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DEVICE FOR GENERATING EPICYCLOID PROFILE AT WANKEL ENGINE

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Abstract: *The paper presents a solution for a cutting device which generates epicycloids curves used at internal surfaces. The device it has a gear mechanism which develops the epicycliod trajectory, and a jig used to position the work piece related to the cutting edge. The whole assembly can be attached at a milling or a boring machine to generate the surface used at housing for Wankel engines.*
Key words: *epicycloid curve, Wankel housing*

1. INTRODUCTION

In the past years, due to progress in computer engine management and materials manufacturing, the Wankel engine is more often choosen to fit at the last car models. One of the major impediments at this type of engine still remains the manufacturing of the inside housing profile, which drives the tip of the rotary triangular piston. From mathematical point of view, this profile is a particular case of the epicycloid curve, problems which are presented by (Keating, E., L., 2007) and also by (Monickavasagom Pillai, K., et al. 2008). The major difficulty is the impossibility to generate such a profile on a universal machine tool, so it is necessary a special device that can drive the cutting tool along the epicycloid trajectory.

Related to the aspects of manufacturing the Wankel profile, in literature there are not so many solutions with complete description and parameter correlation between theoretical equations and cinematic of machine tools. A general overview is presented by (Rosculet, S., V. et al. 1983), but the details and calculations are not exposed. In figure 1 we can see a housing from a Wankel engine, having the following constructive parameters (see also figure 3):

- `e` - eccentricity: 15 mm
- `r` - rotor radius: 102 mm

These parameters will be very important later (as we can see in figure 4), to proper adjust the cutting device.

The holes for spark plugs and exhaust manifolds (see figure bellow), which goes through the combustion chamber, should be executed after the epicycloid profile. The admission holes are executed in this case in the side plates, which are not represented here.

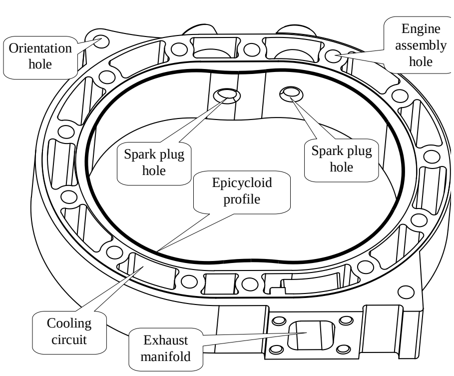

Fig. 1.Wankel housing with epicycloid inside profile

2. MATHEMATICAL BACKGROUND

The epicycloid curve is generated by a fixed point P, related to a circle, which is rolling slidingless outside of another fixed circle, as in figure 2.a.

The parametric equations of this curve, as we can see in equation (1), are widely presented in literature, such us (Bachmann, K.H., et al., 1980).

$$x = (R + r) \cdot \cos\varphi - a \cdot \cos\left(\frac{R + r}{r} \cdot \varphi\right)$$
$$x = (R + r) \cdot \sin\varphi - a \cdot \sin\left(\frac{R + r}{r} \cdot \varphi\right) \quad (1)$$

where: r - radius of mobile circle, R - radius of fixed circle, φ - angle described by P point, a - distance from the centre of circle to the P point.

In all the particular cases of epicycloids from figure 2.b, 2.c, 2.d, the ratio R/r is 2, so all the curves have 2 leaves. The other different shapes of epicycloids are generated for different values of the ratio a/r, related to 1. From the bellow situations, in Wankel engine is used the shape from 2.d, where a practical value for the ratio a/r is around 0.5, resulting so an epicycloid with a good tangent continuity. This ratio has a great influence on the compression ratio of the engine, and is determined from combustion evaluation as presented in (Keating, E., L., 2007).

As we can see from the figure 2.d, such a generation process for epicycloids can be used only in graphical applications, not in manufacturing process. The problem is the tool (associated to the "a" segment), which is switching the position relative to the curve: in some areas is situated inside the profile, but in some other areas is outside the profile, so it collides with the housing of Wankel engine during manufacturing.

In figure 3 is presented a Wankel rotor related to the theoretical epicycloid.

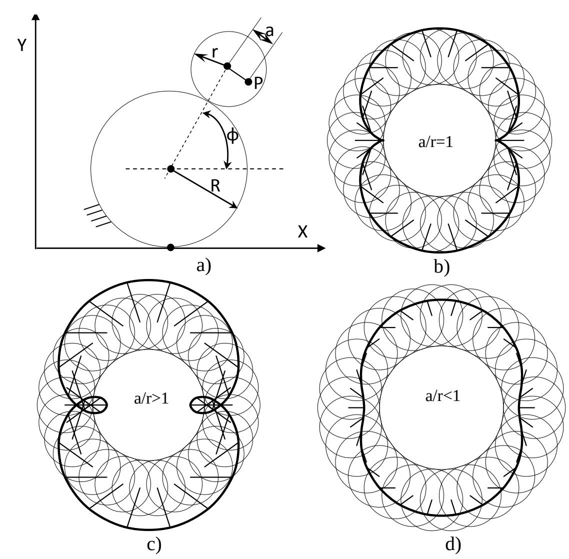

Fig. 2.Epicycloid parameters and different particular cases

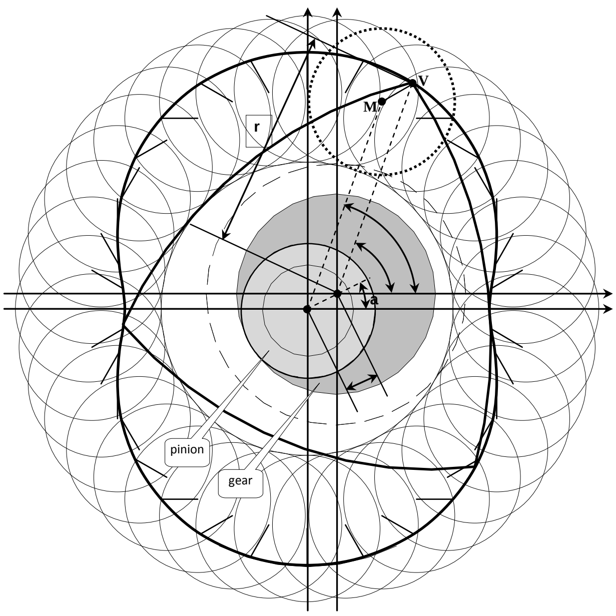

Fig. 3. Wankel parameters

In Wankel engine, the complex movement of the rotor is realised by the combination of internal gears with the eccentric shaft as it can be observed above in figure 3, where the inside pinion is fix, and the gear is rotating with the triangular rotor.

From the figure 3, for point V, we can have the expressions:

$$x_V = \varepsilon \cdot \cos\alpha + \rho \cdot \cos\beta$$
$$y_V = \varepsilon \cdot \sin\alpha + \rho \cdot \sin\beta \quad (2)$$

To obtain the correct movement is mandatory that b=3a, and R=2r. Imposing the conditions that both coordinates from relations (1) and (2) are equal, we can derive a relation between constructive and mathematical parameters of engine.

3. DEVICE SOLUTION

The proposed solution is a device which replicates the movement from the engine, having 2 major subassemblies: cinematic (which generates the curve), presented in figure 4, and a jig subassembly, (which fixes the housing related to the tools), presented in figure 5.

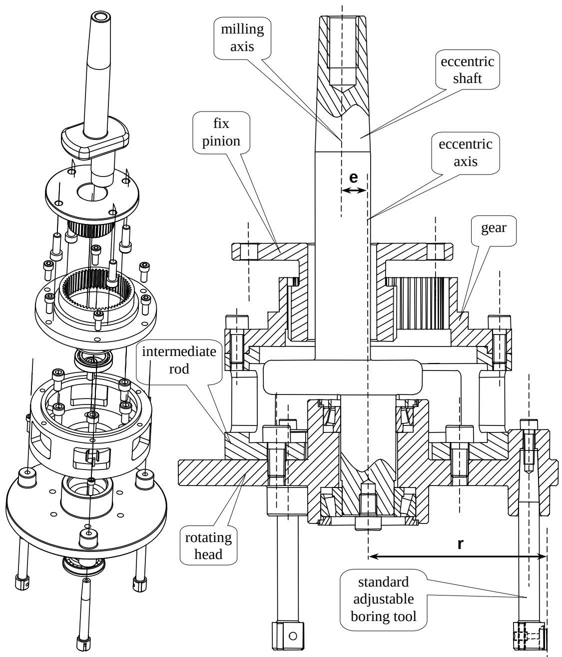

Fig. 4.Cinematic subassembly

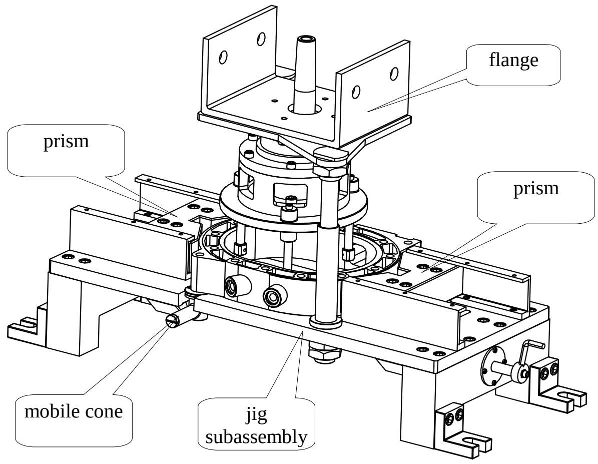

Fig. 5. Device assembly

The pinion is grounded, and is connected to the FUS32 milling machine, through a flange, as in figure 5. The rotating head executes the same movement as the rotor in Wankel engine: a rotation around milling axis, and a rotation around eccentric axis with a ratio 1:3, imposed by the gear train. The whole subassembly is suspended, attached to the eccentric shaft. The last one is introduced in the power head of the milling machine, and receives rotation movement through an ISO cone, which also locks the cinematic subassembly. To ensure the correct distance between axes at the gear train, the pinion position can be adjusted with a special pin, inserted in the milling head. For lower revolution, as in (Dumitru, N. 2008), the gear train can operate open, with periodic greasing.

According to (Cernăianu, A. 2002), the device can generate the surface using the vertical feed of the table. In this case the jig subassembly is locked on the table and moves up toghether.

For a better guidance, on the jig there are fitted two columns, which drives the corresponding pins from the flange. The jig ensures the position of the work piece, with a self-centred mechanism with prisms, and with a mobile cone.

4. CONCLUSIONS

The device is a solution in engine research, or for engine developers, when a small production is required. The accuracy of the surface is very good, being affected only by the tool adjustments and stiffness of the system. For a better flexibility the rotating head and eccentric shaft can be made with the possibility to adjust parameters from figure 4. Also the tools can receive a system with cams and rack-pinion to maintain a constant angle against the profile.

The next step should be the development of a commercial solution, as a highly productiv standalone equipment, based on the same ideea, fitted with the above mentioned improvements.

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