Development of a Virtual Model for an Over-Determined Parallel Kinematics Structure

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Overview

Modern cutting processes make high demands on new machine tool concepts with improved mechanical stability and better dynamic behaviour. A main focus of the Institute for Production Engineering and Laser Technologies at Vienna University of Technology is on the design of machine tool structures with parallel kinematics [1][2][3].

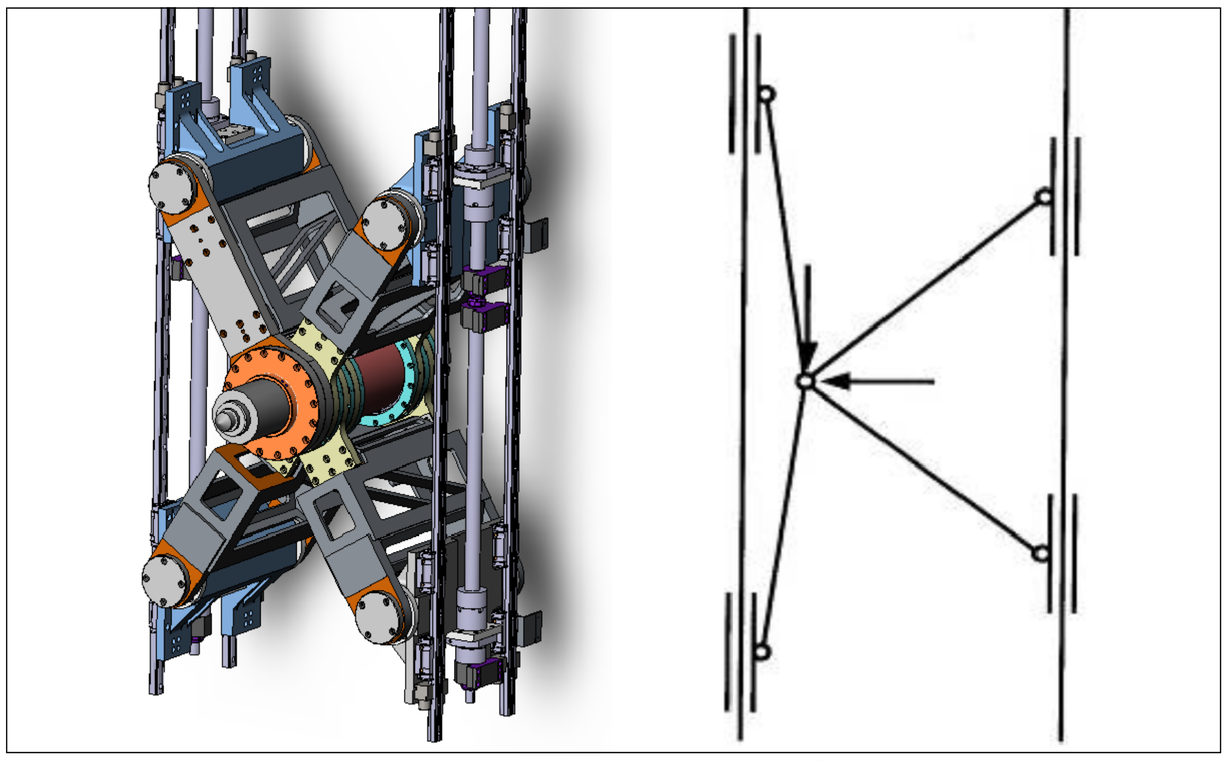

Figure 1: Mechanical structure X-Cut

The newly developed machine tool "X-Cut" (refer to Figure 1) has a degree of parallelism of two, incorporating four drives for the X-Y plane movement whereas in simple scissors kinematics only two drives are necessary [2]. Due to the complex behavior of the kinematics structure a new method in NC-controller programming and parameterisation is needed [3].

I. Introduction

These new controller strategies require an accurate model to test and optimize control algorithms. In the following a specifically developed Matlab/Simulink© model of the X-Cut-structure will be presented.

II. Mechanical Model

In a first step the geometric structure of the X-Cut was reduced to a mechanical model and parameterised as shown in Figure 2. The length of the struts are variable (restricted to spring rigidity and damping constant) to expand the system by additional degrees of freedom and solve the over-determination.

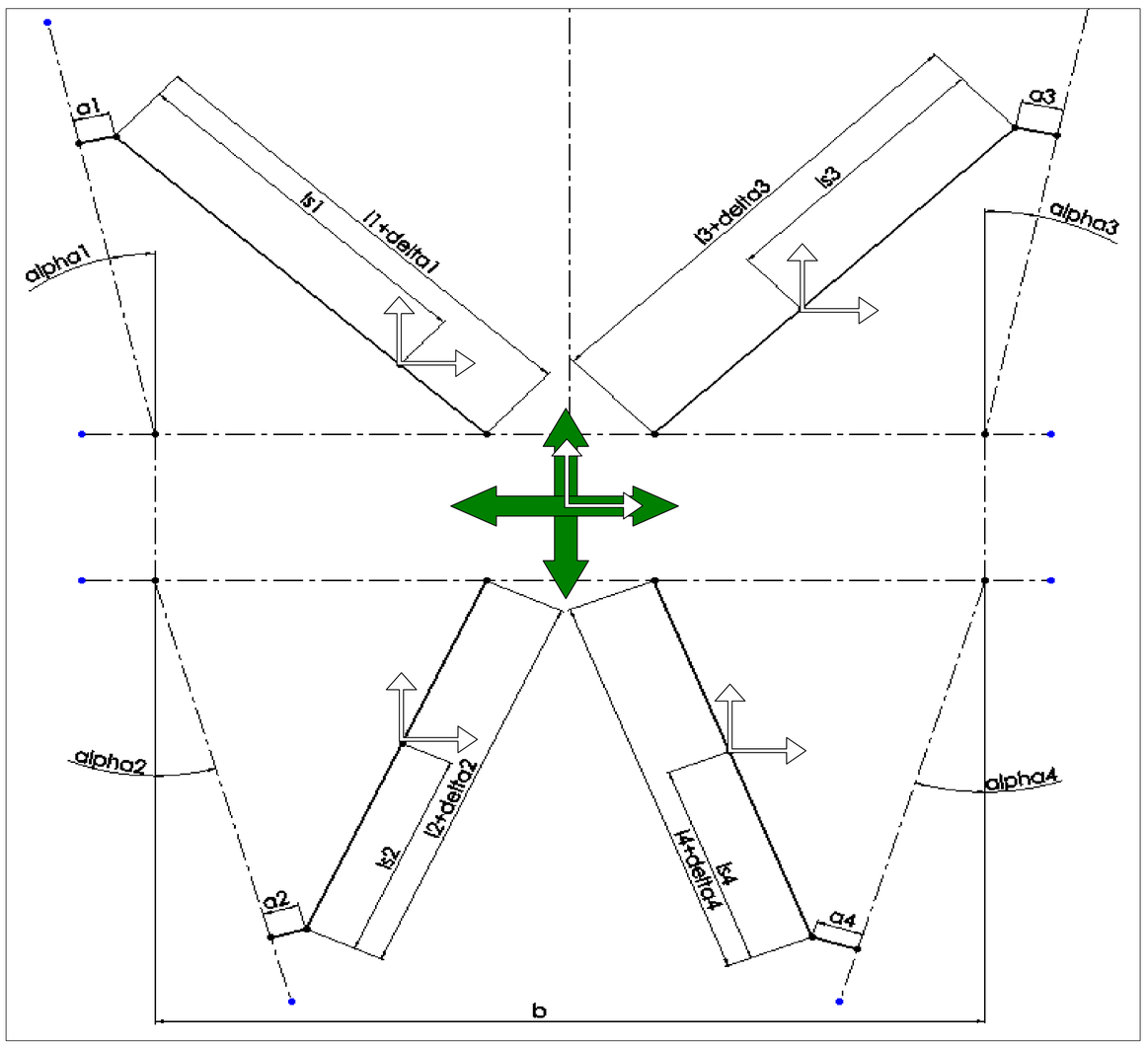

Figure 2: Geometric structure X-Cut

III. Matlab modelling

This model of the mechanical structure was transferred to a Matlab/Simulink© model, using the Simscape/ SimMechanics© library (refer to Figure 3).

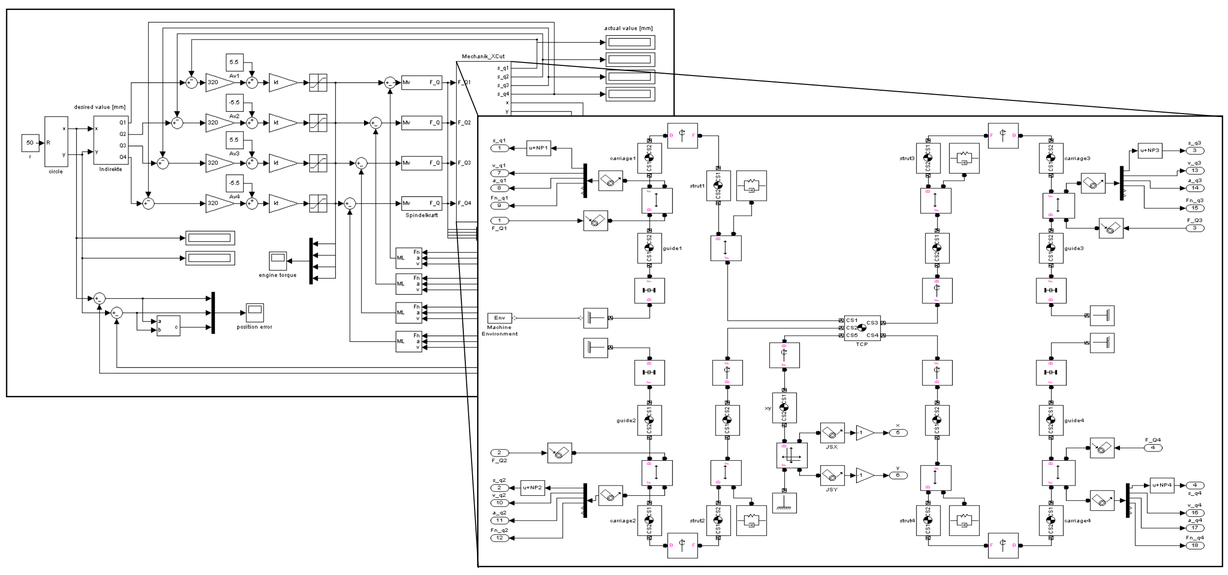

Figure 3: Simulink model

IV. Experimental Results

A test with a circular path showed reliable and consistent results with an average position error of 0.02 mm (refer to Figure 4). The sizeable error at the beginning of the simulation can be traced back to the sudden impact of the gravity, which can be seen as a force step input at the start to the unloaded structure.

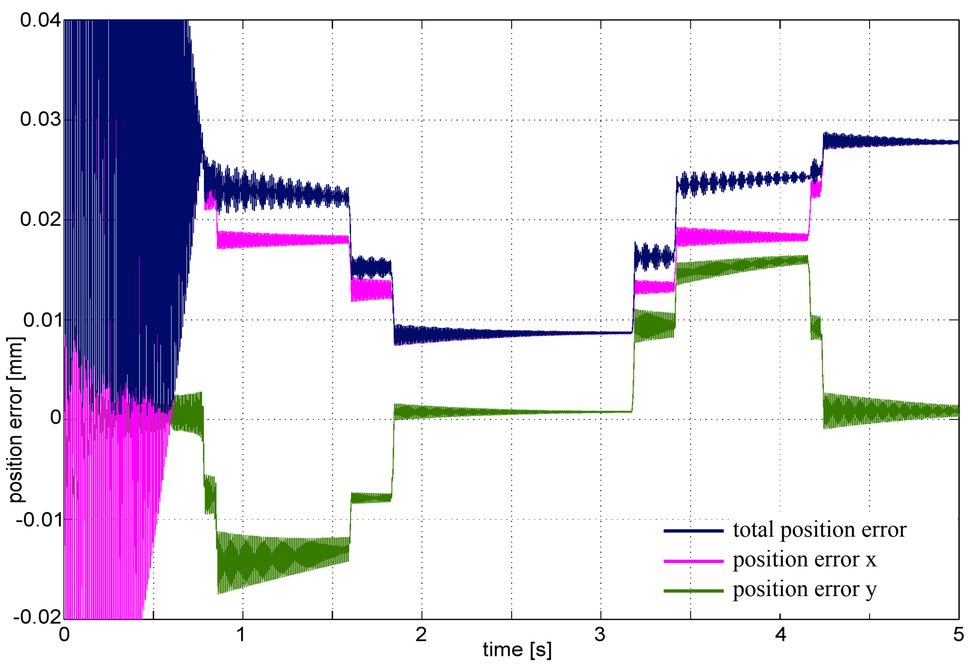

Figure 4: Position Error

V. Conclusion

The results of the simulation tests show that sophisticated controller algorithms are necessary to use the full potential of the X-structure. Especially the different kinetic characteristics within the workspace and changes of the slide movement direction have to be compensated by appropriate controller algorithms. The model itself is qualified to test and optimize these algorithms.

For example, in this design's controller algorithm two carriages are position controlled and the other two carriages are force controlled, which exert a constant pressure to the position controlled drives. In this case the forces are dependent on the x/y position, the speed, and the acceleration. The dependency of the x-position and the acceleration in x can be seen in Figure 5.

Additionally the model will be fine-tuned, particularly in the field of the electrical drives and the friction of the joints.

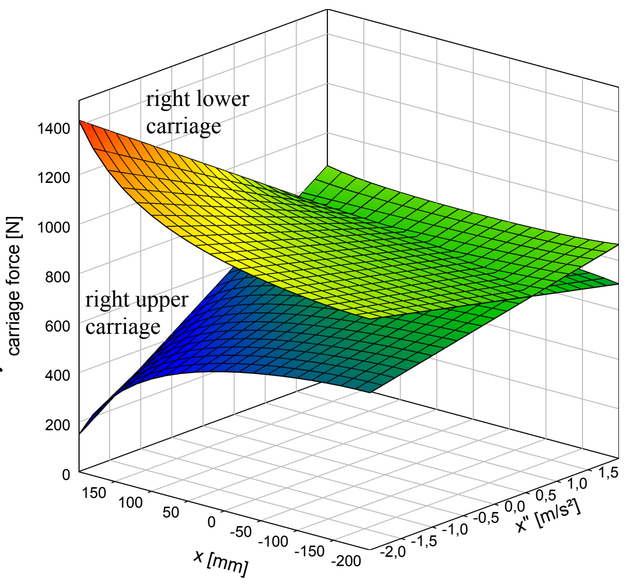

Figure 5: Carriage force over x, x¨

References

[1] Bleicher, F., Entwicklung einer parallelkinematischen Bohr- und Fräseinheit für den flexiblen Einsatz in automatisierten Anlagen. TU Wien, Habil.-Schrift. (2001)

[2] Mikats, T., Puschitz, F., Bleicher, F., New Machine Tool Concept 'X-Cut [online] http://www.br-automation.com/files_br_com/ Mikats09_New_Machine_Tool_Concept_X-Cut.pdf (2009)

[3] Puschitz, F., et al, NC-Controller strategy for the novel machine tool 'X-Cut'. In: The 20th DAAAM World Symposium (2009), pp. 1691-1692