

## Tensile force measurement by image processing

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*The Sometimes unexpected overloads start up in multi sheave friction drives which could cause the breakage of the wire rope. To analyze the breakage and the overload process a 7 sheaves examiner machine was developed and built. Since the visual measuring process provides several good advantages in this machine a spring is used instead of wire rope. At the beginning the distance of threads and pixels (in the picture) were measured manually. The aim of this paper is to show the automation method of the visual measuring process by the Matlab software in the Image Processing Toolbox.*

**Key words:** Image processing, Visual force measuring, Automation of image analysis

### Introduction

By a 7 sheave examiner machine the tensile force in the spring is measured visually. The elongation of the spring defines the force in the branches. At first this elongation was measured manually. An example can be seen in fig 1. A lot of new results show that our problem is a dynamical problem, so we have to measure the force continuously. Usually 100-200 images are taken from on setup, so the manual analysis takes too much time. For example: one image needs ~5 minutes, so 100 images need ~500 minutes (more than 8 hours). The automation of the image processing and analysis were necessary to get further and relative quick results.

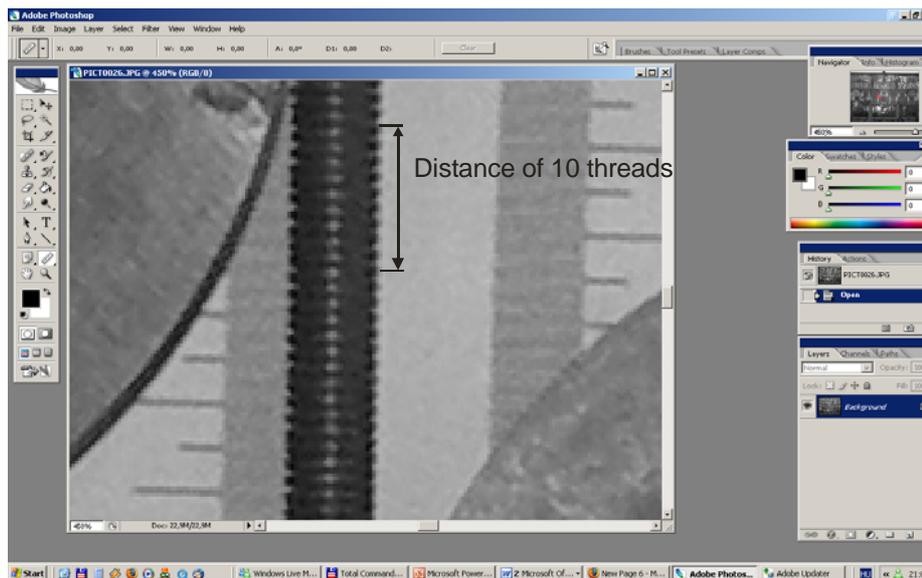


Fig. 1. The manual measuring of 10 threads by spring. The elongation shows the force in the spring because of the linear characteristic.

### Used methods

There were examined a lot of methods which could be useful for automation. The list is too long but the edge detection, the shifting method and the cepstrum method seem for the best solutions. After a comparison of the three methods the shifting and the cepstrum are usable for this problem (Malik, Czap, Németh, 2008).

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### Shifting method

The shifting method is usually used by compression of the images or movies. The method is simple. At first a reference part must be chosen in the image or movie. Then with a shifting algorithm the whole image has to be examined. The result of this compression method is a matrix, what contains the coordinates of the most similar parts to the reference. The size of the image or the movie can be decreased with this method, because the reference must be store only one time. In our case the coordinates have great importance. If the reference is one thread then on the examined part of the image the most similar part can be searched. This reference could be the arc part of one thread (fig 2.). The distance of several threads can be calculated easily with the coordinates.

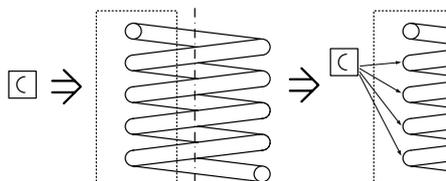


Fig. 2. The arc part could be the reference, then the examined image has to choose. The final step is the analysis.

The resolution of the image has great influence for the correctness. This method has three different kinds. They are the absolute failure(1), the square failure(2) and the cross correlation(3):

$$M_k(i, j) = \frac{1}{MN} \sum_{m=1}^M \sum_{n=1}^N R_k(m, n) - X(m+i, n+j) \quad (1)$$

$$M_k(i, j) = \frac{1}{MN} \sum_{m=1}^M \sum_{n=1}^N [R_k(m, n) - X(m+i, n+j)]^2 \quad (2)$$

$$M_k(i, j) = \frac{\sum_{m=1}^M \sum_{n=1}^N R_k(m, n) X(m+i, n+j)}{\left[ \sum_{m=1}^M \sum_{n=1}^N R_k^2(m, n) \right]^{1/2} \left[ \sum_{m=1}^M \sum_{n=1}^N X_k^2(m+i, n+j) \right]^{1/2}} \quad (3)$$

where the  $M_k(i, j)$  is the similarity value of the  $k$  reference by  $i$  and  $j$  translation. The  $M$  and  $N$  is the measurements of the examined reference.  $R_k$  is the reference  $k$ .  $X$  is the brightness matrix of the selected examined image. By the absolute failure and the square failure the minimum value and by the cross correlation the maximum value of the  $M_k$  matrix shows the most similar part to the reference. This method is programmed in Matlab. It can be seen in fig 3. As it was mentioned the resolution of the image has great influence to the result. The resolution of the arc part is not the best, so in this case bigger references should use. These could be two or three threads, but in the 8 branches have to choose new references.

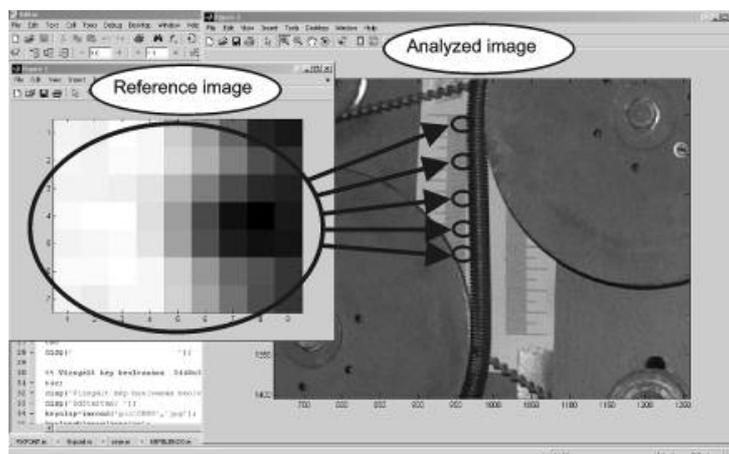


Fig. 3. The shifting method in Matlab. The arc part as a reference is not always the best solution. Sometimes two or three threads are used for reference.

### Cepstrum method

The cepstrum method is not as well known method in image process as signal analysis. The name comes from the first usage of this method. The scientists send radio waves through the intermediate layers of the earths. Some part of the radio waves has reflected from the limit of these layers. But the reflected signal has mixed with original and other reflected signals. This method was used to separate the right signals.

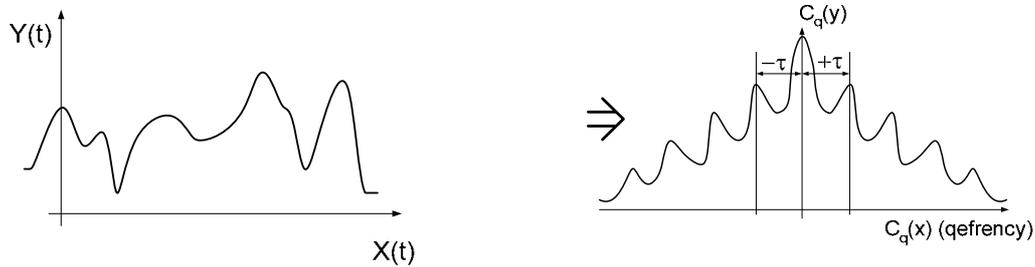


Fig. 4. The requested signal can be easily separated from the mixture of signals by cepstrum method.

An example can be seen in fig 4 where the  $t$  is the time and  $Y(t)$  is the signal,  $C_q(y)$  is the cepstrum with the reflected signal and the  $C_q(x)$  is the cepstrum of the signal without the reflection. The frequency of the reflected signal can be defined easily. In our case this method can be used to calculate the distance of two threads, because the frequency will be defined according to the peaks. The distance of two neighbouring peaks is the distance of two threads. The main steps of this method are:

signal  $\rightarrow$  FT  $\rightarrow$  abs()  $\rightarrow$  log  $\rightarrow$  phase unwrapping  $\rightarrow$  IFT  $\rightarrow$  cepstrum. The equation of the signal:

$$Y(t) = X(t) + aX(t - \tau) \quad (4)$$

where the  $Y(t)$  is the echo of the signal, the  $X(t)$  is the original signal, but these two value are depending on the time. The “ $a$ ” is the attenuation and  $\tau$  time shift of echo. The next step is the Fourier transformation of the equation (4):

$$Y(\omega) = X(\omega) + aX(\omega)e^{-j\omega\tau} \quad (5)$$

The next step is the square of the equation (5), what is used as absolute value of the signal:

$$(Y(\omega))^2 \cong (X(\omega))^2(1 + 2a \cos \omega\tau) \quad (6)$$

The next step is the log of equation (6) (as  $\log(1 + \varepsilon) \cong \varepsilon$ ):

$$\log[(Y(\omega))^2] \cong \log[(X(\omega))^2] + 2a \cos \omega\tau \quad (7)$$

The next step is the phase unwrapping, what is the following:

$$(Y(\omega))^2 \cong (X(\omega))^2(1 + 2a \cos \omega\tau) \quad (8)$$

The last step is the inverse Fourier transformation, what is the  $F^{-1}$  transformation:

$$Cq(y) = Cq(x) + a\delta(t - \tau) + a\delta(t + \tau) \quad (9)$$

One of the results in Matlab can be seen in fig 5. As a last step the program measure the distance of two neighbouring threads. This method can be used well to solve our problem. The right resolution is also very important, because it has great influence to the final results too.

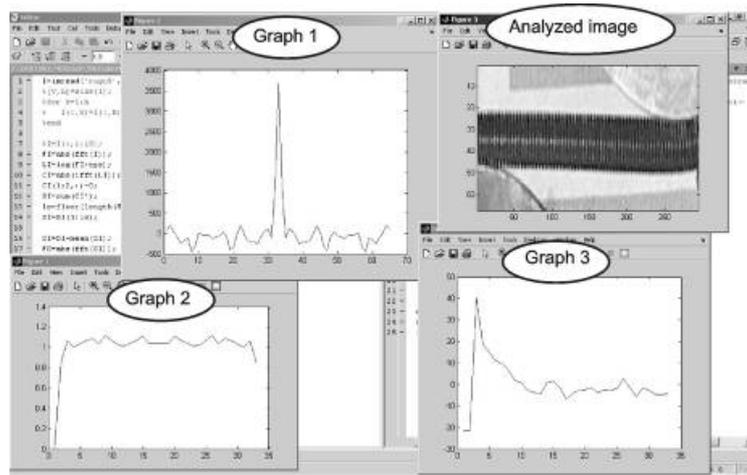


Fig. 5. The requested signal can be easily separated from the mixture of signals by cepstrum method.

### 3. Image analyser

The final result of this project is an image analyser program. The steps of the program can be seen in fig. 6. The first steps are the collection of images and the definition of start and end numbers. Here the directory, the type and the numbers of images have to define. The next step is the selection of method. We can compare the result of shifting and cepstrum methods. Then the right choice of the references is the next. If the check does not go well then a new reference is necessary, especially if there are some failures in the images. After the program have good references it will examine and analyse all images. This takes the most time in the process. The last step before saving data is the visualization of the surface. This surface is a force transfer surface where the angle of wrap, the time and the force in the branches are on the axes.

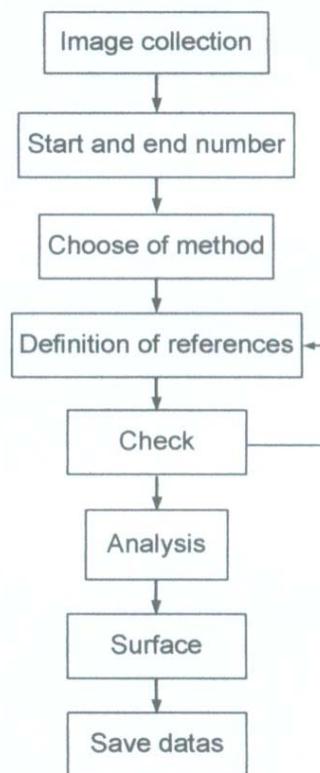


Fig. 6. The steps of the image analyser program.

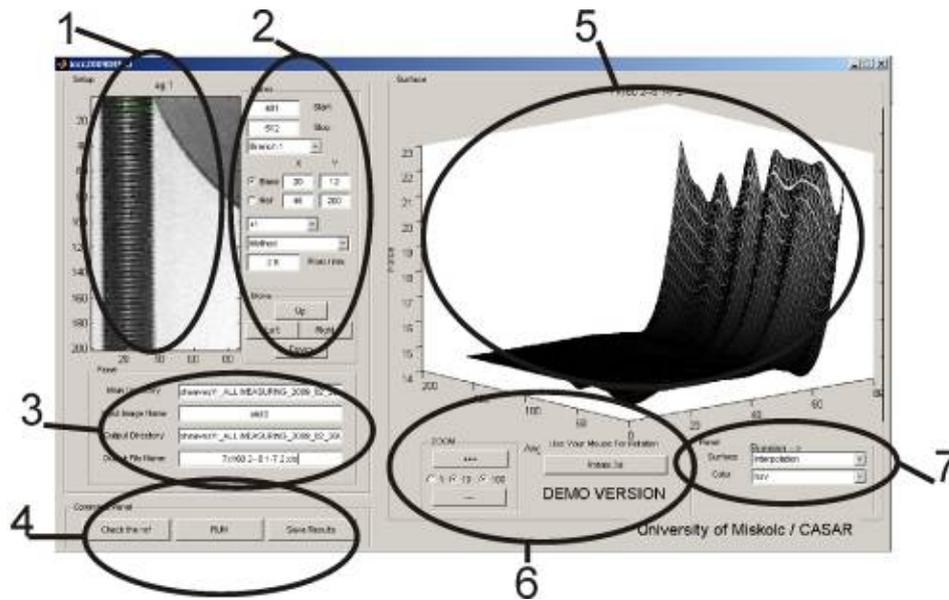
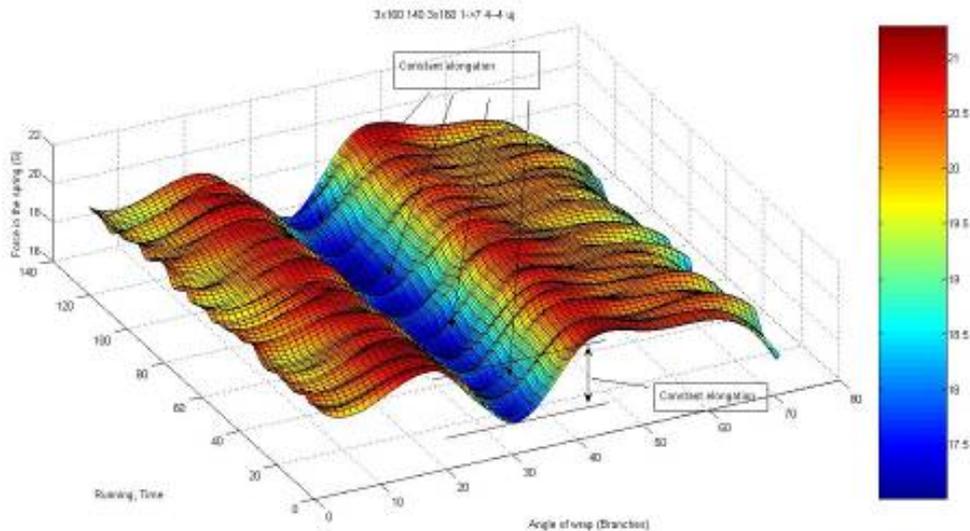


Fig. 7. The final image analyser program.

The final window of the program can be seen in fig.- 7. There are 7 sections. In the first section the actual branch and the rectangle of reference can be seen. In the second section the start and end number of the images, the actual branch, the measurement of the reference and examined image, the method, the pixel in mm and the increment of the moving can be set up. In the third section the current directories are defined: the directory of files, the name of files, the output directory and the name of output file. In the fourth section there are the function buttons of check, run and save datas. In the fifth section the surface of force transfer is visualized. It can be rotated with mouse what function can be turned on in the sixth section. Beside this the zoom can be used here. In the last section the method of visualizations can be defined. With the new program there are several new results. The influences of the parameters can be defined easily, because the analyse process time can be reduced for more than 200 times. So 100 images need 2 minutes instead of 8 hours.

### Some results

The program can be used to get results much more sooner. There are another two results in fig. 8. The results are saved to an excel file, so they can be examined later too.



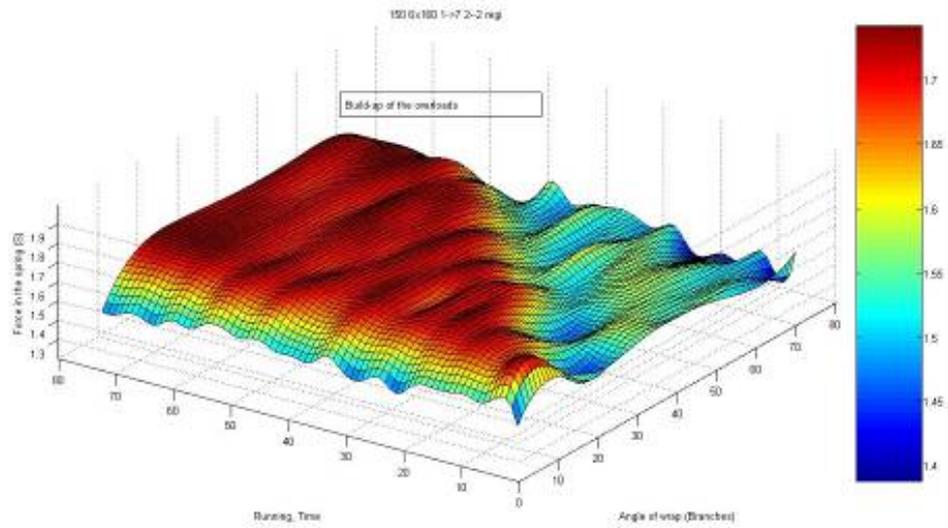


Fig. 8. Some result what are given by the new program.

#### Acknowledgement

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#### References

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