Analysis of Kinematic Features in Non-conventional Piston Device with Wobble Board

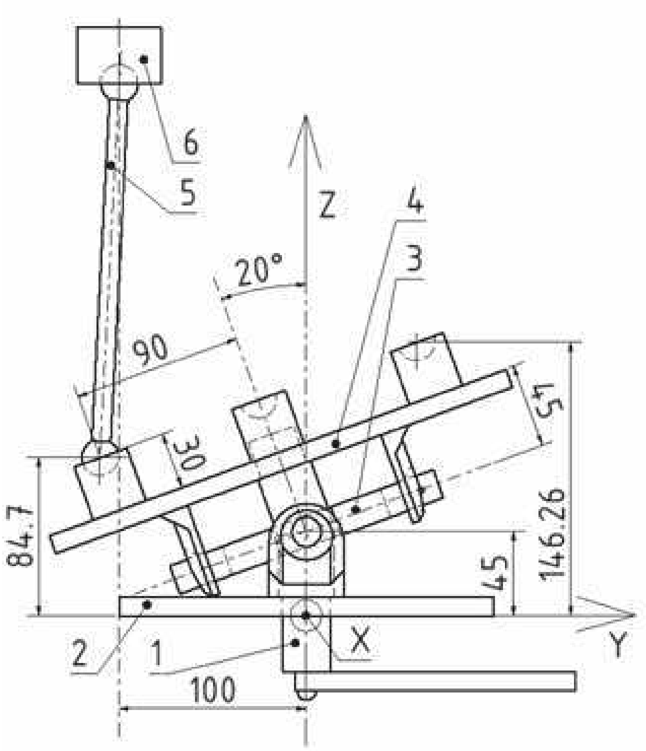
Peter Baran, Pavol Šťastniak, Pavol Kukuča, Miloš Brezáni
Faculty of Mechanical Engineering, University of Žilina, 010 26 Žilina. Slovak Republic. E-mail: peter.baran@fstroj.uniza.sk, pavol.stastniak@fstroj.uniza.sk, pavol.kukuca@fstroj.uniza.sk, milos.brezani@fstroj.uniza.sk.

In the case of constructing combustion engines, it is possible to use not only classical crank mechanisms, but also non-conventional mechanisms. Article deals with description of non-conventional piston mechanism with ring, which may be suitable for special applications in the engineering industry. Investigation of kinematic parameters of the machines is important step to know its basic movement behaviour, and from this, it is then possible to create the alternate dynamic model or force analysis. The aim of this analysis is to investigate the movement of several points on a wobble plate. The next section will deal with the analysis of waveforms of the piston stroke depending on connection with a specified point on wobble board.

Keywords: Non-conventional Device, Kinematic Features, Wobble Board.

1 Introduction

Mechanism with ring (Fig. 1) is a swinging system, which is characterized, that the centre of the swinging plate (4) acting circular motion around *z* axis during the rotation of the shaft (1). Ring (3) is used against parallel rotation of swinging plate with shaft. Reciprocating movement of the piston (6) is transformed to the rotational movement of shaft through ball joint segments (5), according [3]. This schematic and virtual representation was designed for application in type of a Stirling engine, especially for connection of ball joint segment with swinging plate. Fig. 1 shows simple CAD model with basic dimensions and position of piston in default case.



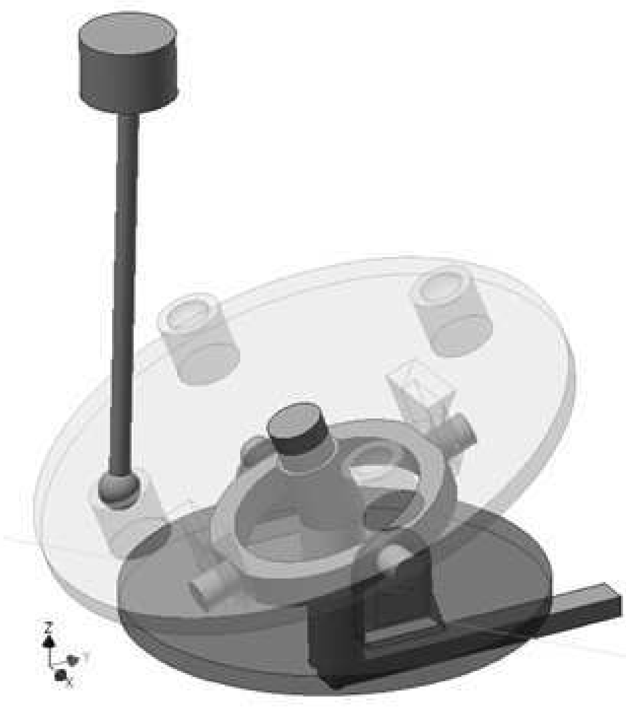


***Fig. 1** Mechanism with ring- schematic representation (left side):1- Output shaft, 2- Part of crankcase (fixed part), 3- Ring, 4-Swinging plate, 5- Ball joint segment, 6- Piston, CAD model (right side)*

2 Determination of points on the swinging board and analysis

Basic dimensions of schematic model are the most important parameters for creating a CAD model, according [2]. Kinematic analysis refers to the observation of the movement (in all three axes *x, y, z*) of five points in the swinging plate (see Fig. 2). For each of these five positions will be determined waveforms and trajectories for points Av1 and P1. During the analysis of the piston stroke was used always the same ball joint segment (distance between spherical centres is 200 mm). The position of cylinder axis is also set by angular adjustment as points Av1.

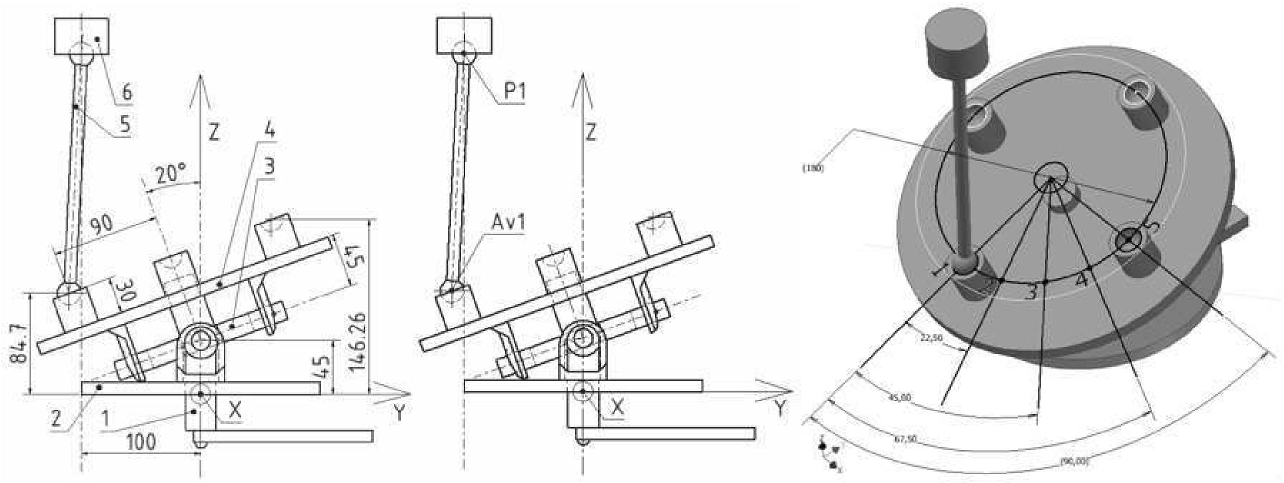


***Fig. 2** Determination of five positions on swinging plate: model with dimensions (left side), schematic representation of examined points (middle part), position of points (right side)*

The first preview of the trajectories projections in the individual planes are shown in the Fig. 3. Point markings means Av1_1 is Av1 and Av1_5 means last fifth point. From figure it is possible to see differences in the courses of individual points on swinging plate.

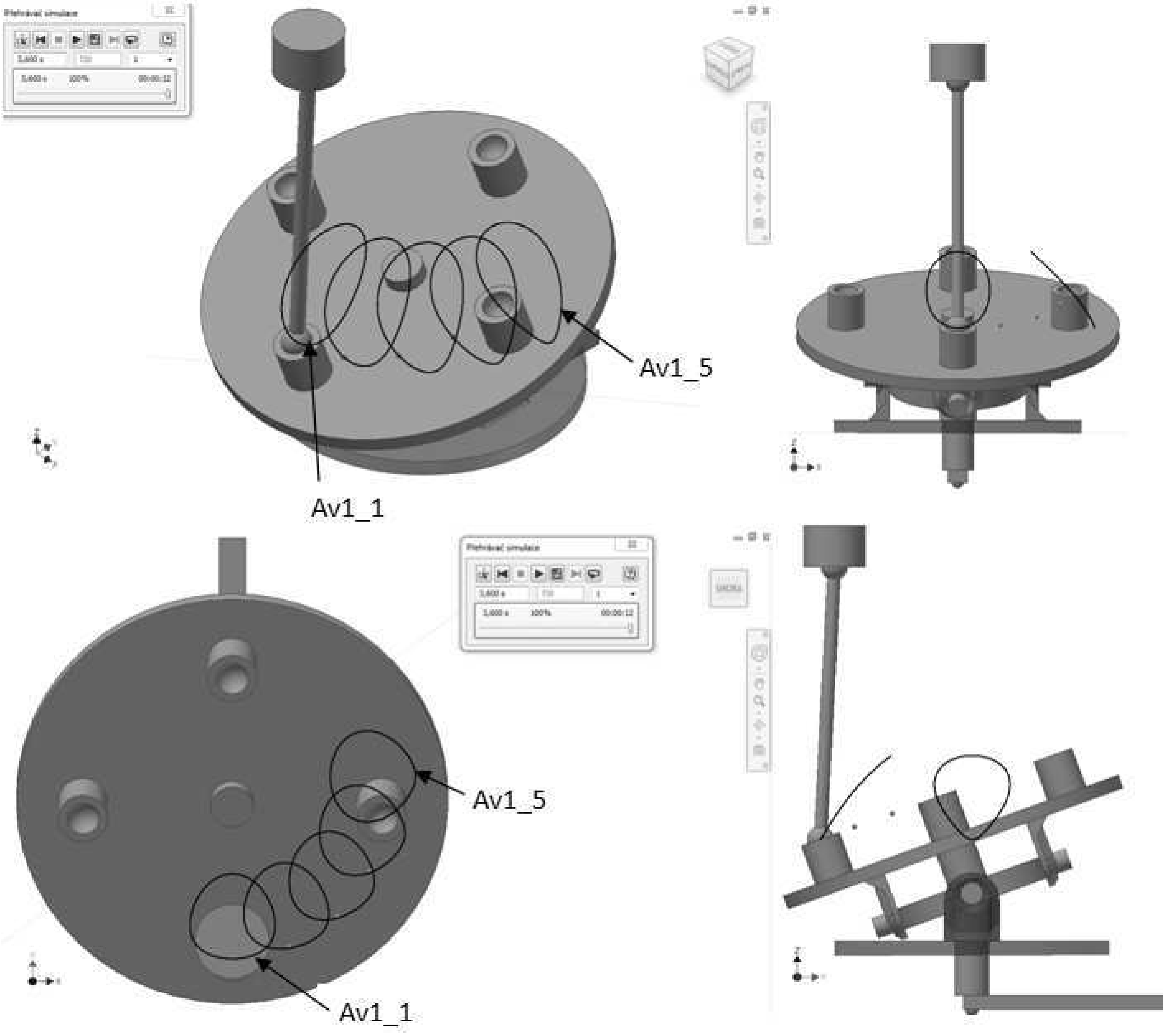


***Fig. 3** Trajectories of points Av1_1 to Av1_5*

Setting conditions for changing the coordinate system position with grounded part of a model. In this case, the *x, y* axes will be rotated around the *z* axis, according to the positions of the individual points Av1_1 to Av_5, because it is easier for comparison of all waveforms.

CAD model, kinematic analysis and the courses were created in Autodesk Inventor. The simulation was set at a constant angular velocity of the output shaft and its duration was calculated to perform exactly one revolution. For the points on the swinging plate, were plotted the following projections in the individual planes (Fig. 4).

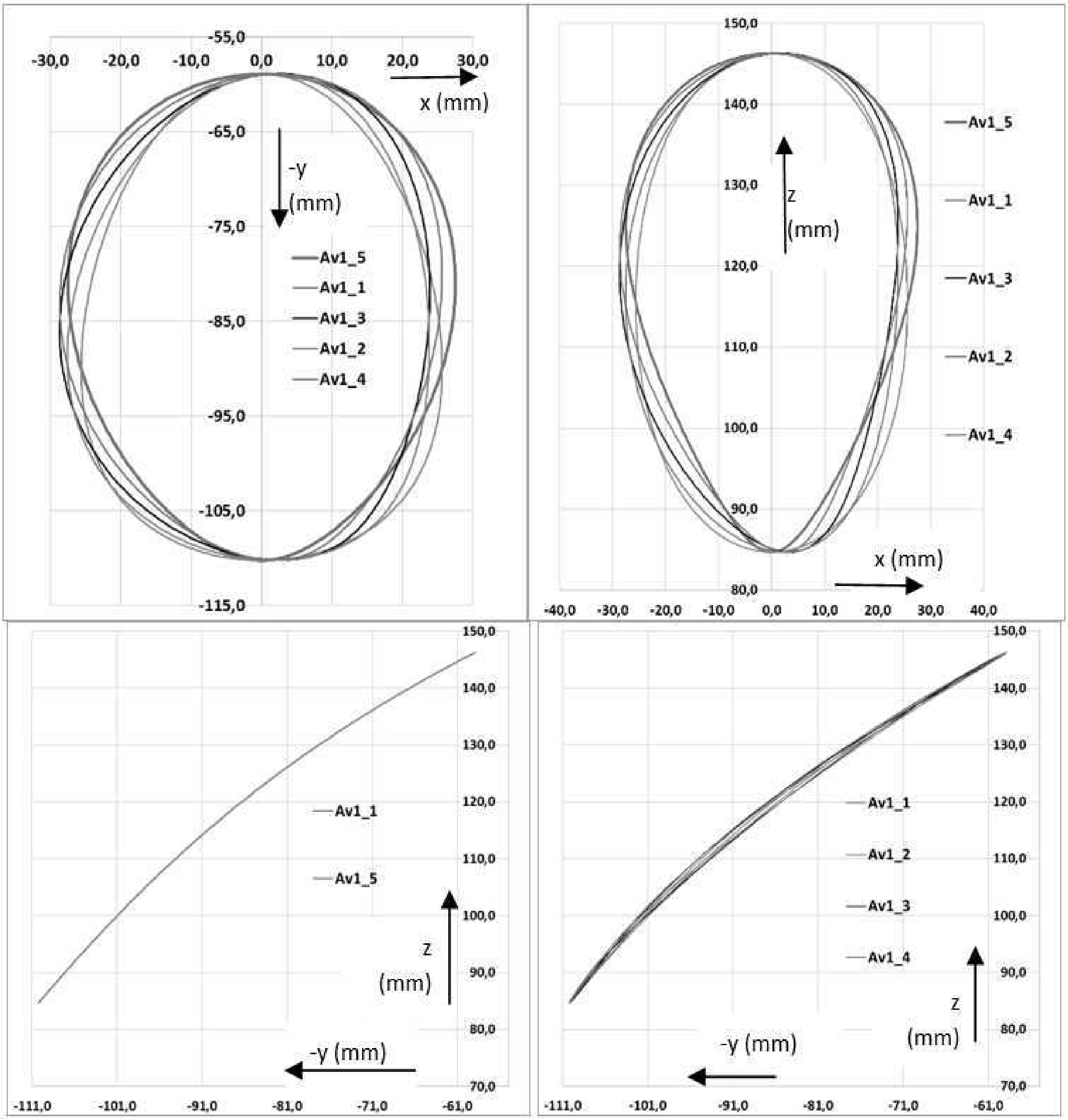


***Fig. 4** Projections of trajectories of points Av1_1 to Av1_5 in (at the top, from left side of picture) x-(-y), x-z and z-y plane (at the bottom)*

From Fig. 4, it is possible to see precisely what extent modification of paths occurs when changing the position of Av1 points on a swinging plate. From the observation of these data it can be argued that the courses of piston strokes will be also different. In Fig. 5 are plotted position of points Av1_1 to Av1_5 depending to the angle of rotation of the shaft (P[X] (Av1_1) (mm) means position x of point Av1_1 in millimetres).

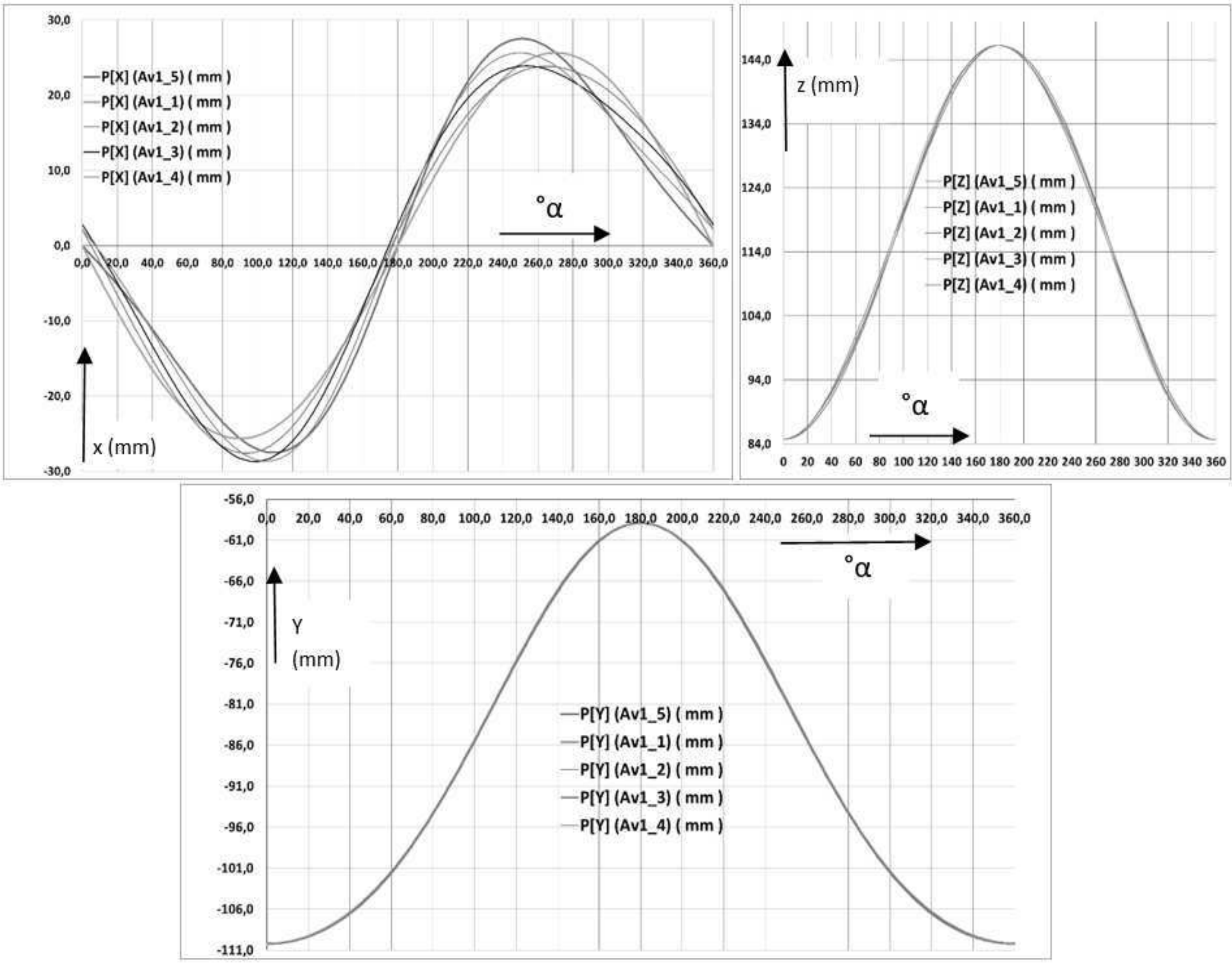


Fig. 5 *The sequence of movements of the point Av1_1 to Av1_5 in all three planes according to the angle of rotation of the output shaft*

Courses of the piston strokes will depend on the courses of Av1 points in the vertical *z* direction. The Fig. 6 shows the differences of courses of piston strokes.

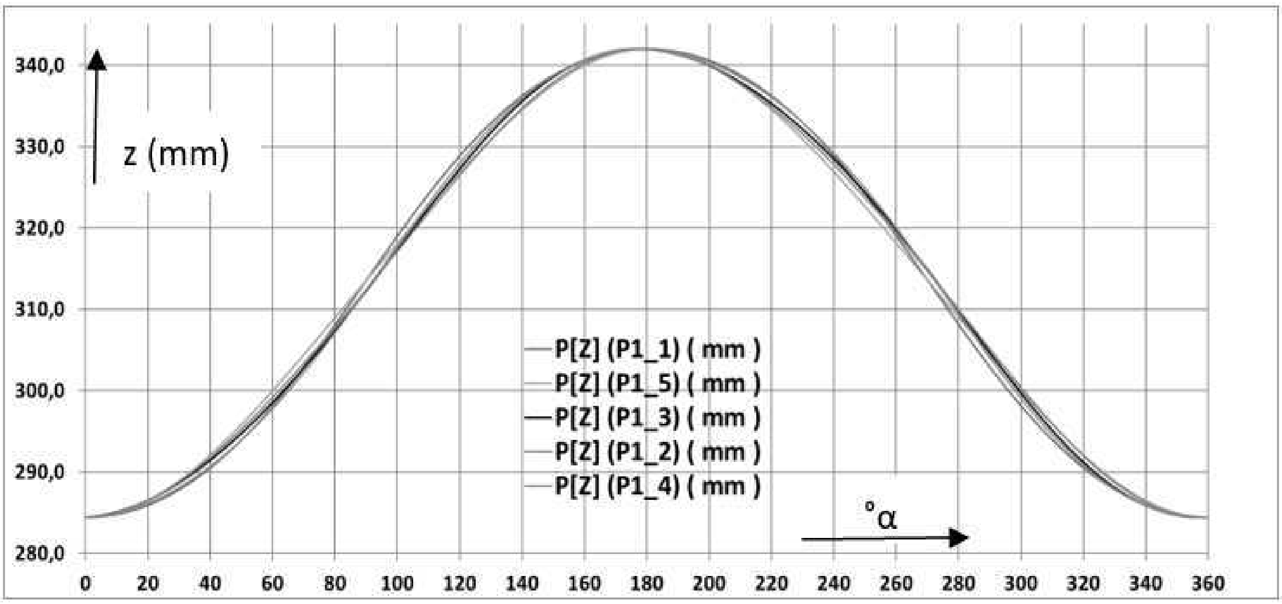


Fig. 6 *The sequence of movements of the points P1_1 to P1_5 in z direction according to the angle of rotation of the output shaft*

2.1 Investigation of the differences in strokes P1 and Av1

In this case it will be pointed to the differences in the plotted of the piston stroke and points Av1. The curves in Fig. 7 were modified so that the P1 stroke curve was approximately in the Av1 point curve region. This analysis show, how are these curves different.

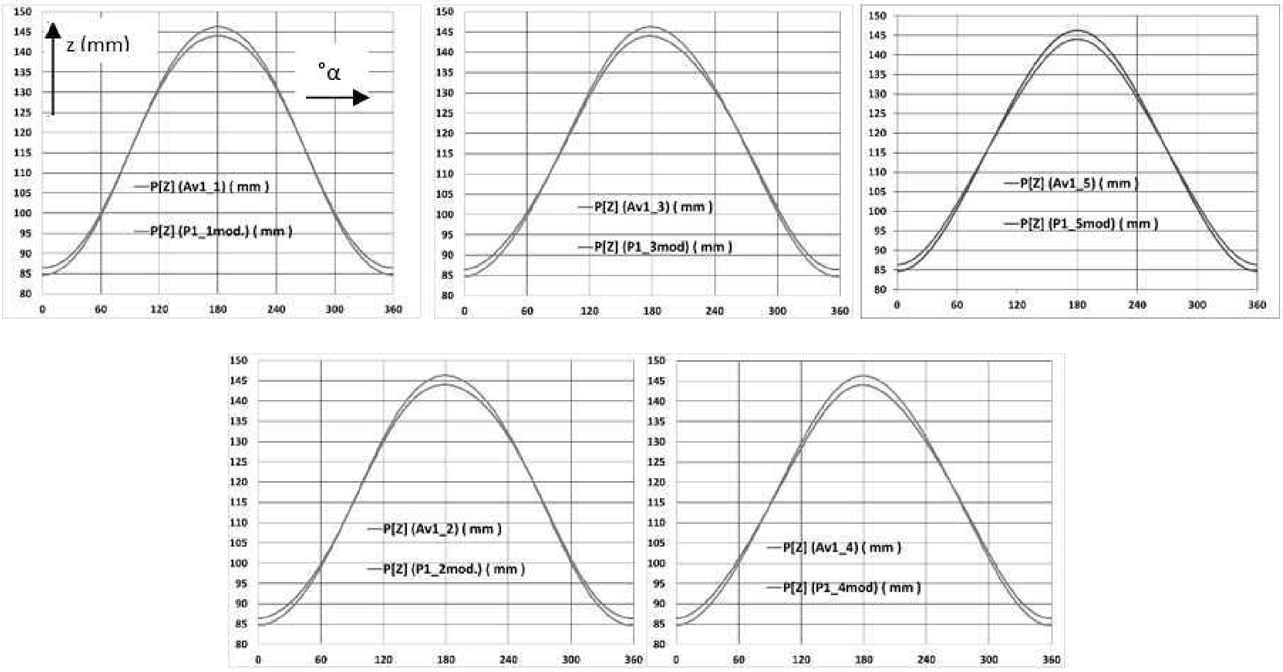


***Fig.** 7 Courses for P1 and Av1 (horizontal axis °α, vertical axis z for all diagram)*

2.2 Overall view of the swinging plate points

In Autodesk Inventor were finally generated trajectories of points in other quadrants of the swinging plate. The aim was an overview of the movement behaviour of the ring mechanism (Fig. 8). From figure it can be seen that the trajectory Av1_1 (marked 1) and Av1_9 (marked 9) are similar, mirror-reversed.

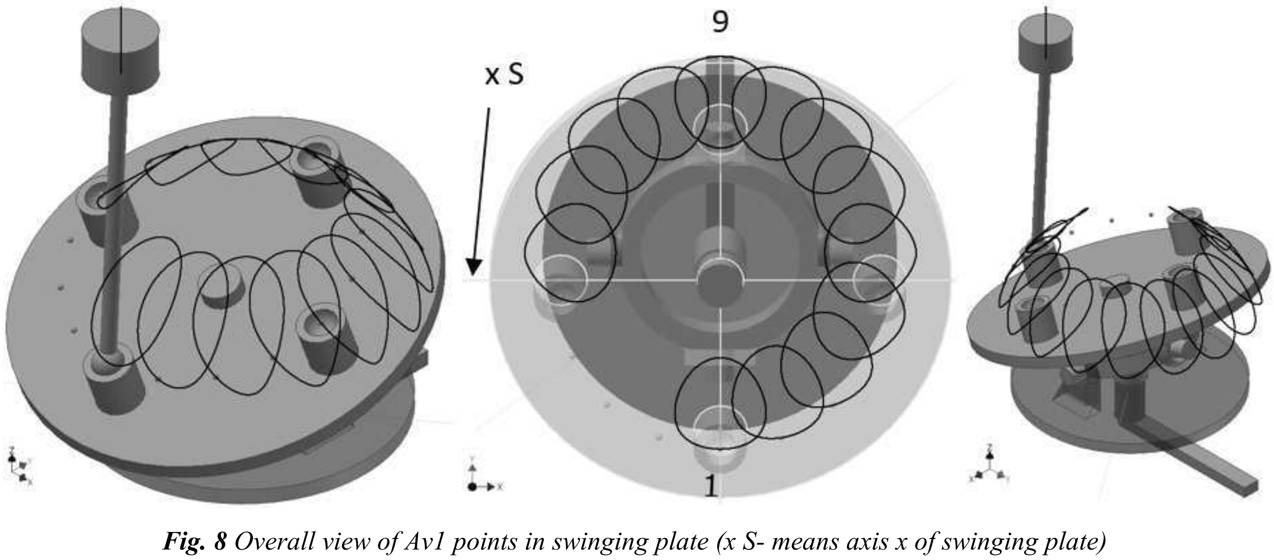


***Fig. 8** Overall view of Av1 points in swinging plate (x S- means axis x of swinging plate)*

3 Conclusion

The resulting graphs were imported from Autodesk Inventor to Microsoft Excel. This analysis shows the differences in kinematic waveforms at the set positions of the points on the plate and the position of the cylinder. From Fig. 4, there are visible differences in all planes, but most interesting is projection in *y-z*, between points Av1_1, Av1_5 with Av1_2 to Av1_3. These points also perform the curve (some type of a closed loop) path in this plane. From Fig. 5 it is possible to see again the differences in the projections of points in the direction *x*, *z*, but in the direction *y*, the deviations are minimal, resp. none. Fig. 7 compares Av1 points and piston strokes (P1) in *z* direction. From this analysis, it is possible to see only minimal differences in the individual progresses, mainly the Av1_4, P1_4 and Av1_5, P1_5, P1_5 have a slightly different curvature around the angle of rotation of the output shaft by 180°. Fig. 8 shows the waveforms tracks in several quadrants of swinging plate, which can be seen as mirrored projections of these trajectories (points 1 and 9 around the axis *x S*). In the difference of the trajectories of the examined points and their courses, depending on the angle of the output shaft, will be speeds and accelerations courses different as well. From this basic analysis it is possible to predict the degree of difficulty in creating a dynamic model and for example in order to creating balancing system on this mechanism. These parameters would have an effect on the torque curve, for example in the case of an internal combustion engine. The resulting values generated by Autodesk Inventor were compared with models created in MSC Adams. On reaching the same results, we consider Autodesk Inventor's overall analysis to be reliable. Movement of points and the overall progress of courses will be different from other factors such as the angle of the output shaft breaks (Fig. 2 - 20° in our examined model) in positions of points AV1 for a distance of pitch and diameter of the wobble board (Fig. 2 – 90 mm), or positions of cylinders. Therefore, there is necessary to make another analysis of this mechanism.

With this research and development subject deals other publication too [1, 4, 5, 6, 7, 8].

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