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Examination of Dynamical Parameters of the Production Line Manipulator

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Abstract. In the automotive industry, manipulators are essential for production lines and production processes. Manipulators ensure transport of materials, parts and tools, and are frequently based on linear rolling guides. However, the failure of any linear guide may cause stopping the production and may lead to significant production losses. Therefore, firms demand their sufficient reliability and prediction of possible failures. For ensuring these demands, at first, we need to identify and verify the dynamical parameters of production manipulators that are necessary for computing the operational loads of linear guides. The paper describes a method for identifying dynamical parameters of production manipulators on a specific manipulator. Dynamical parameters were determined by experimental and numerical methods, comparing the measured and simulated accelerations at two points on the manipulator. The measured data were cleared by finite impulse response filtering and explored by fast Fourier transformation for getting the natural oscillation frequency. This oscillation frequency could be compared with frequencies of a dynamical model at different mass and stiffness parameters. Results showed a sufficient match between measured and simulated acceleration values.

Introduction

Nowadays, the reliability of production machines is highly required. To prevent possible losses, producers demand prediction of failures. Production Line Manipulators often use linear rolling guides for linear motion. As well as rolling bearing in rotational machines, linear guides are a bottleneck of a manipulator design.

For ensuring reliability, the failure prediction of linear rolling guides is needed. The failure prediction is related to a dynamical load of linear guides [1], which is connected with dynamical parameters, the effect of mass inertia and operating conditions of production manipulators [2]. Therefore, the objective of this paper is to identify and verify the dynamical parameters of a manipulator.

Clamping Frames Manipulator

Dynamical parameters are identified and verified on a specific manipulator for clamping frames. The manipulator horizontally transports clamping frames of car bodies during the welding process. Clamping frames are connected to the cart through telescopic parts. For transporting, the manipulator uses linear rolling guides and an electric motor. The power from the electric motor is transmitted and transformed through a rack gear. For finding dynamical parameters, the acceleration was measured at two points of the manipulator and in two directions – x and y [3]. Fig. 1 shows a 3D model of the manipulator with marked positions of acceleration sensors.

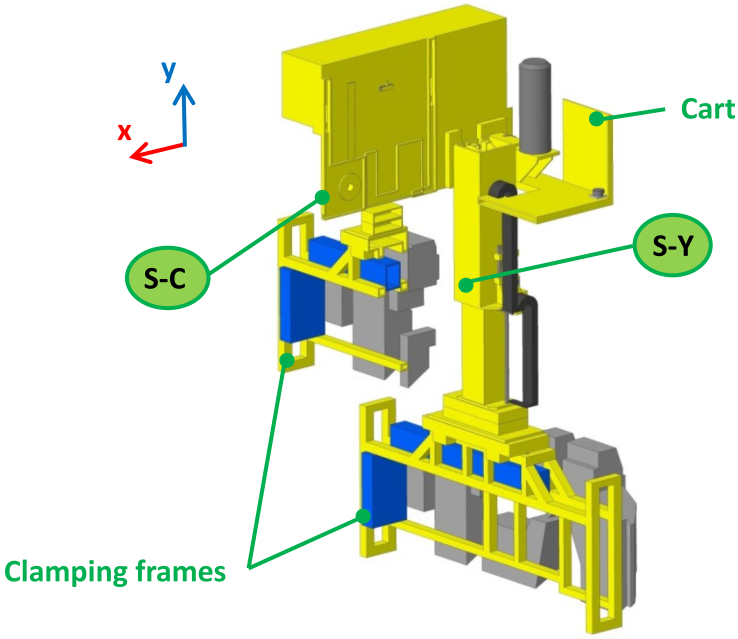

Fig. 1: Clamping frames manipulator, positions of sensors

The first acceleration sensor "S-C" is placed nearby the electric motor; the second one "S-Y" is placed on the telescopic part.

FIR Filtering

For getting a pure acceleration of motion at two chosen points, measured data were filtered by the FIR filter. Measured and filtered data in x and y directions are shown in Fig. 2 - Fig. 5.

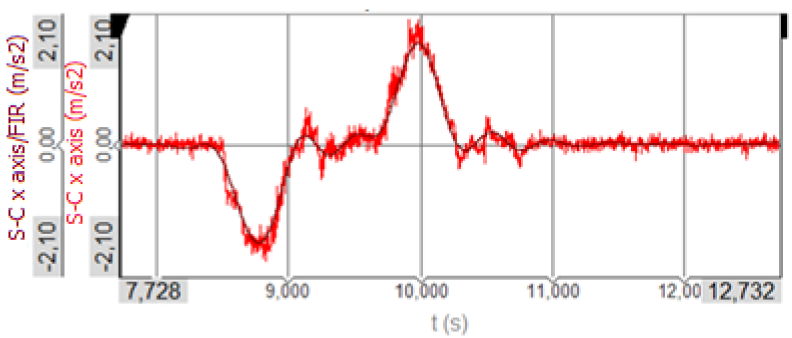

Fig. 2: Acceleration in x axis direction at the first point

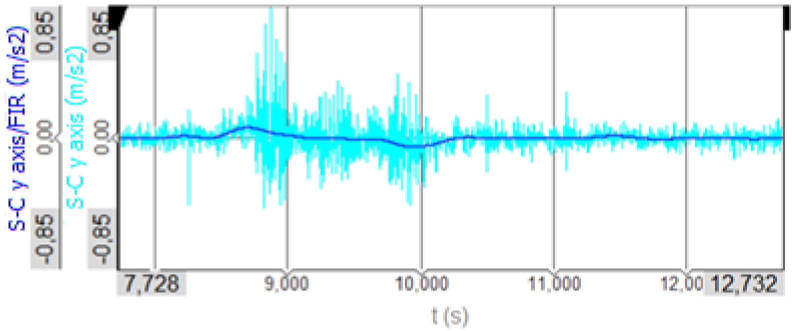

Fig. 3: Acceleration in y axis direction at the first point

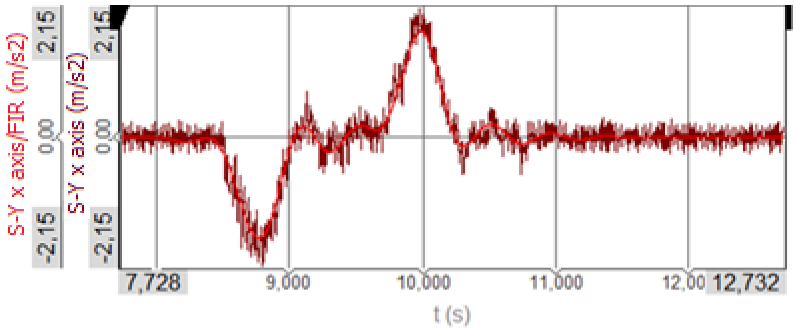

Fig. 4: Acceleration in x axis direction at the second point

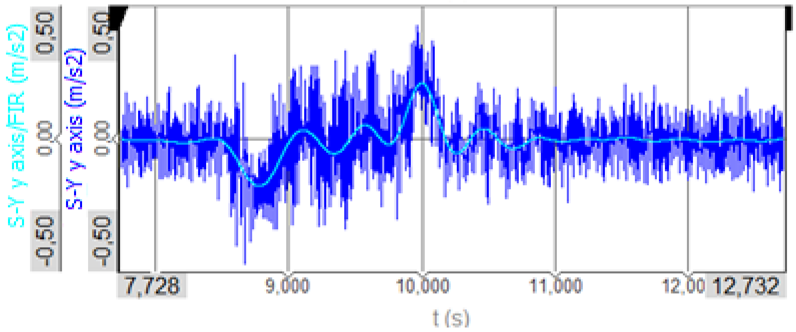

Fig. 5: Acceleration in y axis direction at the second point

The filtered data shows the oscillation of the manipulator during the linear motion. This oscillation is the natural oscillation of the manipulator related to the inertia effect of its mass.

FFT Analysis

The natural oscillation frequency is evaluated by Fast Fourier Transformation (FFT). The results of the FFT Analysis are summarised in Fig. 6.

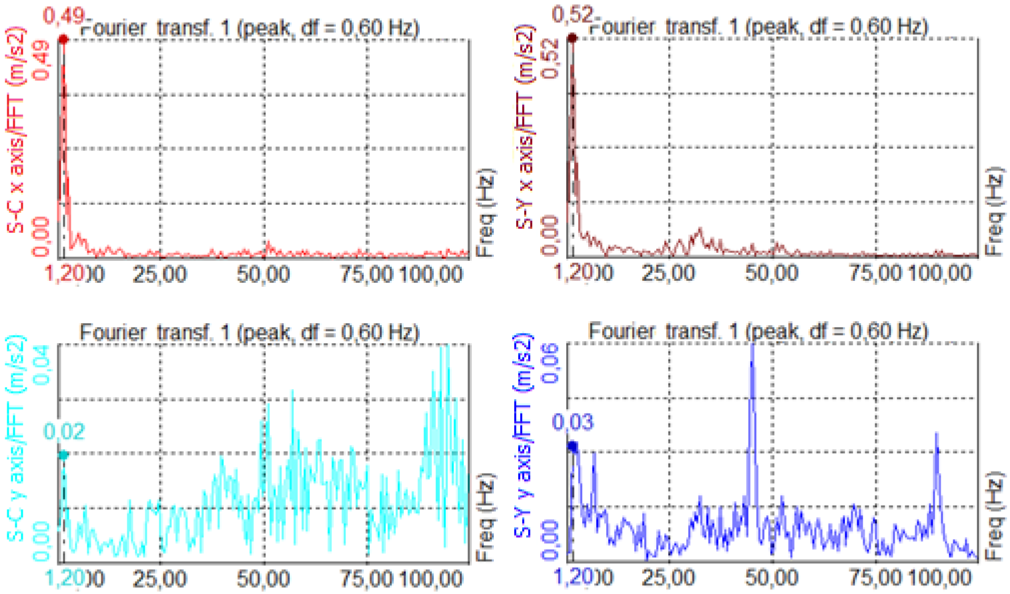

Fig. 6: Frequency spectrum

The highest peak at the lowest frequency in each spectrum corresponds to the natural oscillation frequency 1,2Hz that is marked in each graph.

MBS Analysis

The linear motion of the manipulator was simulated using a multibody system analysis. Where, linear rolling guides were substituted by elastic and damping connections (Fig. 7). The contact point of the rack gear was substituted by a pin and slider connection with assigned kinematic excitation at L point [4,5].

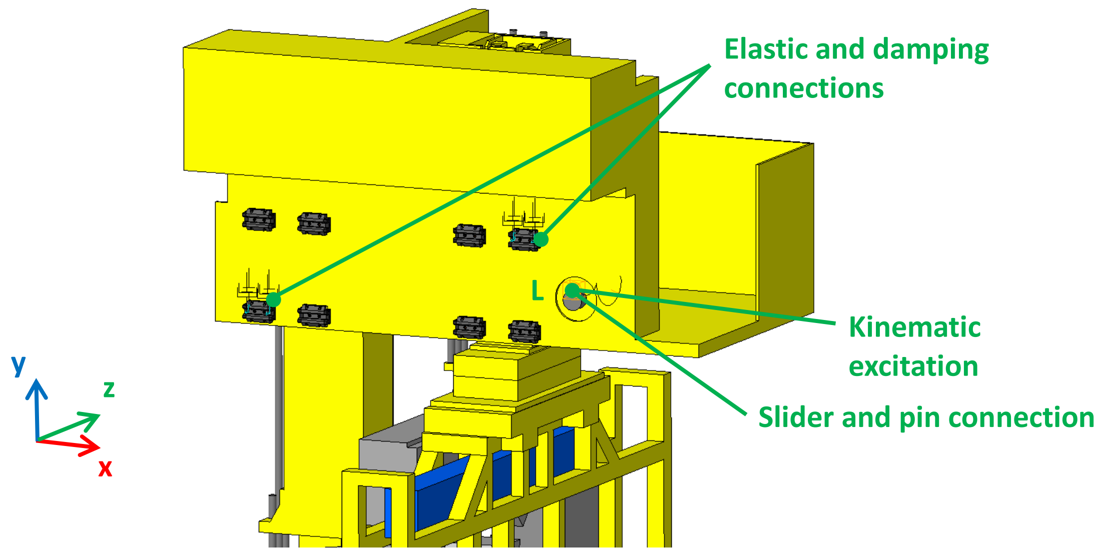

Fig. 7: Dynamical model

The velocity data used for kinematic excitation were taken from the data of an electric motor frequency converter. Stiffness and damping coefficient may be calculated using the evaluated natural oscillation frequency. The stiffness is

$$k_y = \frac{J_z (2\pi f_z)^2}{\sum_{j=1}^{n} l_j^2} \quad (1)$$

where J_z is the moment of inertia related to the z axis, f_z is the natural frequency related to the z axis, l_j a perpendicular distance between L point and damping and elastic connection and n a number of damping and elastic connections.

The damping coefficient equals

$$b_y = \frac{2\sqrt{J_z k_y \sum_{j=1}^{n} l_j^2}}{\sum_{j=1}^{n} l_j^2} b_{rel} \quad (2)$$

where b_{rel} is the relative damping coefficient.

Results

The measured and simulated values of acceleration are compared in Fig. 8 – Fig. 11.

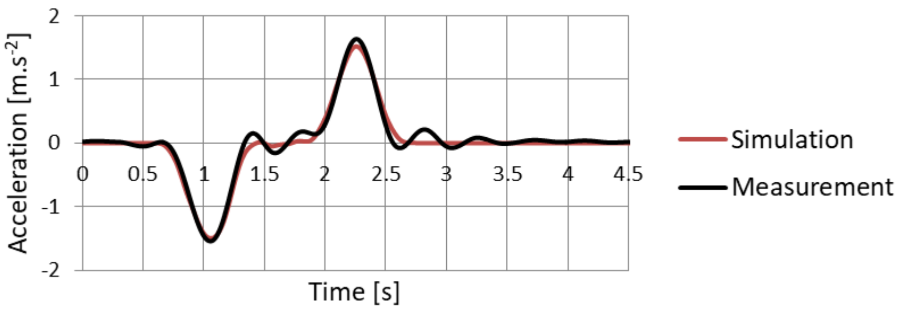

Fig. 8: Acceleration in x axis direction at the first point

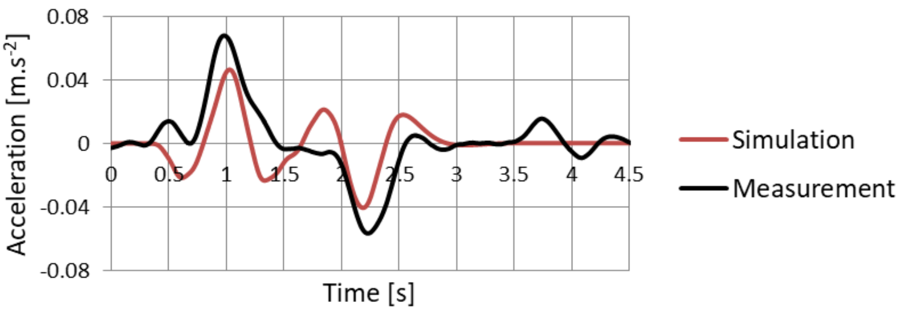

Fig. 9: Acceleration in y axis direction at the first point

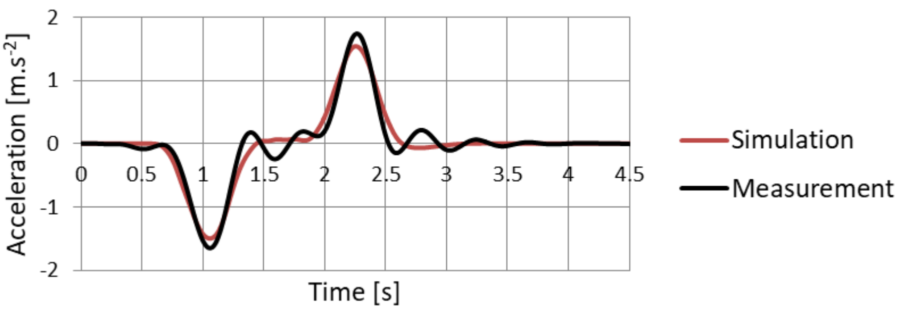

Fig. 10: Acceleration in x axis direction at the second point

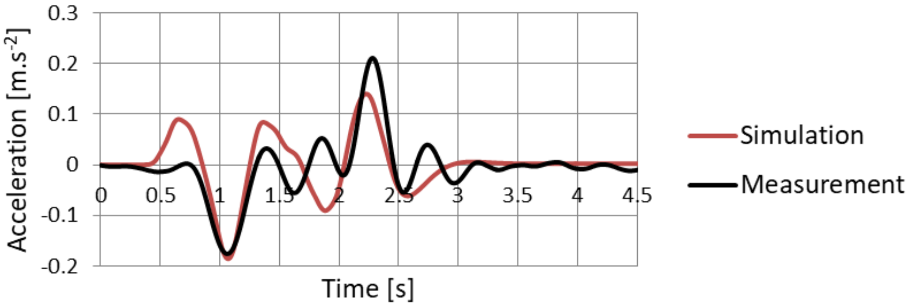

Fig. 11: Acceleration in y axis direction at the second point

Results show a sufficient match between measured and simulated values of acceleration. The identified dynamical parameters, especially stiffness and damping coefficient, may be further used for calculation of the dynamical load of manipulator linear rolling guides.

Conclusions

The paper describes the identification of dynamical parameters of manipulators. The proposed method uses a comparison between measured values of acceleration at two defined points and acceleration values calculated by numerical simulation. The results, demonstrated on the specific manipulator of clamping frames, show a relatively good match. Identified dynamical parameters might be used for calculation of the dynamical load of linear rolling guides. In granted patent [1], the authors pointed out the negative effect of linear rolling guide load on identifying their wear. For evaluating this negative effect to the failure detection in practice, dynamical parameters of the operated machine need to be sufficiently identified at first.

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