REAL POSSIBILITIES OF CONSTRUCTION OF CI WANKEL ENGINE

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Abstract

In the paper deliberations on constructing the CI Wankel engine and some problems of using this kind of combustion system are presented. Many problems have been known for years but their solution seems to be available nowadays. Special meaning will probably have electronically controlled injection systems which fast evolution and common use in CI reciprocating engines could be seen during last few years. Also use of numerical methods with taking advantages of newest computers in designing process will be helpful. The CI Wankel engine with advantages of rotary engine and virtues of CI combustion system could become an attractive powertrain for passenger cars. This kind of construction could have a chance of finding its place in the market and increasing its popularity in this hard times for rotary engine.

Keywords: internal combustion engine, rotary engine, CI combustion system

1. Introduction

The first run of rotary combustion engine took place in 1957 in NSU research and development center. Author of the project and main constructor was German engineer Felix Wankel. The prototype was four-stroke SI gasoline engine. Information about successful tests of first rotary engine made producers of combustion engines interested in this kind of construction and it was predicted that the era of reciprocating engines is about to end. In that time reciprocating engines already were sophisticated constructions and their constructors had rich experience in range of constructional solutions and materials. This referred both types of engines, SI which were the most popular powertrain for passenger cars and CI which, owing to development of more perfect injection systems and turbocharging, have been founding more and more wider possibilities of their use. Research and development centers of many producers started intensive works on rotary engine and the main goal was to start as soon as possible serial production of the Wankel engine. It was obvious that conceptions of rotary engine and CI combustion system used together could be the turning point in designing of internal combustion engines. Quite early rotary engine revealed its main disadvantages such as high value of specific fuel consumption and low durability of trochoid surface and rotor sealing elements. During designing the CI Wankel engine the main problem was disadvantageous shape of the combustion chamber. For that and many other problems conception of the CI Wankel engine was discontinued without correctly working prototype. However the progress that proceeded during last decade in sphere of turbocharging and

electronic control of CI engines permits to put a question if it is possible to construct the CI Wankel engine which parameters like wattage rating, torque, emission of toxic exhaust gases would meet today's standards.

2. Problems connected with shape of combustion chamber and possibilities of their solution

As it was noticed in introduction the main problem for constructors was the shape of combustion chamber which in CI engines is essential for quality of fuel/air mixture and as a result course of combustion process. Combustion chamber has to ensure as good as possible mixing quality of drops with air mainly by swirling the fresh charge so the combustion air factor would guarantee the highest value of total efficiency. What is more it is desirable to shorten the self-ignition delay so the maximum values of pressure and temperature, which in CI engine occur during kinetic phase of combustion process, can be reduced. In Wankel engine there are not many ways of improving the shape of combustion chamber because of its basic geometry. Long shape of combustion chamber in rotary engine do not allow to fulfill earlier specified requirements connected with formation of fuel/air mixture in CI engine. This shape is also unfavourable because of the volume to field of surface ratio. The less is value of this ratio the higher are losses of heat to the cooling system so thermal and total efficiency get worse. This means that the value of specific fuel consumption of the Wankel engine is higher than for reciprocating engine of comparable power.

The only way of forming combustion chamber in Wankel engine is making recesses in rotor and this solution is also applied in the SI Wankel engines. Adding recesses can improves quality of the fuel/air mixture but unfortunately the value of volume to field of surface ratio remains poor. In SI engine this kind of treatment is possible because the maximum value of needed compression ratio is $\varepsilon = 11$ while in CI engine it is much higher what decides of its better total efficiency. Moreover the temperature after compression stroke in CI engine has to be high enough for self-ignition of the fuel. In the Wankel engine the maximum value of compression ratio depends on Z parameter which is defined as:

$$Z = \frac{R}{e}. \tag{1}$$

The e parameter specifies value of the journal eccentricity and the R parameter specifies the distance between rotor's centre of symmetry and its apex. The greater is the value of Z parameter the highest value of maximum compression ratio is available but in the same time the shape of combustion chamber gets worsen which becomes longer and thinner. This means that it is needed to make greater recesses in the rotor in order to optimize the combustion chamber shape. Value of Z parameter has its influence on apex seal angle of attack which is connected with maximum difference of the pressure in adjacent chambers. Higher value of Z parameter allows to increase the difference of pressures which is very important for CI engine. The combustion chamber shape without recesses for two Z parameter examples are shown on Fig. 1.

In 1972 the Rolls-Royce company built the CI Wankel engine with configuration of two rotors where first larger rotor was used to initial compress of the air and also to use energy from expanding exhaust gases for getting power. Combustion process where the exhaust gases and main part of the engine power were produced took place in smaller second rotor. Because of complicated construction and problems with course of combustion process this conception was not developing any longer [2].

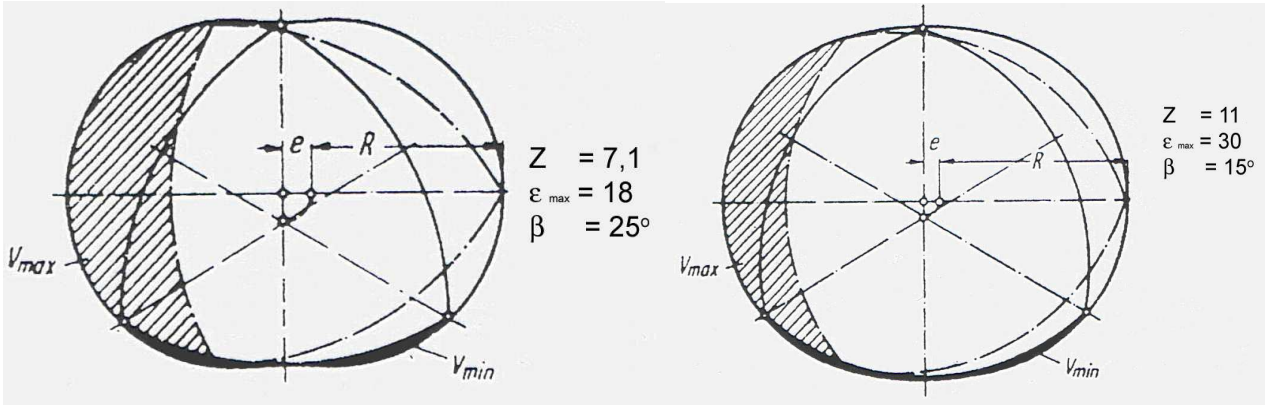

Fig. 1. The combustion chamber shape for two values of Z parameter [1]

Observing development of modern reciprocating CI engines a tendency of decreasing geometrical compression ratio can be noticed. This allows to increase the supercharching pressure. The use of modern turbocharger with variable geometry of turbine guide vanes in CI engine gathers great meaning because besides of obvious increasing output power it betters conditions of combustion process and increase total efficiency of the engine. The turbocharger increases the pressure at the beginning and at the end of the compression stroke, what in spite of lower compression ratio makes the temperature of the fresh charge, where the fuel is being injected, higher. The higher temperature accelerates the self-ignition process what allows to attain greater engine speed.

Summing up, it seems that with use of high pressure turbocharging it is possible to obtain suitable thermodynamic parameters in Wankel engine combustion chamber for fuel self ignition with maintaining the correctability of combustion chamber shape.

3. Modern injection systems of CI engines in aspect of the Wankel engine

During last decade a tendency of increasing CI engines share in automotive market could be observed. Two deciding factors were application of high pressure electronically controlled injection systems and development of turbochargers construction. Advantages of new technologies have led to considerable improvement of engine parameters with simultaneous reduction of toxic gases emission and bettering so called culture of work.

In field of injection systems two competitive systems have appeared: common-rail system and injection unit system which have been promoting by Volkswagen company because of its higher injection pressure. However features of common-rail system like easiness of controlling fuel injection course and cost of production have decided that most CI engines from the smallest one for passenger cars to the biggest marine are supplied with this type of injection system. Also in the CI Wankel engine common-rail system seems to be the most suitable. The latest generation of common-rail system is characterized with maximum injection pressure of 1800 bar and application of piezoelectric injectors which allow to divide fuel dosage on five parts. This allows to precise control of combustion process course in CI engine. Partition of fuel dosage, especially usability of extremely small and precisely measured pilotage dose, could be very useful in the CI Wankel engine. Because in Wankel engine combustion chamber rotates with the rotor it is necessary to choose number and moment of injection particular doses so the optimum form of fuel/air mixture is provided. Proper fuel atomization is obtained by high pressure of injection. The goal of using pilotage dose is to prepare and better conditions in combustion chamber before the main dose is injected. Apart from recesses shape in the rotor the combustion chamber of the Wankel engine will

always have oblong shape so it is possible that usage of two fuel injectors for injection to different combustion chamber areas will be necessary. With today's processor capacity it is not a problem to determine in real time moment and duration of injection for particular dose in both injectors. Parameters of injection have to be optimized dependent on combustion chamber shape, engine speed, engine load and other parameters that have their influence on combustion process course. If the optimization process is done properly it should be possible to obtain required CI engine cycle parameters. These are theoretically brief foredesign which firstly should be put on many simulation tests and next confirmed on test bed. Special attention should be focused on combustion chamber and swirl optimization because it is very important for injection system design process.

4.Rotor sealing

The rotor of the Wankel engine is sealed in two ways. First is side seal which makes the fresh charge and exhaust gases impossible to move between adjacent chambers. It also prevents the lubricating oil flowing from rotor bearing to combustion chamber. Second type of seal, which always has been much more problematic for constructors, is the apex seal.

All functions of piston packing of reciprocating engine in the Wankel engine have to be fulfilled by only one apex seal on each rotor vertex. It is not possible to separate functions of tightening and oil film thickness controlling. In everyday use, when the engine is running often in cold stage, the apex seal is the weakest element and in short time lead to worsen parameters of the engine and next to destruction rotor housing trochoid surface.

In the CI Wankel engine another problem is greater difference of pressures in adjacent chambers, because when in one chamber intake stroke is about to end in the adjacent chamber power stroke begins and the combustion pressure reach its maximum value. For CI engine with direct injection maximum pressure exceeds 10 MPa while for SI engine it is usually of 6 MPa. Greater pressure difference puts higher requirements for apex seal which has to ensure proper separation of chambers and not generate high friction looses in oil film. The worst situation is when the oil film is ruptured because of the forces that push the apex seal to the rotor housing. This means that apex seal is in direct touch with the trochoid surface what leads to early wear of rotor housing and sealing elements. For this reason oil film parameters course during full engine cycle should be subject of precise studies. Designing reliable sealing system, appropriate combustion chamber and injection system are the main problems that need to be solved during designing the CI Wankel engine.

5. The newest CI Wankel engine achievements

Wankel Super Tec GmbH company has started their researches on designing the CI Wankel engine. Brief foredesign are similar to this one that authors of the paper have mentioned. The injection system will be based on common-rail system with partition of fuel dosage. Self-ignition assist device is also planed to be used but no specific information about this device were published. Cross-section design of CI Wankel engine with visible position of injector is shown on Fig. 2.

Two other examples of different combustion chambers and injectors positions, which were also studied and tested by mentioned company, are presented on Fig. 3. It is worth to pay attention on draft on the right where very complicated injection system with more than two injectors is visible.

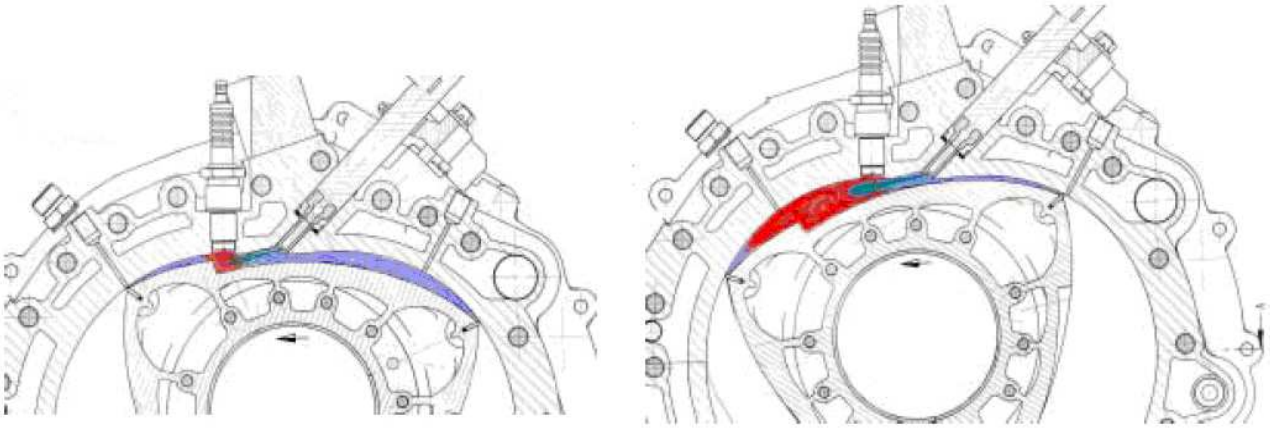

Fig. 2. Cross-section of the CI Wankel engine designed by Wankel Super Tec GmbH [3]

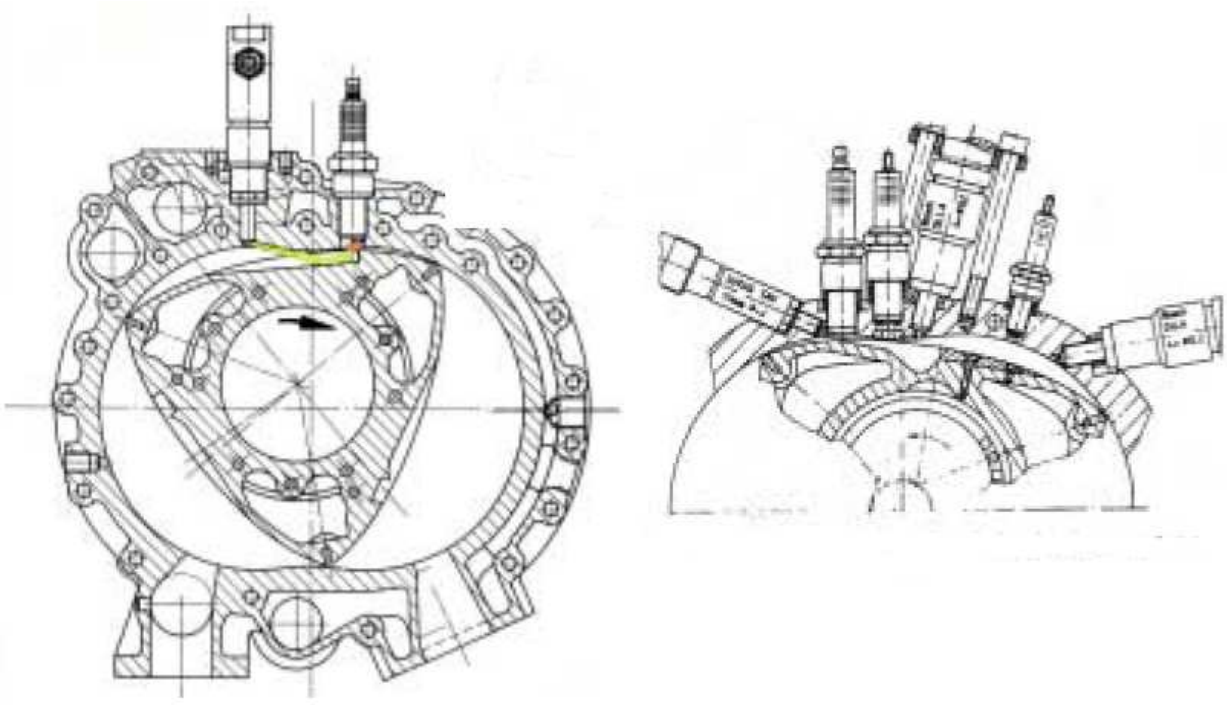

Fig. 3. Different possibilities of combustion chamber shape and injectors position tested by Wankel Super Tec GmbH [3]

Wankel Super Tec GmbH company had announced start of mass production the CI Wankel engine in 2006 but although it is 2007 now no information were published. It is more than certain that during design process much more problems occurred than it was first expected.

6. Conclusions

Both the Wankel engine and CI engine characterize with many advantages, and theirs connection could be a chance to create new alternative for passenger cars powertrain. Many problems are very interesting science challenge and their solving can be much improvement in understanding of many phenomena which are connected with combustion and lubrication processes in internal combustion engine both reciprocating and rotary. Great example is injection system which thanks to evolution in reciprocating engines can find their application in rotary

engine. It is probable that evolution of rotary engine will bring achievements that could be used in reciprocating engines. Scientific success could be an impulse to intensify researches by commercial companies which goal is to get a profit. If science centers and of automotive industry would join their efforts vision of properly working CI Wankel engine and its application as a passenger car powertrain could be very realistic.

References

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[3] Wankel Super Tec GmbH press materials