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A DYNAMIC ANALYSIS OF AN INDUSTRIAL CNC PLOTTER

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Abstract: *In the paper the drive parameters for a planned machining process have been determined. For this purpose, a dynamic analysis of a CNC plotter has been carried out in the Motion module of the SolidWorks program. The results have been used in the design stage of an industrial plotter for a Polish company producing CNC machines.*

Keywords: dynamics, CNC plotter, SolidWorks.

1. Introduction

This work illustrates how the parameters of drives, for the planned machining process, can be determined using the SolidWorks software (Weber & Verma, 2014). The research was conducted for an industrial CNC plotter (Fig. 1b) which is produced by the Kimla company. This machine tool is designed for processing materials such as non-ferrous metals, plastics, composite materials and wood.

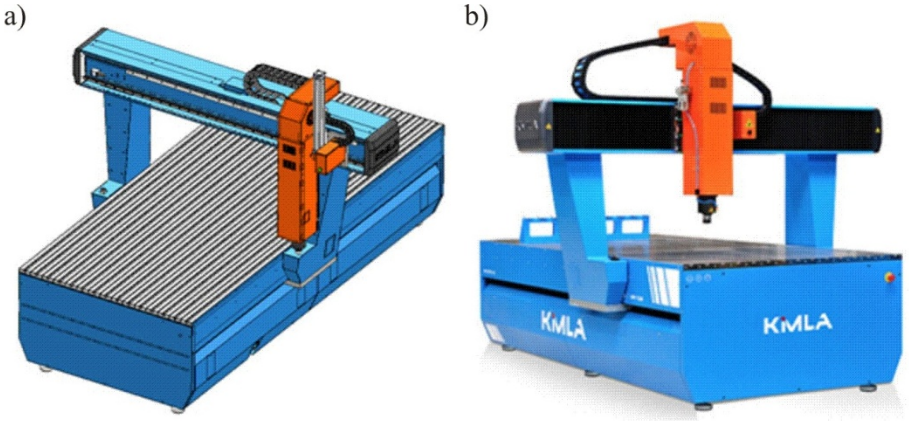

Fig. 1: An industrial CNC plotter: a) geometrical model, b) real object (www.kimla.pl).

2. Simulation of duty cycle

For the dynamical research (Cekus, 2013; Posiadała et al., 2013; Waryś et al., 2014) a parametric geometrical model (Fig. 1a) (Cekus et al., 2014) was worked out in the SolidWorks program. The study was conducted in the Motion module. It was assumed that some parts of the machine could be treated as rigid assemblies during the analysis. This procedure is not required, but can significantly reduce computation time. During the computation, those parts, located inside the rigid assembly, were constructed as being stationary relative to each other. This is to avoid errors caused by the insufficient restraint of some components.

The conducted research concerned the machining processing of an aluminium plate. The task was divided into three stages (Nagata & Watanabe,2014; Zhao et al., 2014; Siciliano et al., 2009) (Fig. 2):

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- start-up - the tool length and the start position is set,
- working of the detail,
- tool retracting - the gateway machine moves away from the working area in order to facilitate the removal of the made details.

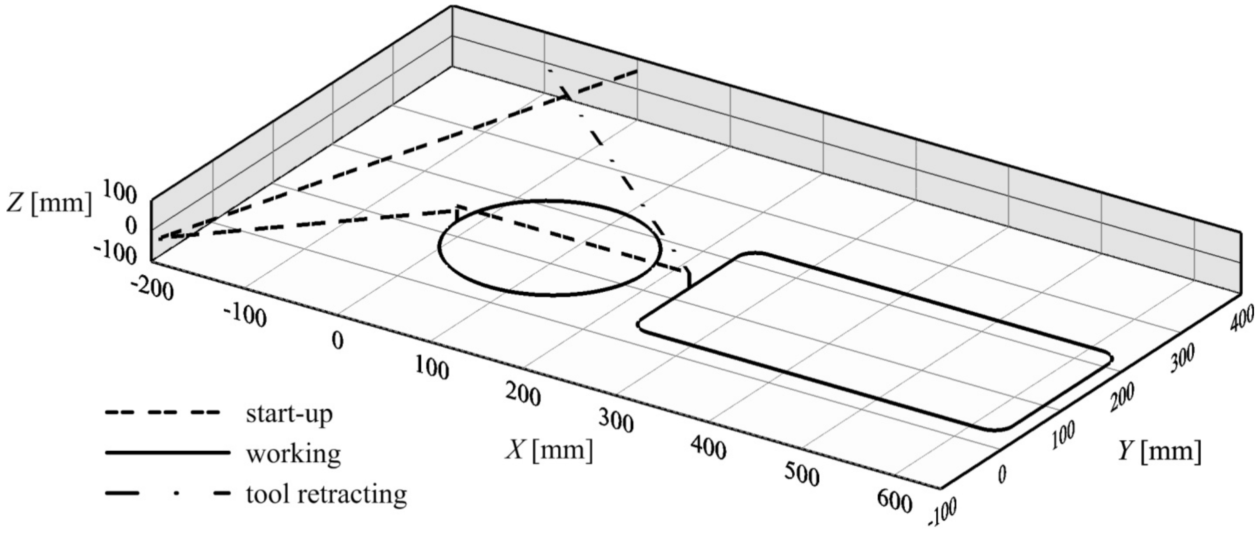

Fig. 2: Tool path.

For each machine axis (*X*, *Y*, *Z*) a separate drive was defined and, on the basis of the planned duty cycle (Fig. 2), the dependence of the position versus time was assigned (Fig. 3). These functions were imported into the SolidWorks using a function generator.

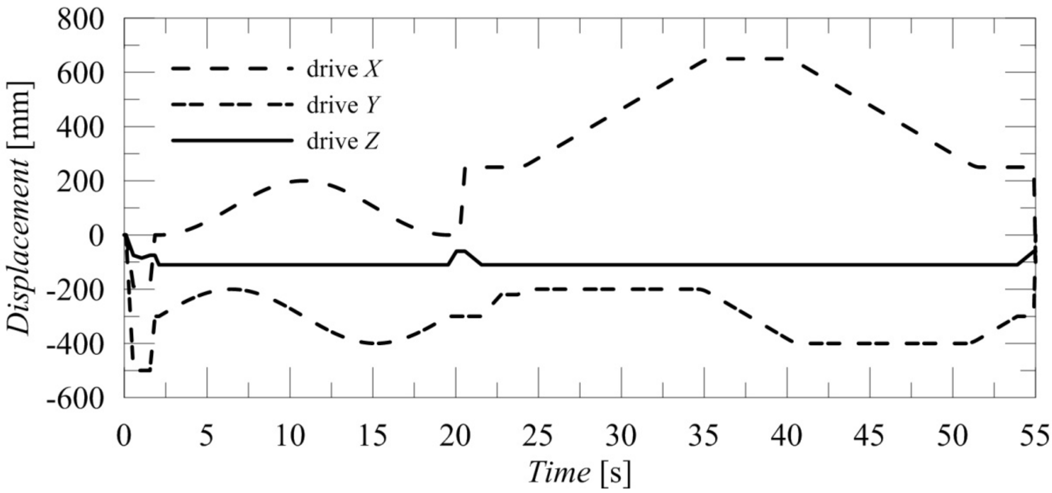

Fig. 3: The dependence of the position versus time for the drives.

3. The results of dynamic analysis

The loads of the plotter drives during the planned working cycle were determined using the above assumptions. The obtained results are presented in Figures 4-6.

The force values (Fig. 4-6) required to move the drive contain many overstated values, which are visible as so called "pins". Therefore, statistical computations were performed to determine the arithmetic mean value (1), standard deviation (2) and typical area of variability (3) (Table 1).

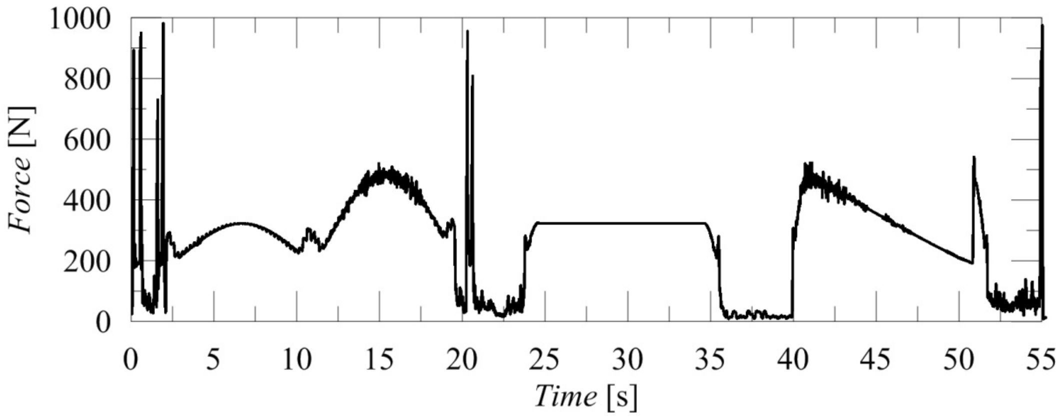

Fig. 4: The load of drive X during the duty cycle.

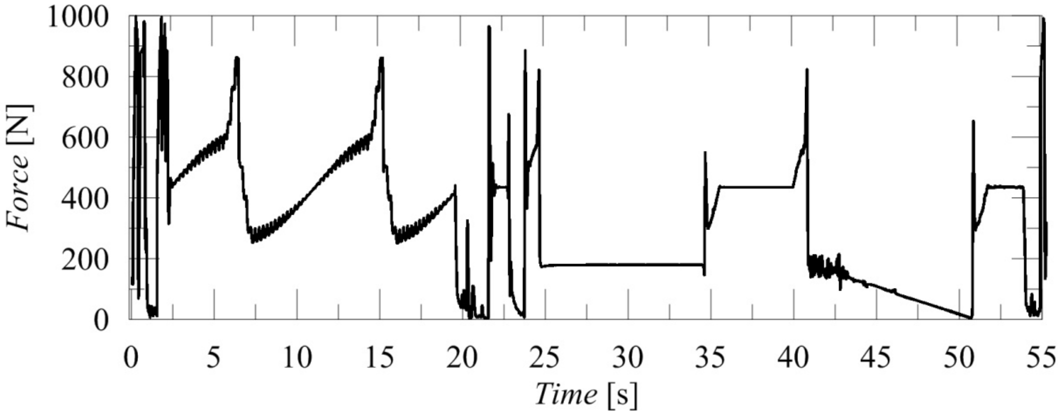

Fig. 5: The load of drive Y during the duty cycle.

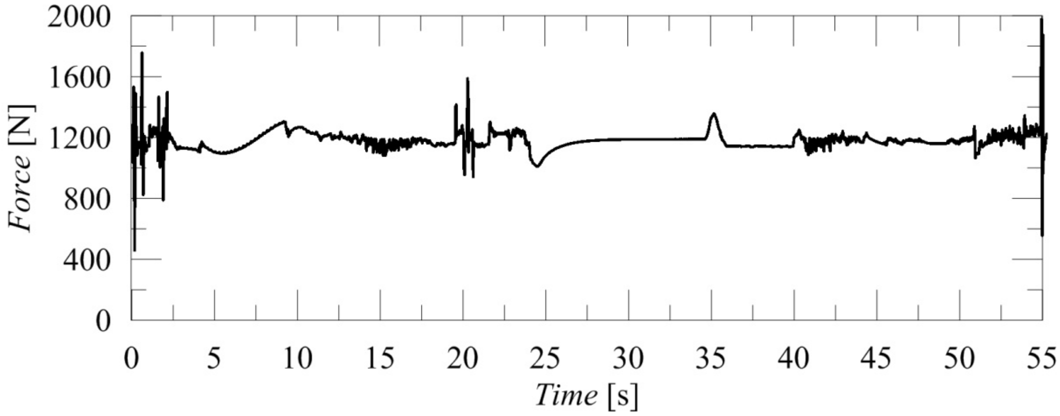

Fig. 6: The load of drive Z during the duty cycle.

$$\overline{x} = \frac{\sum_{i=1}^{n} x_i}{n}, \; s = \sqrt{\frac{\sum_{i=1}^{n} \left(x_i - \overline{x}\right)^2}{n}}, \; \overline{x} - s < x_{typ} < \overline{x} + s \qquad (1\text{-}3)$$

Tab. 1: The results of statistical analysis

	X axis	***Y axis***	***Z axis***
The arithmetic mean value of the force	*287 N*	*395 N*	*1179 N*
Standard deviation	*465 N*	*1123 N*	*145 N*
Typical area of variability	*-178 ÷ 752 N*	*-728 ÷ 1517 N*	*1034 ÷ 1324 N*

Using the obtained values (Table 1), the drive and transmission parameters can be determined. For drive *X* and *Y* the torques are:

$$M_x = P\frac{d_w}{2} = 16.75\ \mathrm{Nm},\ M_y = P\frac{d_w}{2} = 33.82\ \mathrm{Nm}, \qquad (4, 5)$$

where: d_w - the pitch diameter (44.56 mm), *P* - circumferential force (the maximum value of variability interval for the respective axis)

The torque for drive *Z* for the reversing mode is:

$$M_z = \frac{F_b L \eta}{2000\pi} = 2.34\ \mathrm{Nm}, \qquad (6)$$

wherein: F_b - the axial load [N] (the maximum value of variability interval for the *Z* axis), *L* - pitch of thread (10 mm), η - efficiency of machine (0.9).

4. Conclusions

It is possible to use the SolidWorks program to determine the load drives at the design stage of machine sets. This helps to reduce significantly the cost of making a prototype. The determined values of the driving forces are of minimum values to provide motion. Drives with higher parameters must be selected in order to ensure adequate dynamics and the reliability of the machine.

The dynamic computation method presented in this paper has been implemented by Kimla, a Polish company producing CNC machines.

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