# INTRODUCTION AND VALIDATION OF A 7 SHEAVE EXAMINER MACHINE

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**Abstract:** Sometimes unexpected overloads start up in multi-sheave cable systems by synchrodrive. These overloads can not be foreseen and cause the breakage of the rope(s). There are many parts that have to be analyzed, for example: type of cable or rope, the number and the diameter of the sheaves, type of grease, etc. So, there are several parameters with various effects. These parameters and their influences were need examining. Later with these results an optimization could be made with changing the parameters. The main point is safety and how to avoid the breakage. Planning, producing and validating an examiner machine were necessary.

**Keywords:** Seven sheave examiner machine, validation

## Introduction

A 7 sheave examiner machine is needed to analyze because of the overloads. The influence of the variable diameters can be registered with the developed machine. This machine is a prototype so upgrades can be made later if they are necessary. By the developing there were a lot of aims that have to be accomplished such as using variable type of springs, various loads, using sheaves with variable diameters at variable speeds. The produced machine is fully complete the tasks and aims. There were several questions by the construction but at first a number of sheaves had to be defined. The effect could have been seen by normal conditions has to appear here, too. Seven sheaves were the acceptable and sure choice why the effect can not be seen by 3 sheaves or less. The kinematical draft of the machine is in figure 1.A. By this machine a spring is used instead of a wire rope to achieve the simply and correct measuring. The distance of spring threads can be registered with a camera more easily than bearing pressure by wire rope with force register. The linear characteristics are almost the same, but the main difference between the rope and the spring is in the coefficients of elasticity and cross contractions. The coefficients of elasticity can be recast, and the cross contractions is diagnosable with using several types of springs. The result of this developing can be seen in figure 1 B, and C. These figures are the CAD model of the machine. The operation of the machine is simple. The springs superpose on the sheaves which are lubricated. The ends of the spring are attached to the drums. The drums have a part where the diameter is less because lines are fastened to them. Variable loads can be placed at the other end of the lines. The upper body of the 7 sheave machine is tall enough to ensure the right way of the loads and it is fixed high to the wall. An electric motor drives the "driving sheave" and a frequency changer is used to control it. Two limit switches are used for reversing. The procedure of the measuring is not difficult because of the visual measuring. The ground of this measuring can be seen in fig. 2.

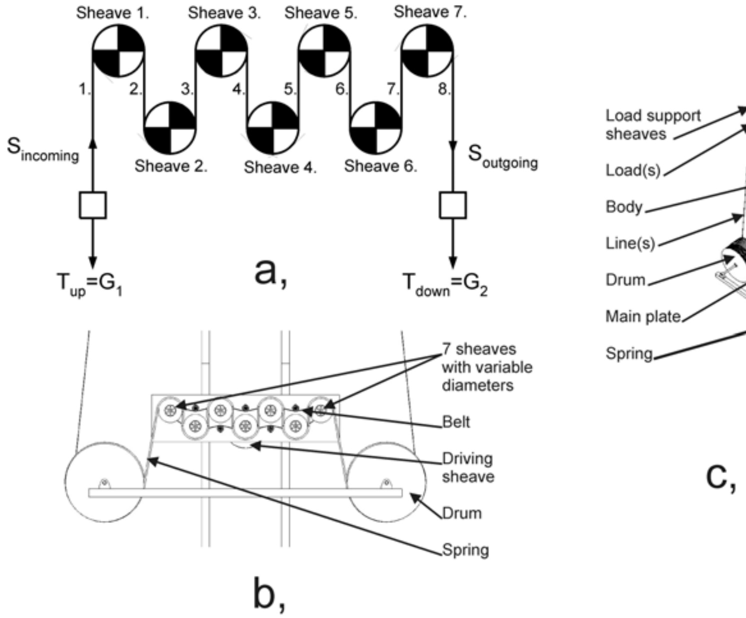


Figure 1. The kinematical draft of the examiner machine (a,), the front view of the CAD model of the machine (b,) and the general view of the CAD model of the machine (c,)

At first the spring has to be placed to the sheaves and then the ends have to be fixed to the drums. After that the loads have to be fixed to the ends of the lines. The following step is the start. The system and the spring need time because of the transient processes. The machine and the spring need 2 or 3 back-and-forth running. A photo has been taken before reversing and after that the distance of the threads can be measured manually with a photo editor program. At first all of the threads were analyzed but that was too much information. When only the vertical branches were measured, the result was the same, so the threads were needed to measure only in the 8 branches. This is a simplification but a lot of time can be spared with this modification.

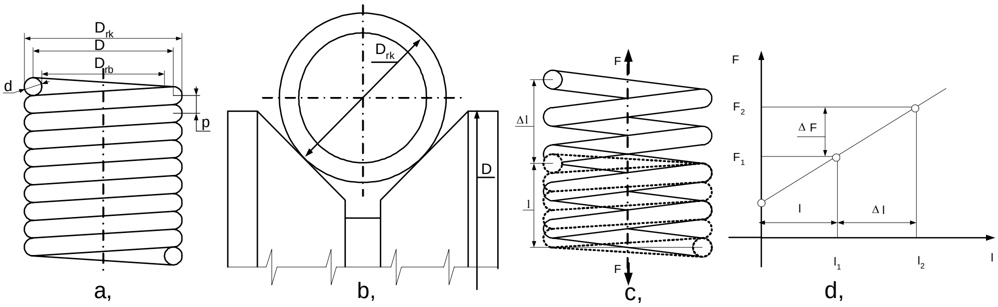


Figure 2. The draft of the used cylindrical spring (a,), the seat of the spring on the sheave (b,), the elongation of the spring is linear (c,) and the force (ΔF) in the spring can be counted from the measured elongation (Δl) (d,).

## The choosen parameters, units and their notation system

At first we had to collect all of the parameters which could have an influence on the overloads. The parameters can be seen in table 1. These parameters can be grouped from another aspect. There are parameters which are predefined, and there are some which can be modified free, and there are some which can be defined as constant ones. For example the diameter, the number, the groove, the material of the sheaves is predefined because these parameters are set under the producing. The parameters of the rope or spring are familiar to the sheaves. The direction of the system can be modified at any part of the measuring. The temperature can be defined as a constant figure, because the examiner machine is in an air-conditioned room.

Table 1. The collected parameters of the system

| **Sheave** | **Wire rope** | **System** | **Environment** |
|---|---|---|---|
| Diameter | Diameter | Direction of running | Temperature |
| Number | Wear | Revolution speed | |
| Wear | Structure | Running time | |
| Place | Lubrication | Lubrication | |
| Groove | Material | Loads | |
| Lubrication | | | |
| Material | | | |

The knowledge of these parameters is not enough for the validation. Several units of these parameters need to define. With the concrete units a measuring program can be made, because all of the parameters and the units can be set by the machine. A table of the basic units is used to define the zero level of the parameters. Beside the zero level, the upper and the lower limits of units are necessary to define. The measuring program can be measured only if the upper, the basic and the lower level units are defined exactly. The chosen units can be seen in table 2.

Table 2.The upper, the basic and the lower level of the units

| | **Lower** | | **Upper** | | | | **Basic** | **units** |
|---|---|---|---|---|---|---|---|---|
| Diameters of the sheaves | 140 | - | 180 | | | | 160 | mm |
| Place of the sheaves | Tr A-Tr G | 140 - 180 | | | | | All 160 | mm |
| Width of the sheaves | 10,00 | | | | | | 10 | mm |
| Diameter of the filament | 0,8 | 0,9 | 1,0 | 1,1 | | | 1,0 | mm |
| Pitch of the spring | 1,0 | - | 2,0 | | | | 1,0 | mm |
| Diameter of the spring | 10,00 | | | | | | 10 | mm |
| Drive system | Only the middle one is driven | - | All of driven | | | | All of driven | |
| Direction of the running | Left to right | - | Right to left | | | | - | |
| Loads | 1,5 | 2,0 | 3,0 | 4,0 | 4,5 | 6,0 | 3,0 | kg |

The diameters of the sheaves are going from 140 mm to 180 mm and the basic is 160 mm. The sheaves can be placed to every place. All of the sheaves are driven by basic set-up. The direction of the system has not basic value. With these parameters and units measuring programs can be made which are explained in the next chapter. But at first we need to present the diagram of the results. From every result a diagram can be made. One of these diagrams can be seen in fig 3. On the vertical axis the force in the spring can bee seen in Newton. On the horizontal axis the angle of wrap can be seen. The integer numbers by the horizontal axis are the vertical branches. Between 2 branches the angle of wrap is 180 degree. In the title of the diagram there is information from the sheave configurations and the direction of the running. By this example the 1->7 means that the system runs from the 1st sheave toward 7th sheave, so from left to right. The 7*160 means that all of the sheaves have the diameter 160 mm. The M=150_6*160 means that the diameter of the first sheave is 150 mm and the others are 160 mm. This is the modified sheave configuration. On the right part of the diagram the load configurations can be seen. The left number means the left load of the system the right means the right load. By these loads configuration the letter "M" means that the modified sheave configuration is used by that measuring.

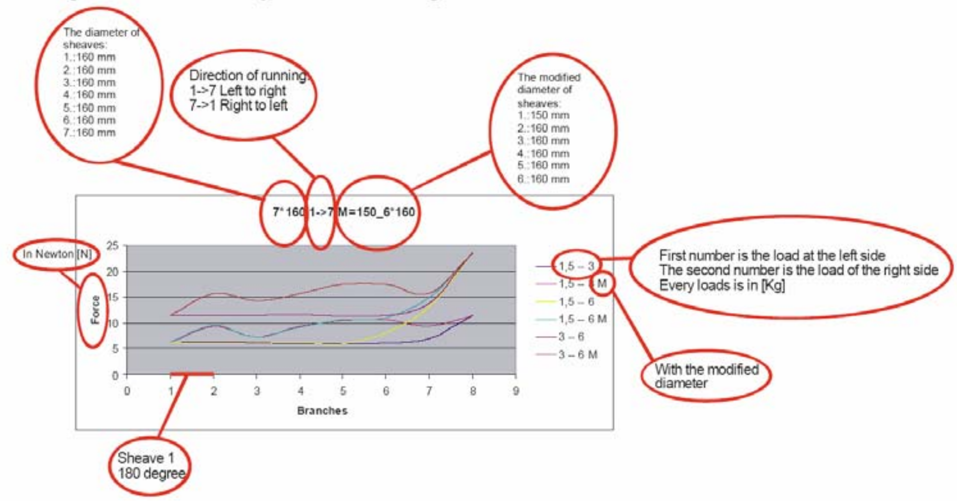


Figure 3. The explanation of the diagrams

## Measuring program of the validation

The validation of our system is one of the most important measuring programs. According to the result of this measuring program we can or can not continue the measuring. By this experience we have to analyze that we can measure the theoretical force transfers in our system. Beside the theoretical diagrams the correctness and the symmetries are important too. If the diagrams of the theoretical force transmission can be measured by our machine, the measuring of extreme overloads will be available too. The second measuring parameter is the accuracy of the system. There is not perfect system, so the knowledge of the failure is necessary to reach further results. And last but not least the symmetry of the system can help us to spare a lot of measuring and time. The parameters of the validation can be seen in the table 3. The measuring program can be produced by the variation of all parameters in table 3. By the validation we can not use any simplification, because the validation will be the ground of all measuring.

Table 3.The measuring program of the validation

| | P1 | P2 | P3 | P4 | Units |
|---|---|---|---|---|---|
| Diameter of the filament | 0,8 | 0,9 | 1 | 1,1 | mm |
| Direction | 1 -> 7 | 1 <- 7 | | | - |
| Loads | 1,5 | 3 | 6 | | kg |
| Sheave configuration | 7x160 | | | | mm |

## The result of the validation

The analysis of the results can be made with the comparison of the theoretical and the measured diagrams. At first the introduction of the theoretical diagrams is necessary. The kinematical draft of the theoretical system and the theoretical diagrams can be seen in fig. 4.

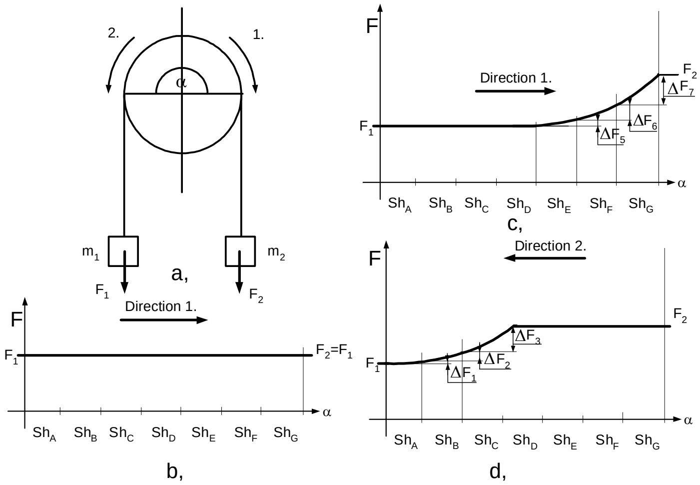


Figure 4 a, Kinematical draft of the theoretical system b, Case of equal loads on both end of the system c, Theoretical lowering diagram d, Theoretical lifting diagram [1]

The kinematical draft consists of one sheave, one rope on sheave and two loads on the both ends of the wire rope. In fig 4 b, c, d, the theoretical diagrams of the case of equal loads, lowering and lifting can be seen. The vertical axis is the force in the wire rope, the horizontal axis is the angle of wrap that is 180 degree here. In fig 4 b, the case of equal loads by both ends can be seen. This is the most common diagram because it is a horizontal line. If the $m_1<m_2$ than there are two more possibilities. The system can run in direction 1 or in direction 2. In fig 4 c, the case of direction 1. can be seen and it is called as the theoretical lowering diagram. Fig 4 d is running backward (direction 2.) and it is the theoretical lifting diagram. The c, and d, diagrams have a horizontal and exponential part too. The validation has been measured by the sheave configuration 7x160. That means all of the diameters of the sheaves in the system are 160 mm. The measured diagrams can be seen in fig 5. The explanation of the diagrams has been introduced in figure 3. The first comparison is between fig 4 b and fig 5 a, diagrams.

These are the cases of equal loads on the both ends of the system. The theoretical diagram is a straight horizontal line. The measured diagram is really close to the shape of the horizontal straight line. Our system measures this theoretical force transmission.

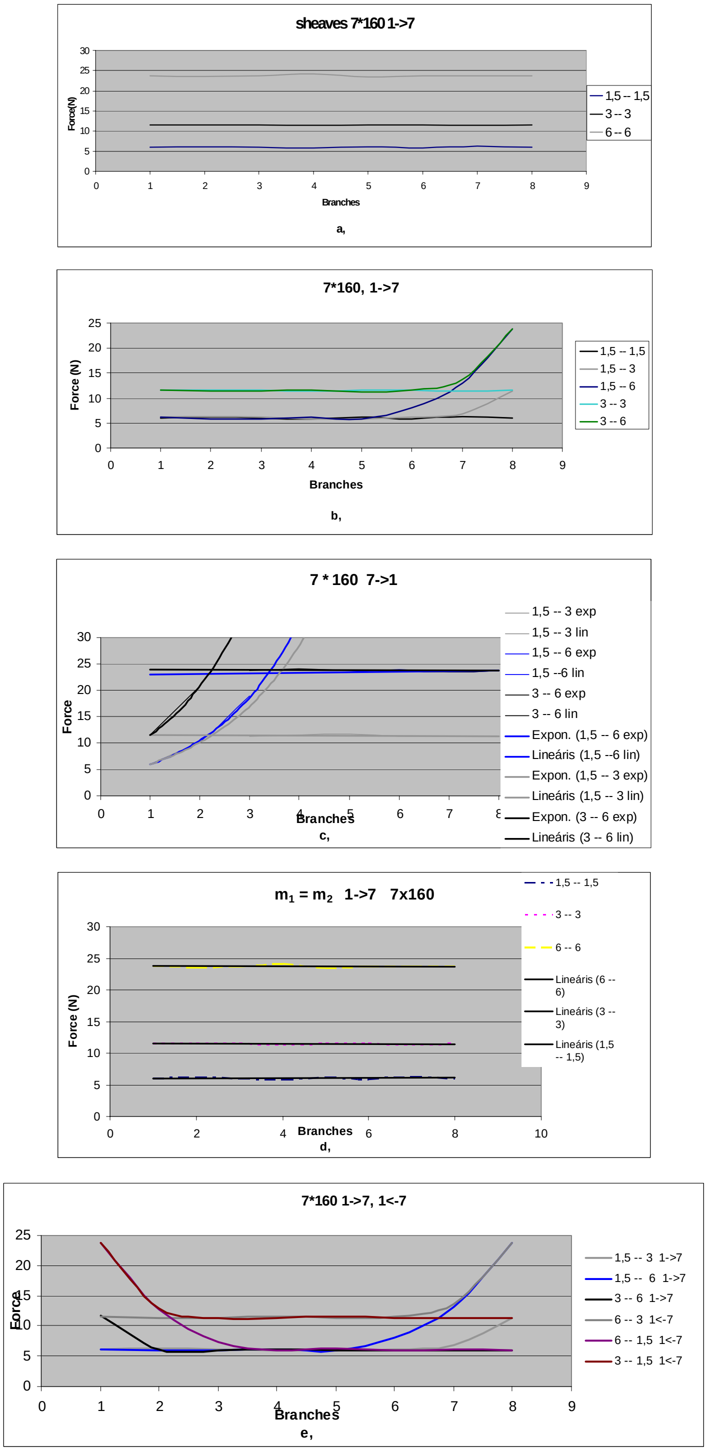


Figure 5. Result of the validation : a, Case of equal loads b, Lowering c, Lifting d, Correctness of the system e, Symmetry of the system

The second theoretical diagram is lowering on fig 4 c. The pair of this diagram is shown on fig 5 b. The shape of the theoretical and measured diagrams are the same. Our system follows the theories well by the lowering too. The last theoretical diagram is the lifting. We have to analyze the difference between fig 4 d, and fig 5 c. The measured diagrams have a lot of unneeded parts. These are here the parts of the exponential line over the horizontal line and the part of the horizontal line on the left side of the exponential line. These are necessary just for the good depiction. The result of the comparison of the two diagrams is that the shapes are near. The diagram in fig 5 d is the correctness of the system. A straight horizontal line has been drawn as a trend line of the force transmission. By this analysis the difference between the trend line and the measured line is important. There can be seen only small differences between the trend and the measured line, so our system is correct enough on this range. The last result is the analysis of the symmetry. It can be seen in fig 5 e, that the symmetry of our system is good. That means the unneccessity of a lot of measuring, so we can do other experiences instead of those ones.

## Summary

The developed and produced 7 sheave examiner machine is available to measure the theoretical diagrams. It is correct enough and also symmetrical. The system is available to make a lot of experiences to get information about the overloads. By this machine a spring is used instead of wire rope. The next step of upgrading could be the modification of the system. With the modification we are likely to measure the system if it runs with wire ropes. In this way we could compare the results coming from either spring or wire rope operated construction.

## References

[1] CZITARY, E.: **Seilschwebebahnen**, Wien: Springer-Verlag 1962