

# Simulation bunching machine – Find the right settings

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## **Kurzfassung**

Dieser Beitrag beschreibt die Entwicklung eines Mechatronik-Modelles eines 5-Achsen Antriebsverbundes einer Draht-Produktionsmaschine im Bereich Verlitz- und Verseilanlagen der Maschinenfabrik NIEHOFF GmbH & Co. KG. Das Ziel: Effizientere Entwicklungsprozesse und ein verbessertes „Time to Market“ beim Testen und Erproben zu erreichen, ergab die Einführung der CAE-Software SimulationX. Nachfolgend wird der Nutzen dieses mechatronischen Simulationsmodells bei NIEHOFF vorgestellt. Es können vorab wichtige Erkenntnisse bezüglich elektronischer und mechanischer Konstruktion gezogen werden. Gezeigt wird die methodische Umsetzung. Dargestellt ist ein Verbund aus Mechanik, Elektrik, Software und der Regelungstechnik. Zudem werden ausgewählte Szenarien (Minimieren von Stillstandszeiten beim Kunden und neue Anforderungen an die Maschinenfähigkeit) erläutert. Die Szenarien veranschaulichen, wie die richtigen Einstellungen für eine Drahtproduktionsmaschine gefunden werden können.

## **Abstract**

This article describes the development of a mechatronic model of a 5-axis drive system of a wire production machine in the field of stranding lines and bunching machines at machine factory NIEHOFF GmbH & Co. KG. The goal in the future was to achieve more efficient development processes and an improved “time to market” for testing and proving. This leads to the introduction of CAE software SimulationX. In addition, presented is the benefit of this mechatronic simulation model at NIEHOFF. In advance, important results regarding electronic and mechanical construction can be gained. Shown is the methodical implementation. Explained is a combination of mechanics, electrics, software and control technology. Also documented with selected scenarios (Minimize down times at

customer site and new requirements for machine capability). The scenarios illustrate how to find the right settings for a wire production machine.

## Motivation

The main goal was to achieve economically benefits for the machinery manufacturer NIEHOFF. One fact is "Time to market". Testing and proving on the machine model closely related to this slogan. The testing effort for a new control constellation in the field of bunching machines currently takes about 15 man-days. This time must be shortened based on a physical model of the machine. Developing a mechanical or electrical system design before the first prototype is another motivation. For this purpose, various simulation options are defined in the first step. The construct of the drive system must provide results on the control characteristics and confirm the function of already inserted control characteristics. Furthermore, the mechanical as well as electrical system properties and disturbances should be configurable parameterizable. In summary, goals have been defined. The first goal is to minimize down times at customer site. The second target is to find an optimal line configurations for each type of bunching machines. Finally yet importantly, another motivation is to find the right settings for new requirements concerning machine capability.

## Implementation

Based on the manual "Simulation of Mechatronic Systems", the simulation model built up with SimulationX. For this, the model was structured. This means that partial models have been worked out. They are building together an overall model. The simulation model is divided into the mechanics, the drives and their control. These component models were tested separately for their functionality [1].

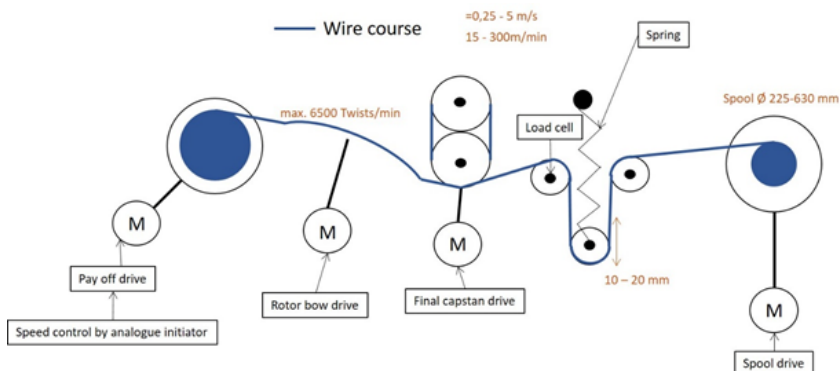


Figure 1: Machine structure of bunching machine

The graphic shown above was used for the implementation of the mechanical model. The design was made by NIEHOFF engineers. Shown are the most important deflection rollers or measuring boxes, mechanical components and the drives used [2]. In addition to this graph, a structure of the spooler control has been outlined. Next to this control structure there is an "auto-tune". The "auto-tune" function adjusts the gain of the wire force PID control using a state machine. If the vibrations exceed a permissible coiling force range, a tripping time will be triggered. The gain is multiplied with a factor over one, if this time is longer than the given "maxHardPeriodTime". The control is too soft. Therefore the influence will be increased. In contrast to this case, the time could be shorter than the "maxHardPeriodTime". Here the gain is multiplied with a factor lower than one. For example 0,66. The influence will be reduced. If the gain has been changed, three seconds will be waited until the next measurement.

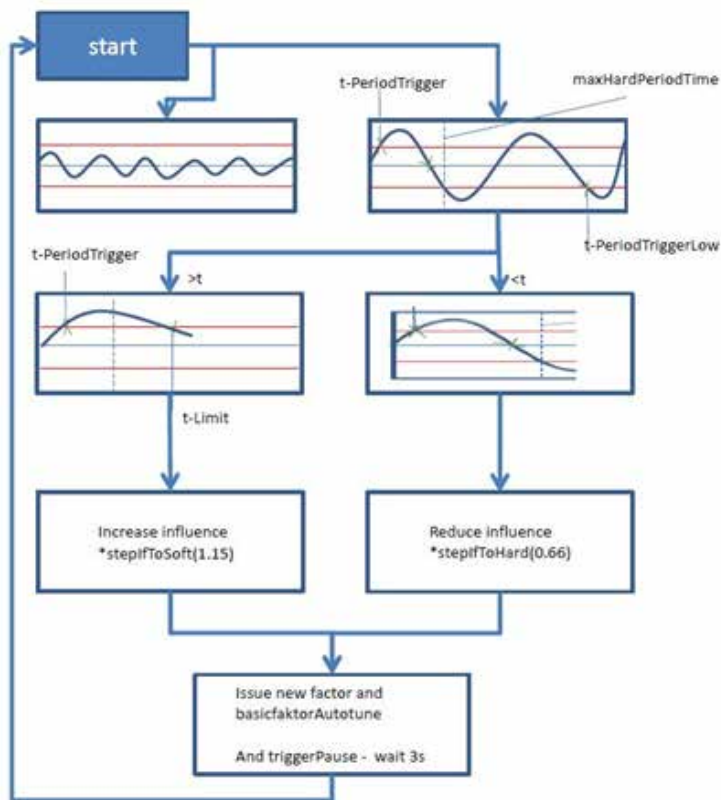


Figure 2: state machine - auto tune

This state machine was implemented in the Type Designer. A part of the source code is shown in Figure 3.

```

when time>tDelayStart and pre(eCurrentState)==EnumState.wait_initial then
    eCurrentState = EnumState.wait;

//////////start Tune
elsewhen valueAct<valueRef+tolVal and pre(eCurrentState)==EnumState.watch then
    eCurrentState = EnumState.start_tune_high;
    tSamplePeriodTrigger = time;

//////////high to hard
elsewhen valueAct<valueRef and time-pre(tSamplePeriodTrigger)<maxHardPeriodTime and pre(eCurrentState)==EnumState.start_tune_high then
    eCurrentState = EnumState.step_to_hard_high;
    faktor=General.Functions.Math.Limit(minFaktor, stepIfToHard*pre(faktor), maxFaktor);

//high-Abbruch
elsewhen valueAct<valueRef+tolVal and time-pre(tSamplePeriodTrigger)>maxHardPeriodTime and pre(eCurrentState)==EnumState.start_tune_high then
    eCurrentState = EnumState.wait;

```

Figure 3: Extract of source code auto tune

The main component of the implementation is, in addition to the control, the inverter motor model. This model is a library model that we got from a converter manufacturer. Therefore, no further graphic was created. A review of the model has been made by the converter manufacturer, so there was no extra test time [3]. These three parts were combined to create a structured SimulationX Modell. So there are areas for the drives, the material properties, spooler drive control and force calculation in the model.

Additional items realized in SimulationX:

- Execution of a calculation matrix via variants wizard
- User-dialog with the most important input and output values
- Modelling of rotor-bow with calculated friction values
- Adaptive control for the spooler drive

## Examples for the use of SimulationX

The following use cases show the achievable benefits when using the simulation and the sub-sequent evaluation of the simulation results.

## 1. Minimize down times at customer site

The first scenario, described below, is to minimize the down times at customer site. Faster error diagnosis with model and simulation are in the focus. If the customer experiences a machine problem, this must be investigated. There are parameters, the model needs from customer site. This includes product-related data, like number of twists, lay-length, coiling and back force and the material properties. In addition to these data, a detailed error description is required, which can be sent via video. The malfunction is set with the mentioned properties and can be simulated in the described operating point. The second step is, for example, to optimize the control parameters. Then the modification is checked by another reproduction in the working point. Finally, a complete test table is simulated to ensure that the revision is in good operating condition over the total range of parameter values. The following graphic shows the result. It is a 3d-diagram created in python. The simulation runs at a production-speed of 60 to 300 m/min. The winding force was kept constantly at 50N. In addition, complete coil fillings were simulated.

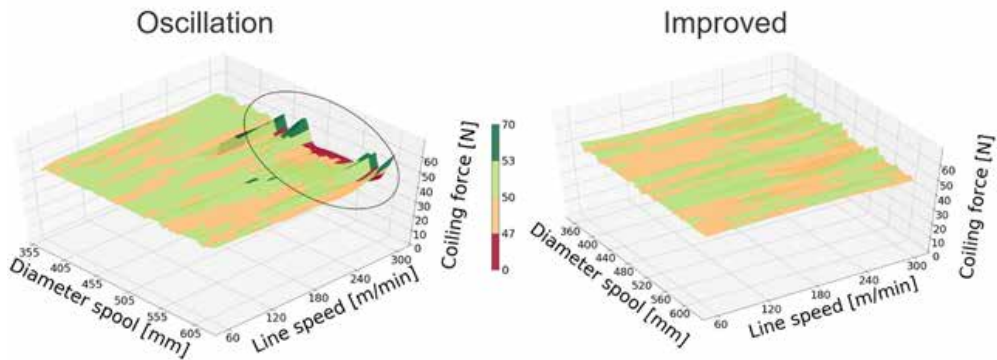


Figure 5: Result Scenario 1

The comparison before and after a malfunction is displayed. Visible is the winding force fluctuation in the left graph at a coil diameter of about 480mm. In the right test run, these fluctuations were eliminated. This improvement was achieved by a control parameter change in the speed control of the take-up drive.

## 2. New requirements for machine capability

Now the benefits of the simulation tool are displayed when the customer is faced with new requirements concerning the machine capability. For example, the customer requires a tighter coil winding beyond the datasheet. Normally forces up to 100N can be realized. It is imaginable, that the coiling force should be 130N. The reason for a stronger coil winding is that the goods are transported by sea. Due to the long transport routes, the wire could loosen at low winding force. Of course, product-related data must also be provided by the customer. These data are used to test the model with the desired settings. The result will be checked. It is recognizable that the standard dancer spring is always at the stop position during winding. The dancer cannot regulate coiling force oscillation. Due to this, the spring must be replaced, a harder spring is necessary. The load cell also has to be replaced to measure bigger forces. Subsequently the stiffness of the spring is chosen stiffer in the simulation model bit by bit. Each new situation is retested in the simulation, whether the dancer spring is again in an optimal control range. 10% change in coiling force is allowed. The following figure shows the curve of the coiling force with the standard spring and the new harder spring.

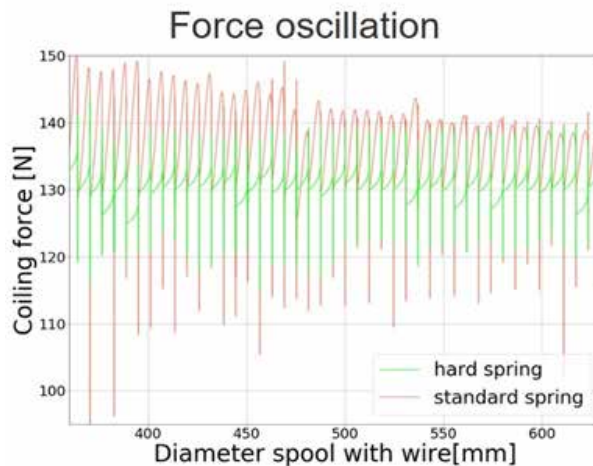


Figure 6: Result Scenario 2.

It can be seen that the new spring oscillates within the specified tolerance. In contrast, the standard spring is outside. Now a spring can be selected from the catalogue, which corresponds to the dimensions in the simulation. The result of these steps is to consider new requirements in advance with the simulation model.

## Summary

This article describes how the integration of SimulationX took place within the development and serial support process of NIEHOFF bunching machines. The presented approach allows an automated simulation with parameter variation using SimulationX as a simulation kernel. Finally, two examples were presented that highlight the benefit of a digital twin.

In the near future, the model will be converted to a larger bunching machine. The D1252 is a new construction. Therefore, the simulation tool is made available to commissioning colleagues for shortening the testing periods when this new design is running for the first time on the test bench. For ease of use, the model is provided as an executable file to colleagues.

## Bibliography

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