + \frac{2c}{k-1} = u_{A2} + \frac{2c_0}{k-1}$$

so:

$$u \pm \frac{2c}{k-1} = \cos t. \qquad (3)$$

the sign is + for all the lines P in which w_+=u+c and the sign is – for all lines N in which w_-=u-c. If u<c we will have two family of curves, the w_+ ones, having a right inclination and the w_- ones, having a left inclination. If u and c are known in two different point of t, x diagram (for example A and B point, see 1), it is possible to find the conresponding values in the C intersection point. The two lines are:

$$w_1 = u_1 + c_1 \quad \text{e} \quad w_2 = u_2 - c_2$$

$$u_C + \frac{2c_C}{k-1} = u_A + \frac{2c_A}{k-1} \qquad u_C + \frac{2c_C}{k-1} = u_B + \frac{2c_B}{k-1}$$

from which:

$$u_C = \frac{u_A + u_B}{2} + \frac{c_A - c_B}{k-1} \; ; \; c_C = \frac{k-1}{4}(u_A - u_B) + \frac{c_A - c_B}{2}$$