

# Analysis of Measuring Chain for Evaluating Residual Stresses by Ring-Core Method

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Received October 21, 2013; Revised October 30, 2013; Accepted November 15, 2013

**Abstract** In this article we describe the parts of measuring string used for residual stress calculations by Ring-Core method. Correct design and usage of the measuring chain is very important for successful measurement and the accurate data acquisition. Therefore it is sufficient to pay adequate attention to this problem before the experimental testing itself.

**Keywords:** residual stresses, Ring-Core method, measuring chain

**Cite This Article:** Patrik Šarga and František Menda, "Analysis of Measuring Chain for Evaluating Residual Stresses by Ring-Core Method." *American Journal of Mechanical Engineering* 1, no. 7 (2013): 313-317. doi: 10.12691/ajme-1-7-32.

## 1. Introduction

Measuring system MTS 3000 Ring-Core [Figure 1](#) is a new developed system for determining residual stresses by Ring-Core method [\[5,6\]](#). This method allows evaluating both uniform and non-uniform state of stress in the dependence on the specimen thickness. The principles of this method are based on the hole-drilling method, but instead of drilling a hole through the middle of strain gage rosette, a notch is milled around the rosette [\[1,2\]](#). Main advantages of such measurement are higher sensitivity comparing to those in hole-drilling method and better accuracy of milling procedure.



Figure 1. System MTS 3000 - Ring-Core

## 2. Measurement Chain

System MTS 3000 Ring-Core consists of these parts [\[3\]](#):

- mechanical device
- electronic control unit
- electronic milling unit
- control and evaluation software

The measuring device is connected with strain gage system Spider 8-30, which enables quarter bridge

connection, and with computer with appropriate control and evaluation software. These are all essential elements of measurement chain using for determination residual stresses by Ring-Core method [Figure 2](#) [\[4\]](#).

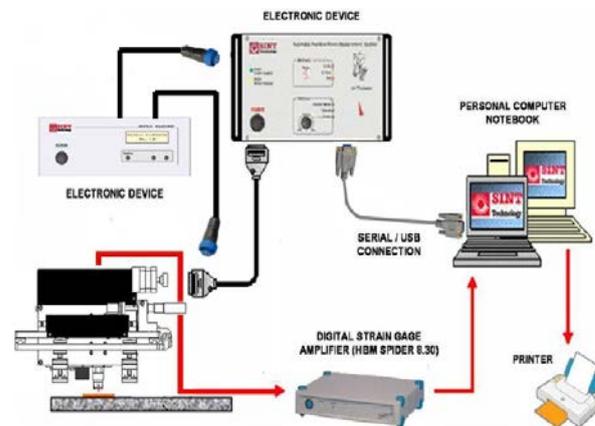


Figure 2. Measurement chain for the Ring-Core method

In the next section, we approach the elements of this measurement chain.

### 2.1. Mechanical Device

Mechanical device [Figure 3](#) enables creating the ring notch around the strain gage rosette by special hollow mill [Figure 4](#). The milling procedure is divided into small step increments. Centering the optical axis with the axis of strain gage is provided by the integrated webcam. The accurate position is subsequently reached by the knobs situated on the sides of the device. For attaching the device to the specimen surface a special magnetic feet are used, if desired in connection with special tensometric glue X60. The notch milling itself is provided by the replaceable hollow mill [Figure 5](#). Through the mill and subsequently through whole device the cables from strain

gage rosette are lead to the Spider 8-30 device, which reads the relaxed deformations. The dimensions of the device are: length=340mm, width=154mm, height=200mm, weight=10kg.



Figure 3. Mechanical device



Figure 4. Milled ring core



Figure 5. Hollow mill

### 2.2. Electronic Control Unit

Electronic control unit [Figure 6](#) is a heart of the measuring system. It controls all parts of the measuring string according the appropriate control software. At the back of this device there are connectors and plugs for connecting with the computer, mechanical device and electronic milling unit, which provides the motive power of the mill. There is also a contact cable, using which it is possible to calibrate the accurate position of the mill against the surface of the specimen.



Figure 6. Electronic control unit

### 2.3. Electronic Milling Unit

Electronic milling [Figure 7](#) unit enables to set the force and speed of the milling, the setting of the parameters for notch milling and for webcam data transfer. It is connected with the electronic control unit and also with the mechanical device.



Figure 7. Electronic milling unit

### 2.4. Spider 8-30

Spider8-30 [Figure 8](#) is an electronic measuring system for PCs for electric measurement of mechanical variables such as strain, force, pressure, path, acceleration and for temperatures [\[7\]](#).



Figure 8. Spider 8-30

All the signal conditioning - excitation for passive transducers and amplification, digitalization, computer interface and connection technology for a maximum of 8 channels - is combined in one housing.

Spider8-30 is connected to the computer via the printer port or via an RS232 interface and is then ready for immediate use.

All the required settings are made by the computer through commands - there are no potentiometers, switches, solder bridges or jumpers. It is only necessary to open the *Spider8* housing if you want to install a module.

The *Spider8-30* uses its 600Hz carrier frequency amplifier to manage all measurement tasks with S/G in quarter, half or full bridge connection.

Three installed compensating resistors (120 Ω, 350 Ω, 700 Ω) are available for measuring with S/G quarter bridges and are accessible through the various connector pins.

The shunt calibration, when each channel is detuned by 1 mV/V, is used to determine and correct the sensitivity loss. The SR30 module extends the measurement options by additional S/G channels.

In our measurement chain we used quarter bridge connection [Figure 9](#).

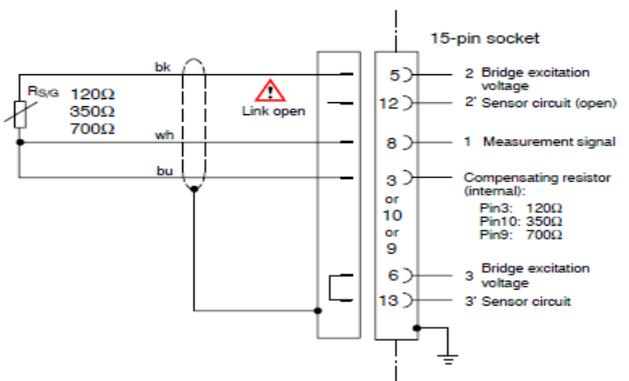


Figure 9. Quarter bridge

Software part of the measuring chain includes two main programs. The primary task of the control software is a data acquisition from the strain gage rosette during the experimental testing and the evaluation software enables the data processing.

### 2.5. Control Software

Simply we can say it is a software [Figure 10](#) using which we set the initial parameters for measuring and data acquisition from specified strain gage rosette. In the next part such a setting process is described.



Figure 10. Control software

One of the most important tasks that need to be done before the milling itself is the accurate positioning of the mill above the center of the strain gage rosette Figure 11.

This process is provided by the webcam situated in the lower part of the mechanical device, by using the program Positioning Control. Except the precise centering the mill position according the surface of the specimen is set here Figure 12. This procedure is done automatically via electric contact between the device and the surface.



Figure 11. Centering the mill

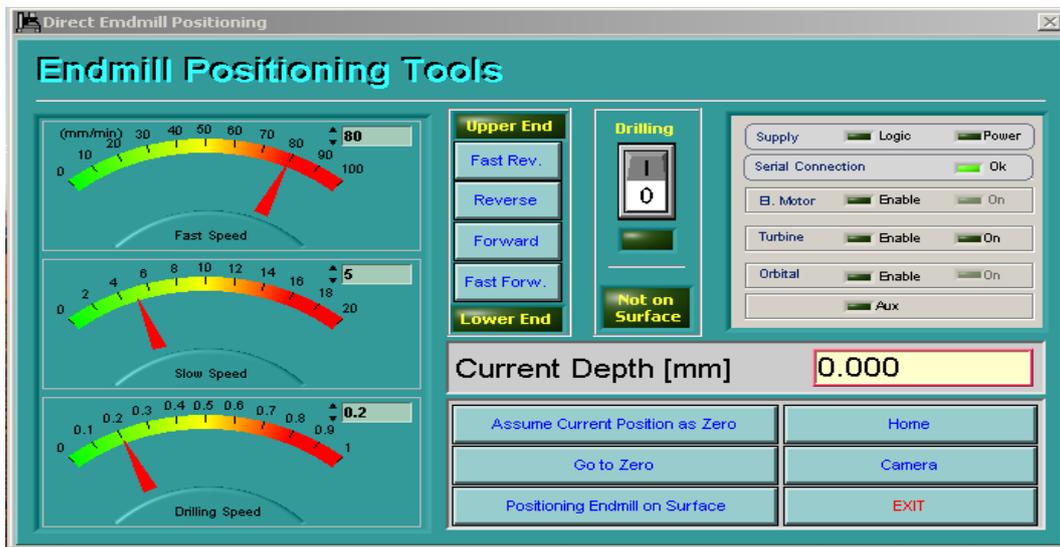


Figure 12. Positioning Control

After those settings we can move to the section Test Setup Figure 13, where we set other parameters for measuring. First we need to choose the right type of the strain gage with adequate parameters. Then we choose the

number of steps and the step distribution up to chosen maximum milling depth. It is necessary to set the material characteristics of the tested specimen and the data acquisitioning device, in our case Spider 8-30.

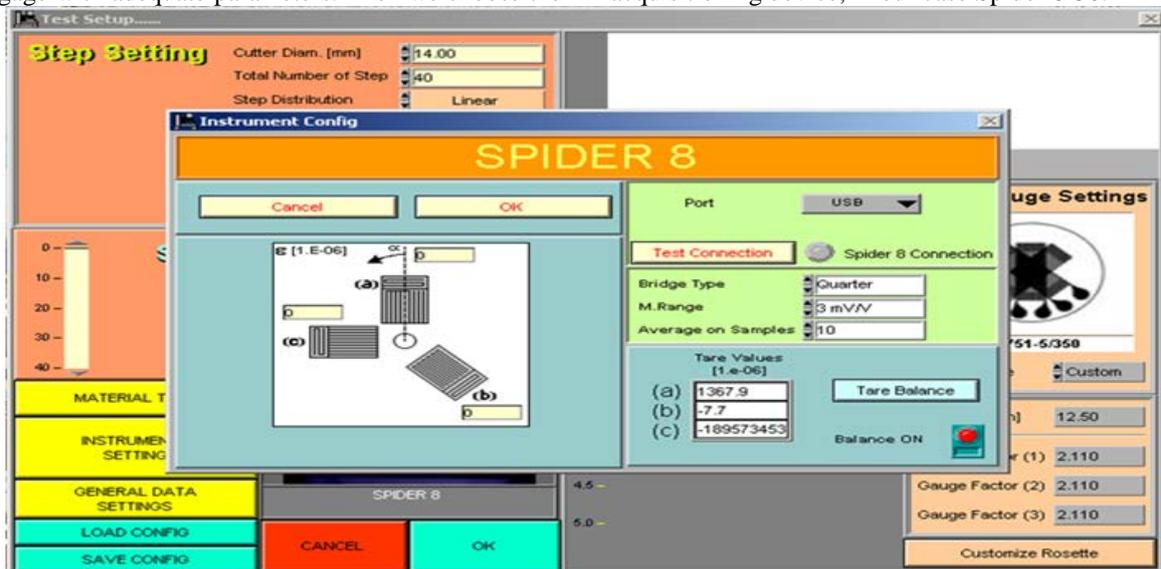


Figure 13. Test Setup

After accomplishing the preprocessing phase, the measuring uses the section Test Manager Figure 14. The measuring could be done using step-by-step sequence or automatically. At first milling steps we can use step by step setup and read the strain values manually, and when

everything goes well we can switch to the automatic mode and just check the procedure. The output from the measurement is a data file. After saving the file we can close the software. The file with the acquired data is then opened in the evaluation software for next processing.

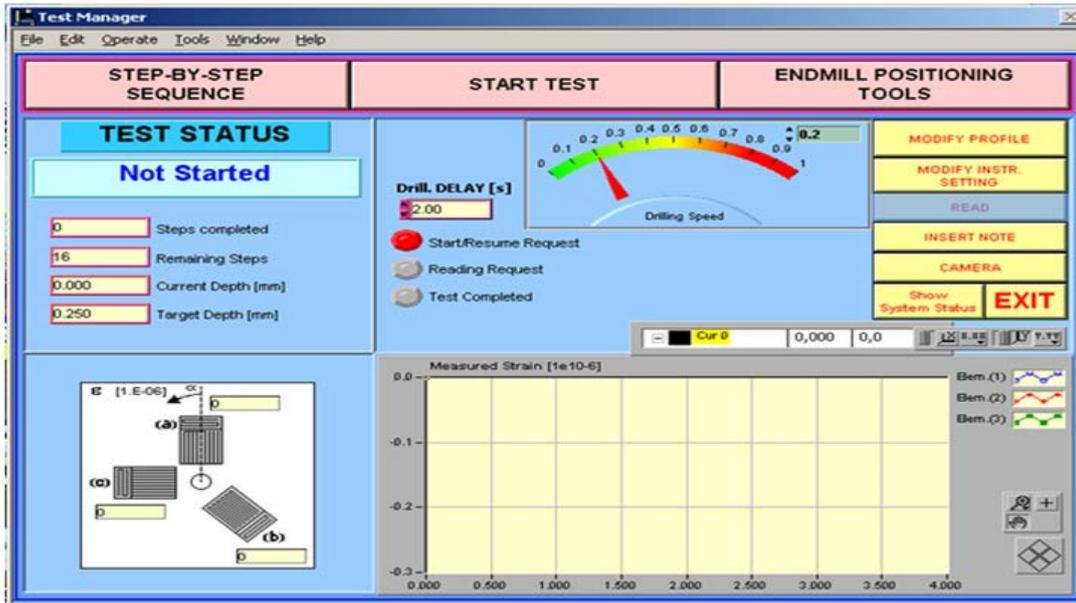


Figure 14. Test Manager

### 2.6. Evaluation Software

This software enables to evaluate both uniform and non-uniform stress distribution in the dependence on the specimen thickness by the Ring-Core method and the appropriate calculated method. There are three calculation methods: Integral, Incremental and Differential method.

is possible to set the interpolation of the measured strain values Figure 16. We can use polynomial or spline interpolation. Subsequently we can evaluate the residual stresses according one of the calculation methods.

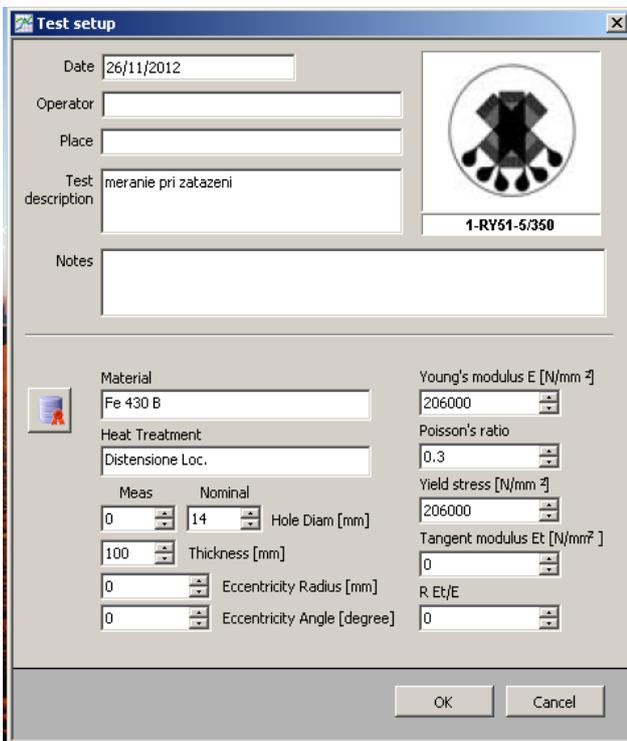


Figure 15. Evaluation software

In next part we partially describe the possibilities of the evaluation software.

After loading the data Figure 15 acquired in the previous software and before residual stress calculations it

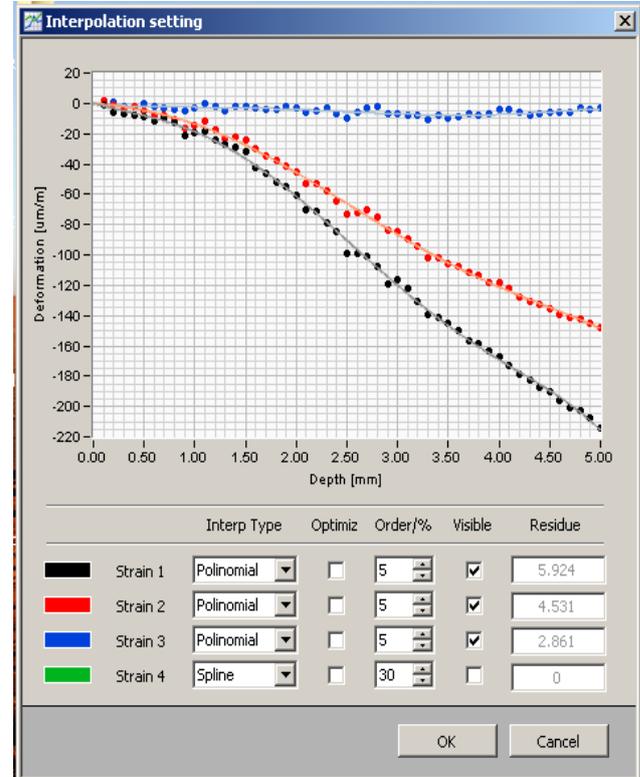


Figure 16. Interpolation setting

First we set the adequate parameters for each calculation method and then we can analyze the results in a stress graph Figure 17, direction graph or as a Mohr's circle Figure 18.

We can save the output results in html form or print them.

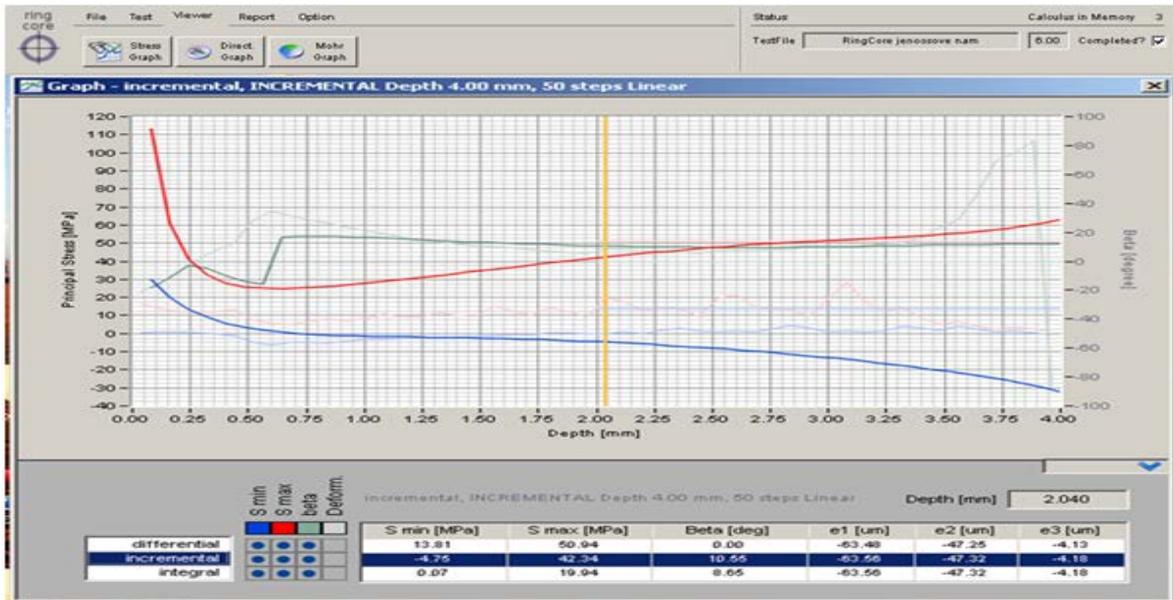


Figure 17. Stress graph

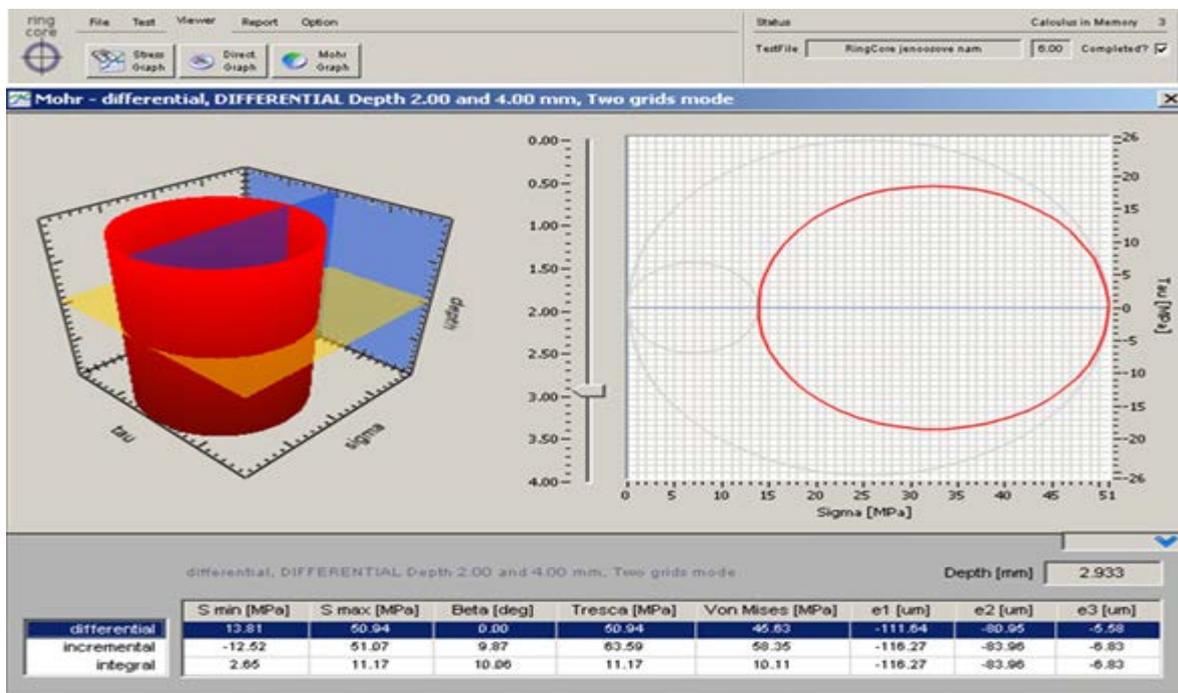


Figure 18. Mohr circle

### 3. Conclusion

This article describes the measuring string, which is needed for residual stress evaluation using Ring-Core method. After describing each unit we mentioned the control software for setting all the necessary parameters for successful experimental testing. We also briefly described the possibilities of the evaluation software. Success in the implementation of the experiment depends on using the appropriate measuring string and on adequate measuring parameters. Therefore it is very important to always pay the sufficient attention.

### Acknowledgement

This work was supported by the Ministry of Education of the Slovakia Foundation under Grant VEGA No. 1/0289/11, VEGA No. 1/0937/12 and APVV-0091-11.

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