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New design for a 6 dof vibration simulator with improved reliability and performance

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Abstract

Simulators are an indispensable tool to study present-day machinery dynamics in a repeatable way and under controlled laboratory conditions. In the past Stewart configurations are described thoroughly using inverse kinematics and forward kinematics. When optimising such a design for specific performance criteria, kinematics and hydraulic restrictions are to be taken into account. In this paper an already designed and constructed 6 degrees of freedom (dof) electro-hydraulic vibration test rig is virtually redesigned, constructed and validated using the Stewart configuration as a basis. The former structure has fundamental faults, which prohibit an optimised performance. An important weakness lies in the use of Hook's joints, which are too weak for the exerted forces and introduce an eigenfrequency that lies in the excitation band of the simulator. The aim is to find the optimal angle between ground and cylinder α that provides minimum rotation, force and torque within the Hook's joints, satisfies a number of performance criteria, respects the symmetry of the construction, tries to minimise the asymmetry in the cylinder movement and provides a movement of the platform with high resolution. An inverse kinematics and a dynamic model are constructed. The result is a vibration simulator with great stability and performance.

Keywords: Stewart; Low frequency; Vibration; Test rig

1. Introduction

Increased vehicle speed and capacity of agricultural machinery, induced by higher labour costs, create a lot of vibration problems, reducing the vehicle's lifetime, working precision and driver's comfort [1]. Also does vibrations decrease the quality of food products as fruit and vegetables in

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transport due to bruising [2,3]. The investigation of vehicle dynamics and the investigation of the effect of vibrations on agricultural products and on the driver, in order to offer the appropriate vibration attenuation solutions, demand a controllable environment. Therefore a vibration simulator is an indispensable tool. It allows controllable and repeatable actions and provides enough space for a multiple set-up. A first configuration was build and described in detail in the paper of Hostens et al. [4]. It was constructed with six actuators allowing movement in all 6 dof (Fig. 1). Three vertically mounted actuators (3, 5, 6) sustain the platform and determine its vertical position. The three remaining actuators (1, 2, 4) are set up horizontally and fix the sideway movements of the platform. The cylinders are placed under the platform such that little space and no specific attachment points are required. The platform is an assemblage of a regular grid of beams, with a surface of 2250 by 2250 mm. The eigenfrequency for the first mode shape of the platform (with a central load of 500 kg) was 38.52 Hz [4]. The latter value is near the postulated lower limit of 40 Hz (for safe excitation up to 20 Hz). The postulated performance criteria of this first design was the reproduction of an amplitude of 100 mm at 1 Hz and an amplitude of 1 mm at 10 Hz, with a weight of 500 kg on top of the platform. Main problem was the almost undamped eigenfrequency of 11 Hz of the Hook's joints, placing the whole system in resonance when exposed to shocks, and limiting the excitation frequency range. An extra factor of instability was the placement of the x and y cylinders (cylinders 1, 2 and 4) with the platform attachment up to

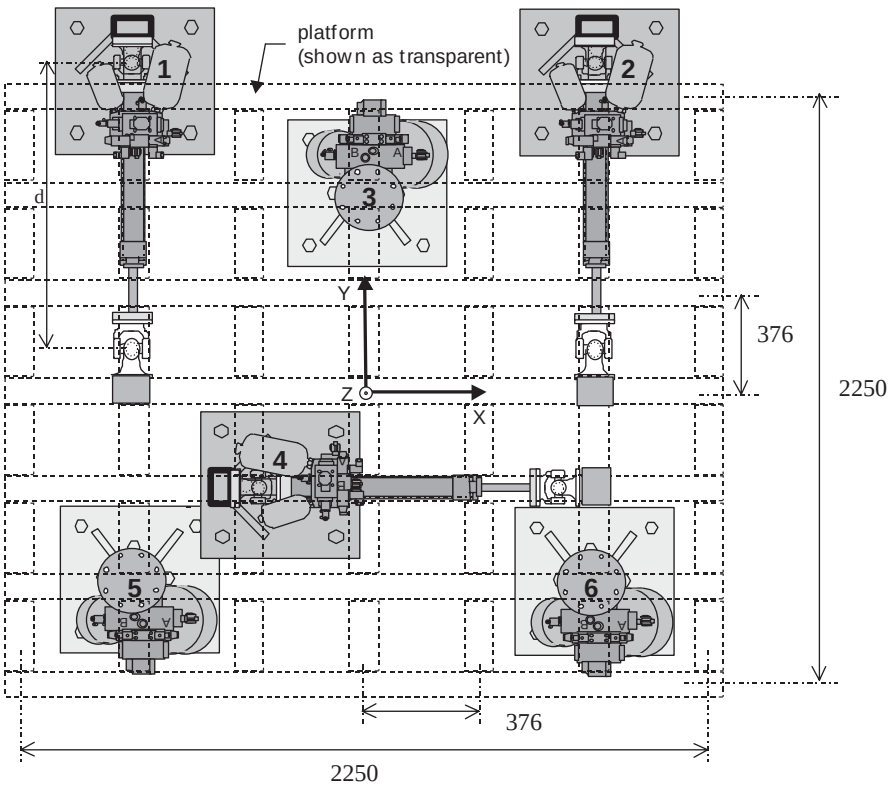

Fig. 1. Top view of the first test rig configuration: platform (dashed line) with six under-lying hydraulic cylinders; all dimensions in *m*.