MODELLING DYNAMICAL BEHAVIOUR OF WOBBLE PLATE MECHANISM

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Abstract: *The paper presents the modelling of dynamical behaviour of wobble plate mechanism based on multibody method. Starting from the simplest constructive solution of wobble plate mechanism, based on conclusions from authors' previous papers, founded on an wear resistance criterion, it is certified the necessity of replacing the kinematical pair sphere-plane with two pairs, a plane one and another one, spherical. For this actual constructive solution, the kinematical analysis cannot be made because in the replacing mechanism a passive mobility occurs. In order to apply the Hartenberg-Denavit method, a new replacing mechanism is required, with removed passive mobility degrees and moreover, with a structure containing only cylindrical pairs. However, the dynamical analysis must be made for the actual mechanism, for which the motions allowed by the passive degrees of freedom are dictated by the friction from the kinematical pairs.*

Keywords: *system dynamics, multibody, wobble plate mechanism, MSC ADAMS modelling*

1. Introduction

The wobble plate mechanism is, due to constructive simplicity, one of the most utilised spatial mechanisms. It can be met from common devices such as the pump with axial pistons, Fig. 1, [1], to complex devices like the sophisticated helicopter rotor blades guiding system, Fig. 2, [2].

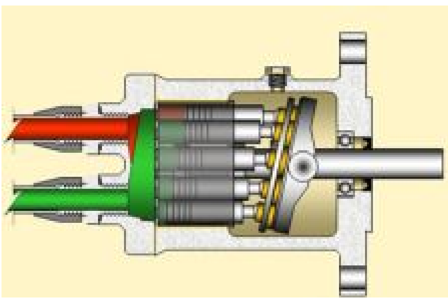

Figure 1: *Pump with axial pistons*, [1].

The analysis of dynamic behaviour for a system can be more or less intricate, depending on the complexity of the system from which the mechanism is part of. The present paper starts from two laboratory rigs, in fact two very simple constructive solutions for the basic mechanism. From the two alternatives, the one offering most reliable solution is chosen for analysing using the MSC-ADAMS software. When the driving element is loaded by a step signal, having different magnitudes, the reaction forces from mechanism's pairs are found and their variation is analysed.

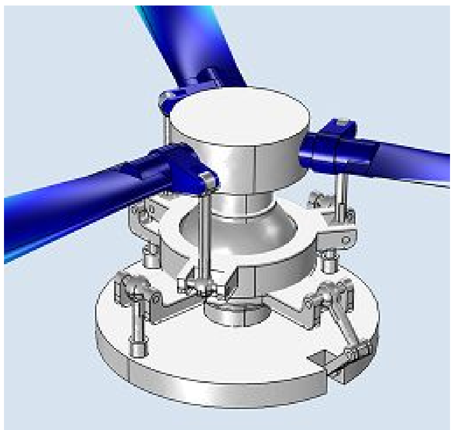

Figure 2: *Helicopter swashplate mechanism,* [2].

2. Models of wobble plate mechanism used in kinematical and dynamical analysis

The device from the laboratory is presented in Fig. 3. In fact, the wobble plate mechanism is a spatial cam mechanism, [3], [4], [5], the cam consists in a disc assembled in such a manner that the disc's centre is on the driving shaft and the normal to it's surface figures an angle, α, with the driving shafts' axis.

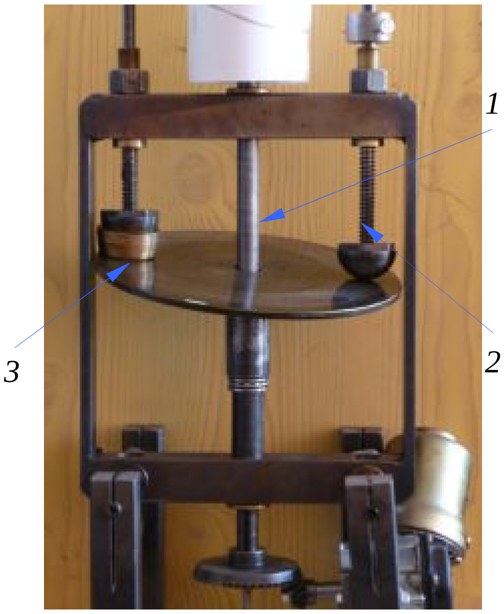

Figure 3: *Actual appliance from laboratory*

The angle α and the distance between the axes of the shaft, 1, and of the plunger, 2, are the constructive parameters of the mechanism.

The wobble plate mechanism is constructed in two alternatives: with Hertzian contact sphere-plane or, by equivalents of the pair, namely a spherical pair and a plane pair, using a intermediate part, 3. This replacement aims to diminish the contact pressure and introduces a mobility degree and the rotation of the bronze shoe around the axis normal to the plate's plane. The degree of freedom DOF of the new mechanism can be obtained with the relation:

$$DOF = 6(n-1) - 2 \cdot c_3 - 2 \cdot c_5 = 2 \quad (1)$$

where $n = 4$ represent the number of the elements of the mechanism, including the ground, $2 \cdot c_3 = 6$ shows the DOF suppressed by the spherical joint and the planar joint, and $2 \cdot c_5 = 10$ represent the DOF suppressed by the revolute input joint and prismatic last joint.

The mechanism, as a spatial one, requires for performing the kinematical analysis, to eliminate the mobility degree introduced by the mean of the two pairs, spherical and plane, respectively, which, together, allow 6 degrees of freedom instead 5 degrees of freedom permitted by the sphere plane pair. Additionally, the homogenous operators' method, proposed by Hartenberg-Denavit, [6], compels replacing the actual mechanism with another one, having in structure only cylindrical pairs or, particular forms of cylindrical pairs, such as revolute pair or prismatic pair.

The spherical pair replacement can be obtained, according to Fischer, [7], by introducing, instead of it, three revolute pairs with concurrent and perpendicular axes, and the plane one, replaced by two prismatic pairs with perpendicular axes and a revolute pair with the axis normal to the translations' plane. The methodology was applied by authors in previous work, [8]. After replacing the plane pair, the rotation axis obtained is brought into coincidence with one of the axes of the system of pairs with which the revolute pair is equivalent, the assembly of the two pairs, revolute and prismatic, can be replaced by a Cardan joint and an Oldham coupling, Fig. 4.

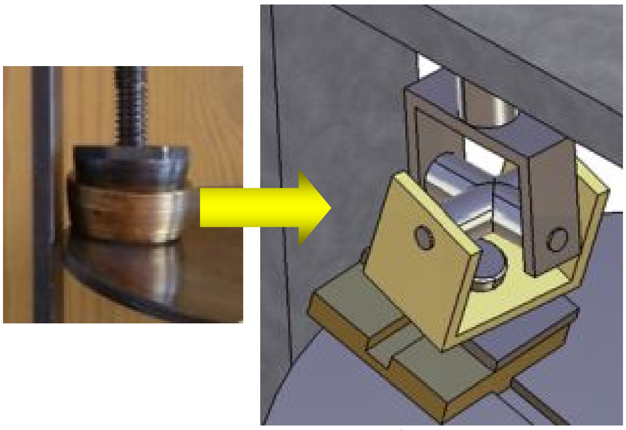

Figure 4: *Replacing the assembly of spherical pair and planar pair with three revolute pairs and two prismatic pairs*

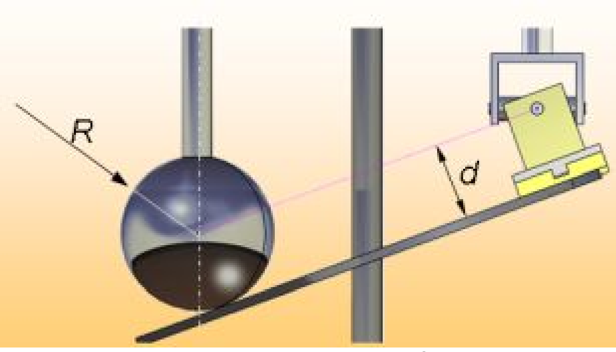

Figure 5: *Geometrical constraint for obtaining equivalency of sphere-plane pair*

Besides the structural condition, the distance between the cross centre and the plate plane is required to be equal to the radius of spherical head, in order to keep unchanged the mechanism's kinematics, Fig. 5.

The dynamic analysis cannot be any longer performed using the method of replaced mechanism because the actual mechanism has the degree of mobility higher than the replacement mechanism and, in addition, the problem of equivalent inertial characteristics both for replacing and actual mechanisms occur. Furthermore, the values obtained for the reaction forces and motions from the replaced mechanism joints cannot be used in dimensioning the actual mechanism's joints.

Therefore, the dynamical analysis of the mechanism must be performed on the authentic mechanism.

3. Dynamical analysis using Multibody dynamics method

The behaviour analysis for the mechanism as a dynamic system consists in finding the

variation of some parameters characteristic to mechanism's dynamics with respect to the input parameters of the system, [9]. Generally, the input parameters of the system should have a simple variation. Commonly, when studying the behaviour of a dynamic system, the input parameters have an impulse function (Dirac delta function) form or step function (Heaviside) form, [10].

The dynamic behaviour simulation of the mechanism was made using the MSC-ADAMS software which is based on multibody dynamics method.

The dynamical model of the mechanism is presented in Fig. 6 together with three step signals of different magnitudes.

To underline the effects of the shocks applied to the driving element, there were found, for the three variations of the driving element, the corresponding variations of the reactions magnitudes from the other pairs of the mechanism. These are represented in Figures 7-9.

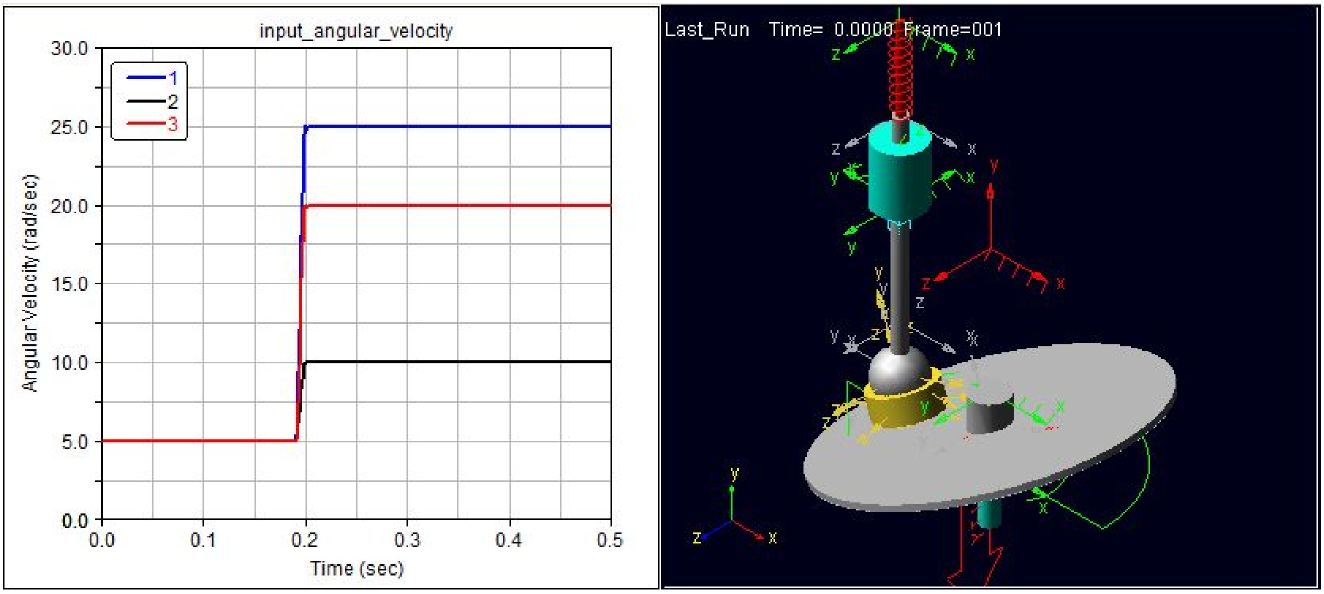

Figure 6: *Dynamic model of wobble plate mechanism and angular velocity step function variation for the driven element parameter*

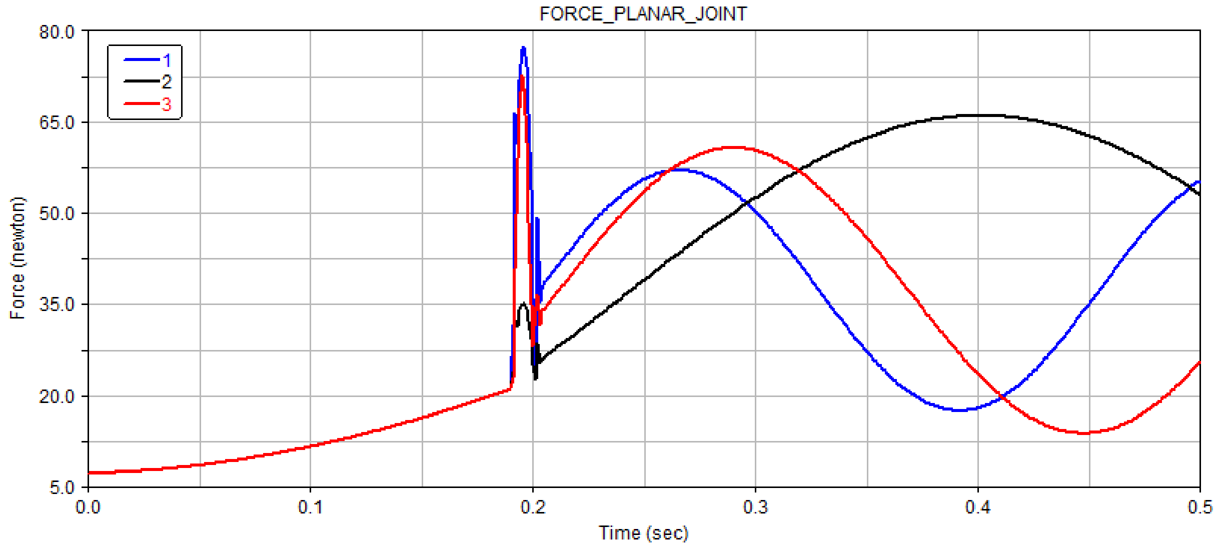

Figure7: *Reaction force from the planar joint*

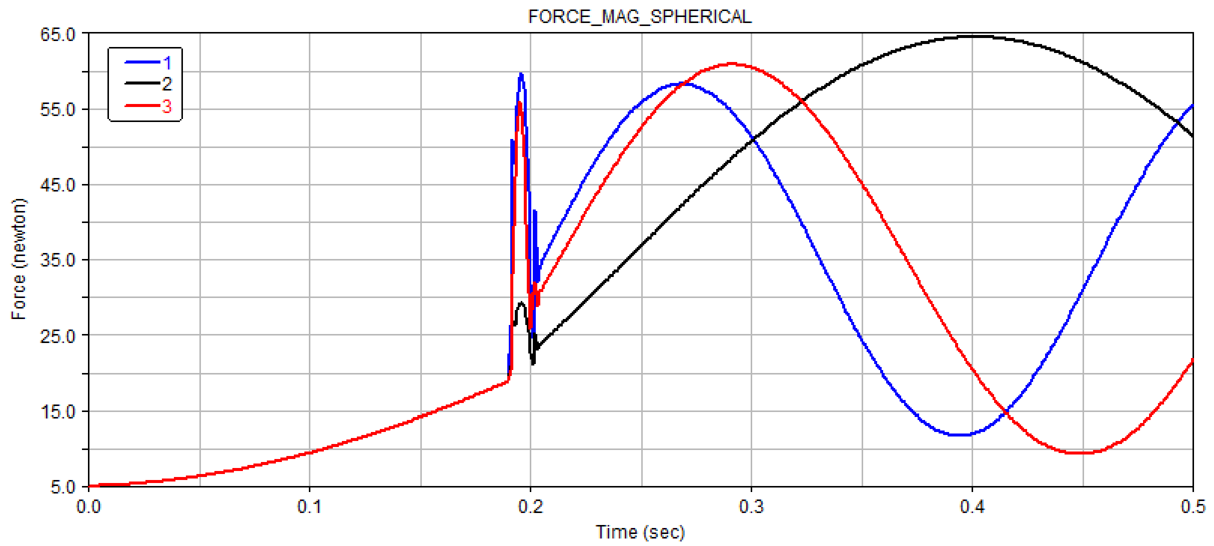

Figure 8: *Force magnitude from spherical joint*

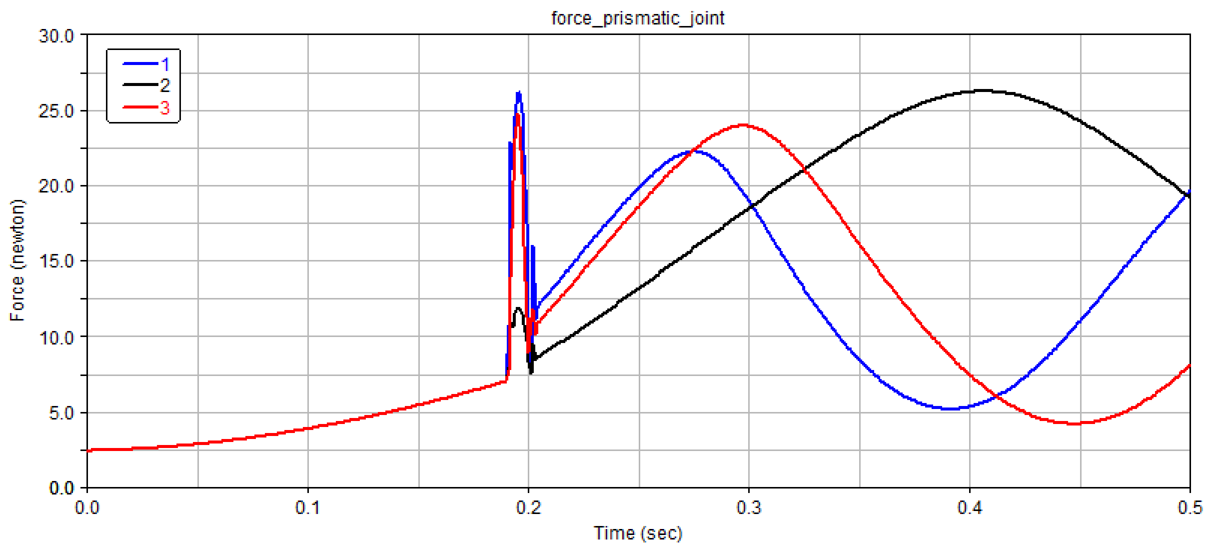

Figure 9: *Reaction force from prismatic joint*

4. Conclusions

The paper presents the dynamic analysis of a wobble plate mechanism. The simplest mechanism solution contains a sphere-plane joint and consequently, a low reliability is expected. With the purpose to improve this parameter, a solution is proposed, based on the replacement of the sphere-plane joint by a couple of spherical and planar joints. As a consequence, a passive degree of mobility will occur in the new mechanism and therefore, the kinematical analysis cannot be applied. The motion allowed by the passive DOF will be dictated by the friction characteristics from the newly two joints. The dynamical analysis can be performed by setting the parameters of friction in all the mechanism's joints.

The main concern was the dynamical behaviour of the new mechanism when shocks are applied to the driving element.

The dynamical simulation was accomplished using specialised software and the shock generation was obtained by imposing a step function variation for the angular velocity of the driving element. For different amplitudes of the entrance signal, there ware found the reaction forces from the other joints of the mechanism. The major observation is that the shock applied to the driving element is also instantly noticed in all other joints.

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