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POSITION CONTROL ACTIVE SYSTEMS IN HEAVY MACHINES

1. Introduction

There are situations during heavy machines operation when position control of its elements improves work precision and enhances operator's comfort. We can give an example of a grader blade which is used for ditch cleaning. When the ground at the foot of the ditch is uneven the motions of the machine are transmitted to the blade and as a result the ditch surface will be uneven too. The operator's cab position has to be precisely controlled as well. It is usually situated quite high so that the operator can observe the machine work. When the machine rides over rough terrain low-frequency high-amplitude vibrations of the whole machine and the cab are produced [1]. In such conditions operator's concentration abilities will be vastly deteriorated, which may impact on work safety.

2. Description of the System

The active systems of position control consist of three sub-systems. The mechanical sub-system connects the frame with the analysed element (i.e. the blade) and consists of hydraulic cylinders arranged in series and passive links. To ensure maximal reliability, each cylinder should be supplied by a separate pump. The passive links are to eliminate the motion in selected DOFs of the examined element with respect to the frame. The measuring sub-system includes sensors which transmit the information about the motion of the frame, of the analysed element and the cylinders to the control sub-system. The control sub-system receives that information, processes it and sends the information about the desired piston position in the control valve.

The most intricate mechanical sub-system consists of six cylinders linking the frame with the blade by means of spherical pairs. In this case the control of cylinder motion determines the blade motion in relation to the frame in six DOFs. In practical applications it is not necessary to control the motion in all these six DOFs. In the case of straight-line motion of the machine over rough terrain the operators cab hardly rotates round the vertical axis. When the machine takes a turn, such rotation is present but it is impracticable to try to eliminate it. To ensure the stable position of the blade with respect to the ditch surface it is sufficient to control the machine motion for three DOFs. The passive links present in the mechanical sub-system eliminate the blade motion with respect to frame in the selected DOF, which allows to reduce the number of applied cylinders.

3.The Condition of Cylinder Control

The basic condition for cylinder control is provided in the following formula. Let the instantaneous angular velocity of the blade be given by the vector $\vec{\omega}_{ob}$ (Fig 1), while the instantaneous linear velocity of the selected point S is given by the vector $\vec{v}_S$. B_i is the end point of the vector $\vec{r}_i$ which has its origin at the point S. The instantaneous velocity of the point B_i - $\vec{v}_{B_i}$ can be obtained from the fundamental formula in kinematics: $\vec{v}_{B_i} = \vec{v}_S + \vec{\omega}_{ob} \times \vec{r}_i$ [2].

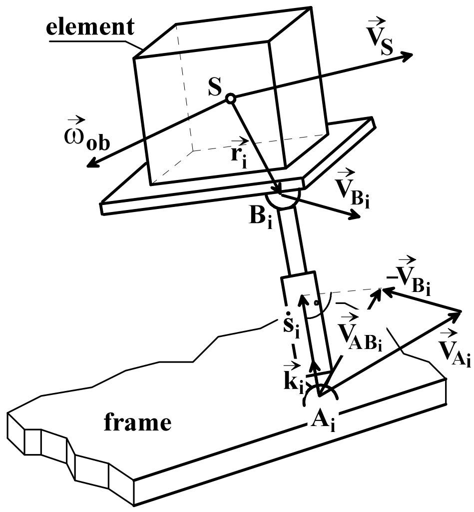

Fig. 1. Velocity of the cylinder

The instantaneous velocity of the point A_i - $\vec{v}_{A_i}$ can be found from measurements. Accordingly, we can find $\vec{v}_{AB_i}$ - the instantaneous velocity of A_i with respect to B_i :$\vec{v}_{AB_i} = \vec{v}_{A_i} - \vec{v}_{B_i}$. The rate of piston rod pullout is the projection of the velocity vector $\vec{v}_{AB_i}$ in the direction of the cylinder:

$$\dot{s}_i = \vec{k} \circ \vec{v}_{AB_i} \qquad i = 1..j \tag{1}$$

where: $\vec{k}_i$ is the unit directional vector.

When the analysed element has $j \in (1, 2, 3, 4, 5, 6)$ DOFs while moving with respect to the frame, the mechanical sub-system shall require j cylinders. We have to assume then j conditions to find velocity vector components $\vec{\omega}_{ob}$ $(\omega_x, \omega_y, \omega_z)$ and $\vec{v}_S$ (v_x, v_y, v_z).

4. Results of Computer Simulation

The operation of various position control systems in heavy machines was modelled using Working Model 3D [3]. The system stabilising the blade position in the plane *XZ* normal to the longitudinal axis of the machine *Y* is presented in Fig 2.

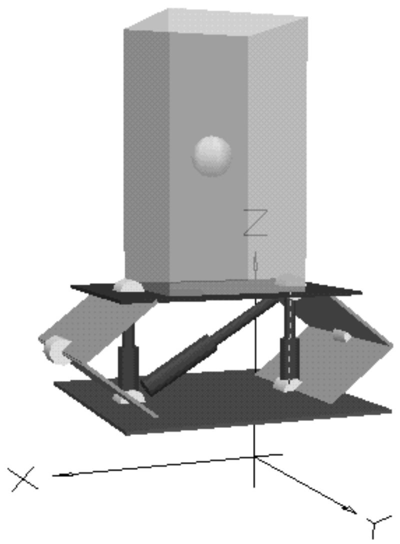

Fig. 2. Model of mechanical sub-system

It consists of three cylinders and two pairs of plates connected to one another, to the frame and to the blade by means of spherical pairs only. These plates eliminate the blade motion along the longitudinal axis of the machine *Y* and round the axes *X* and *Z*. Besides, these plates carry the bending load. In the case considered here the blade has three DOFs with respect to the frame. To eliminate its motion in the plane *XZ* we have to consider three conditions: $v_y = 0$,

$v_z = 0$, $\omega_x = 0$. Frame motion is implemented through a simulator, not shown in Fig. 2, which changes the frame position in the plane *XZ*. The kinematic effect of position control is presented in Fig. 3. The load patterns of three cylinders are shown in Fig. 4, for the blade weighing 1000 kg.

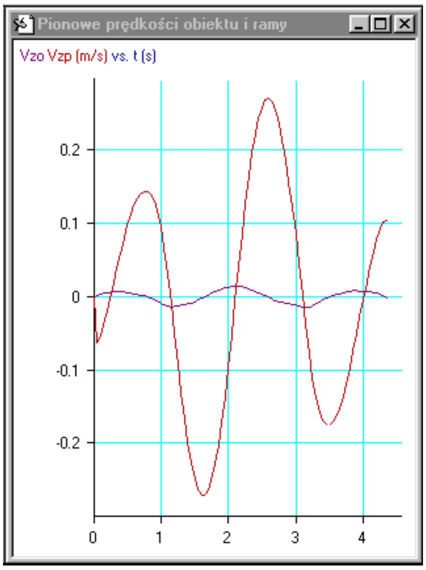

Fig 3. Vertical velocity of the blade and frame

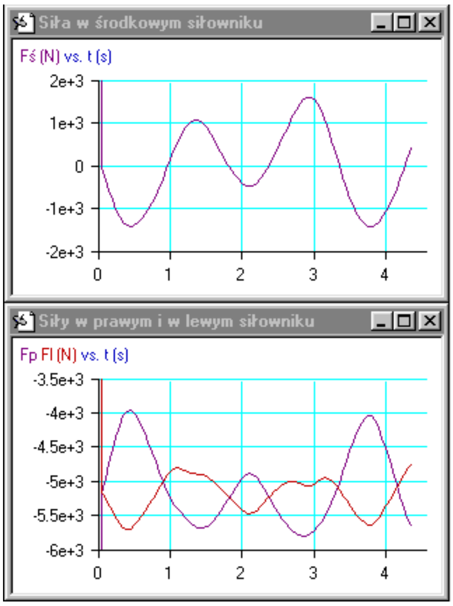

Fig 4. Forces acting in hydraulic cylinders

As the excitation frequency of the simulator increases, some unfavourable processes can be observed. Position control becomes less precise because of the delay in response (time constant) of the control sub-system. Thus produced motion increases cylinder loading, which results in higher power demand for the mechanical sub-system.

References

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