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Bi-axial Stress Effects on Barkhausen-Noise

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***Abstract*—**Mechanical stress has a strong effect on the magnitude of the Barkhausen-noise in structural steels. Because the measurements are performed at the surface of the material, for a sample sheet, the full effect can be described by a biaxial stress field. The measured Barkhausen-noise is dependent on the orientation of the exciting magnetic field relative to the axis of the stress tensor. The sample inhomogenities including the residual stress also modifies the angular dependence of the measured Barkhausen-noise. We have developed a laboratory device with a cross like specimen for bi-axial bending. The measuring head allowed performing excitations in two orthogonal directions. We could excite the two directions independently or simultaneously with different amplitudes. The simultaneous excitation of the two coils could be performed in phase or with a 90 degree phase shift. In principle this allows to measure the Barkhausen-noise at an arbitrary direction without moving the head, or to measure the Barkhausen-noise induced by a rotating magnetic field if a linear superposition of the two fields can be assumed.

***Keywords*—**Barkhausen-noise, Bi-axial stress, Stress dependency, Stress measuring.

I. Introduction

THIS document introduce the laboratory device that was developed by us, with a cross like specimen for bi-axial bending [1]-[3]. The measuring head allowed performing excitations in two orthogonal directions. We could excite the two directions independently or simultaneously with different amplitudes. [5], [6] The simultaneous excitation of the two coils could be performed in phase or with a 90 degree phase shift. In principle this allows to measure the Barkhausen-noise at an arbitrary direction without moving the head, or to measure the Barkhausen-noise induced by a rotating magnetic field if a linear superposition of the two fields can be assumed.

On the lower side of the cross shaped sample a biaxial strain gauge was installed. Strain gauges are also installed on the driving screw actuators.

We have measured the real deformations of the sample surface using a special grid and a real time optical measurement system. Application of this measuring method we have different facility using the results. We can use the optical measurement results to compare the deformation and the stress state of the sample with the Barkhausen-noise measurement. Beside that the results can be an input for finite-element modeling of different types of sheet metal forming methods, especially deep drawing of a sheet metal.

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II. Barkhausen-Noise Measurement

The Barkhausen-effect was discovered by a German physicist Heinrich Barkhausen in 1919 [3], [4]. A coil of wire wound on the ferromagnetic material can demonstrate the sudden, discontinuous jumps in magnetization. The sudden transitions in the magnetization of the material produce current pulses in the coil. These can be amplified to produce a series of clicks in a loudspeaker. This sounds as crackle, complete with skewed pulses which sounds like candy being unwrapped, Rice Krispies, or a pine log fire. Hence is the name Barkhausen-noise. Similar effects can be observed by applying only mechanical stresses (e.g. bending) to the material placed in the detecting coil. The noise-avalanche is illustrated on Fig. 1.

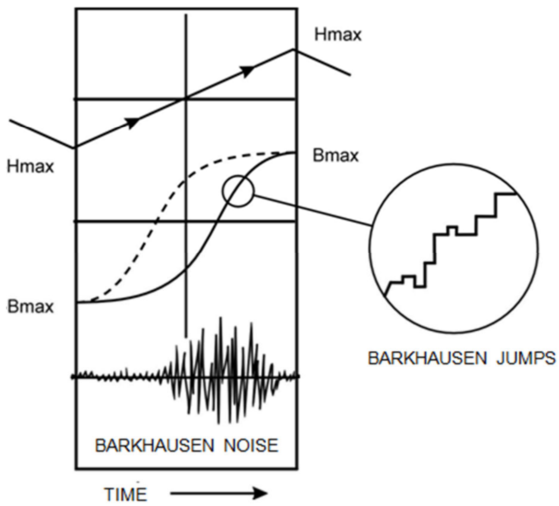

Fig. 1 Barkhausen effect

Applying the BHN measure method we can measure the remaining stresses (RMS) in different directions. During deep drawing process there are identified areas (by FEM calculations) which contain high amount of remaining stresses. Measuring of these stresses is not properly solved. There are different practical ways to estimate these stresses, but these data are not accurate enough. Applying the BHN technique combined with our newly developed system which can indicate controlled stress conditions we can use the same techniques during the forming process. The equipment is shown on Fig. 2.

The next step was the solving of the rotation of the BHN measuring head to create the complete remaining stress (RMS) curve of the zone. We developed a new type of measuring head to rotate the magnetic field without any movement of the head. This new technique is more accurate than we rotating the head by hand in different degree. The new measuring head is shown on Fig. 3.

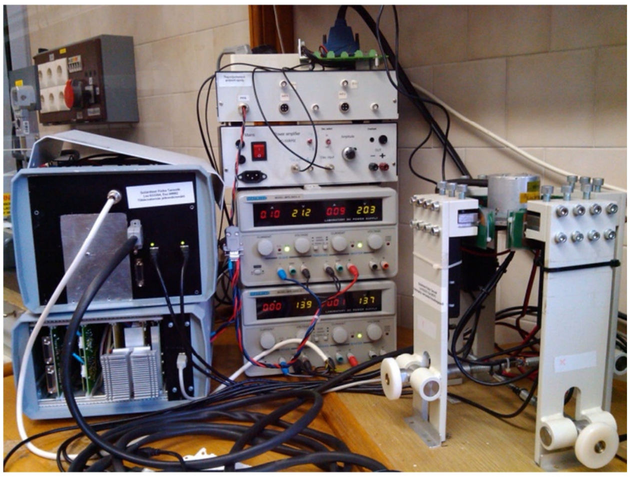

Fig. 2 BHN measuring equipment

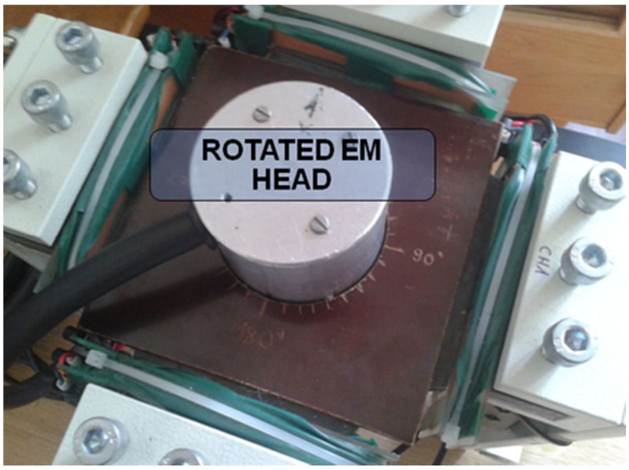

Fig. 3 New measuring head

III. Barkhausen-Noise Measurement Software

We have the method how to measure the remaining stresses in different formed zones, and rotate the magnetic field by software. We need to create measuring software which handles the data and all the input to get the most accurate results. The basic requirements of the software:

1. Dynamic instrument control and signal display
2. Automated measurement sequences
3. Data storage, presentation
4. Noise measure evaluation and comparison

A. Dynamic Instrument Control

We were built a hardware from different modules which handles different tasks. To combine and control the data inputs for different tasks e.g. bending moment of the sheet metal specimen, amplified noise handling, air gap, and voltage and sign control.

B. Automated Measurement Sequences

Measuring and combining different parameters needs different and parallel controlled measuring methods. To control these tasks we have to create different automated sequences to get the best results. Control panel for this process shown on Fig. 4.

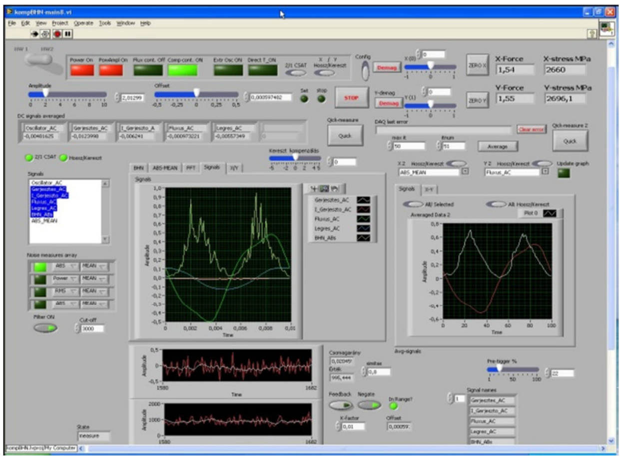

Fig. 4 Control panel

C. Data Storage, Presentation

Certainly if we measured with combined process we have to handle and save these data to the future use. We also made a data handler part. This part of the software is shown on Fig. 5.

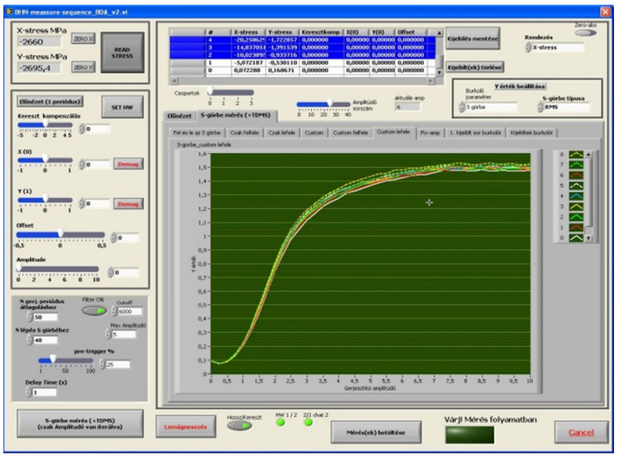

Fig. 5 Data storage & handling

D. Noise Measure Evaluation and Comparison

When we made the measuring we can indicate the stress depending from the mechanical stress with the last module. This module is shown on Fig. 6.

IV. Optical Measuring Method

Measuring of the yield between different points of the grid, we used the VIALUX optical measuring system which is introduced on Fig. 7. This system works with five CCD camera and we can use different resolution grids to measure the yield on the surface of the test sample.

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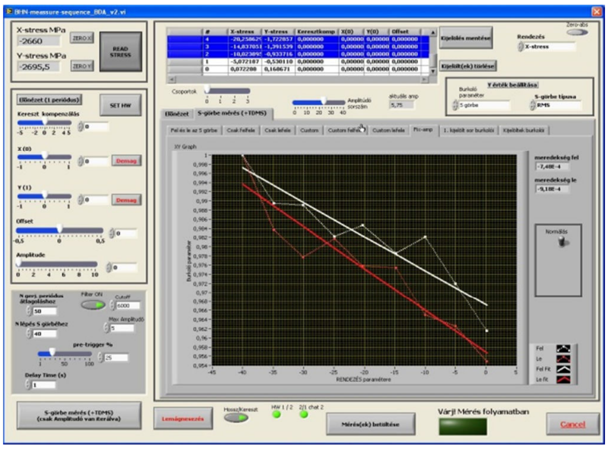

Fig. 6 Noise measure evaluation and comparison

Fig. 7 Combination of VIALUX system & bi-axial stress measuring

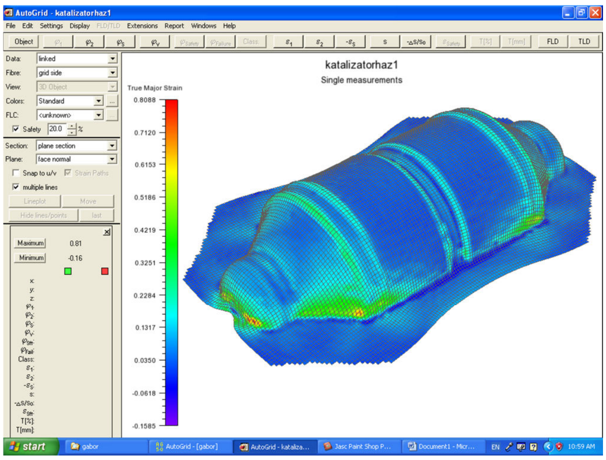

Fig. 8 Measuring of an automotive part by VIALUX system

There are two way of grid creation. We can create the grid on the sample surface by paint or we can use a pre-created grid on a foil. These foils are able to yield near two hundred percent. This system is usually applied in deep drawing of sheet metal parts, especially in automotive industry. On Fig. 8, one can see an example of a usual task or usual application of this system.

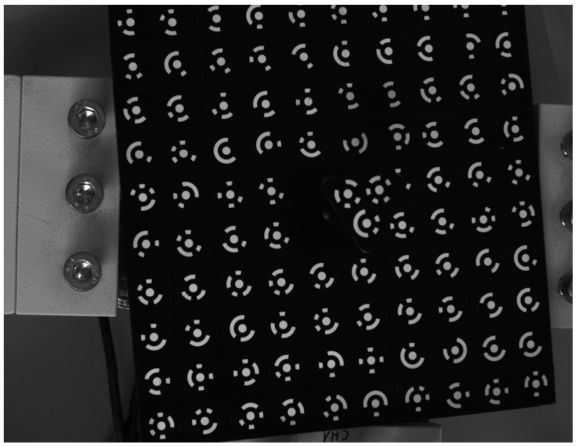

Fig. 9 Calibration of VIALUX system

On our sample the maximal bending stress was 50MPa to keep the sample part in the elastic deformation zone. Before we can start the measure of the sample we have to calibrate the VIALUX system as it showed on Fig. 9 with a special calibration tool.

After calibration we can apply the stresses on the sample by our bi-axial measuring equipment. Because of the small yields (we are in the elastic deformation zone) we measured the start sate (zero stress-state on Fig. 10) and the maximal allowed deformation at 50MPa in X; Y directions (Figs. 11, 12), and after that we've applied 50MPa on both axis (Fig. 13).

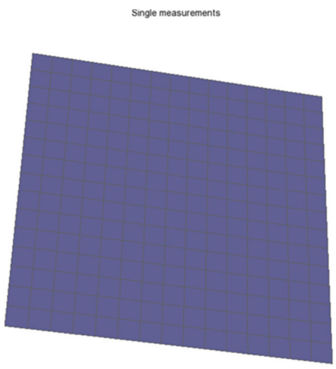

Fig. 10 Zero-stress state

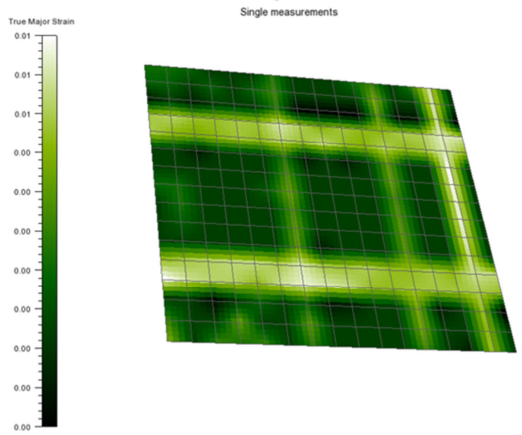

Fig. 11 X-direction 50MPa

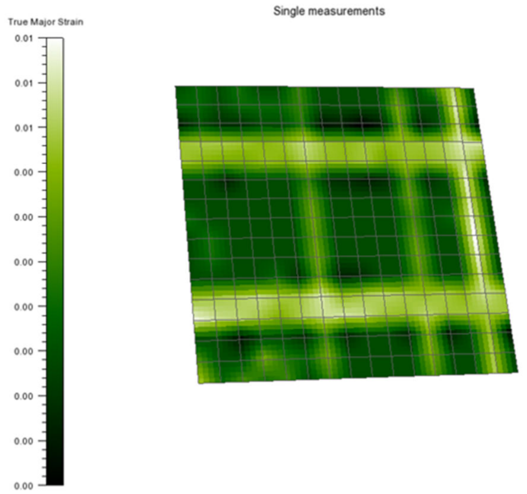

Fig. 12 Y-direction 50MPa

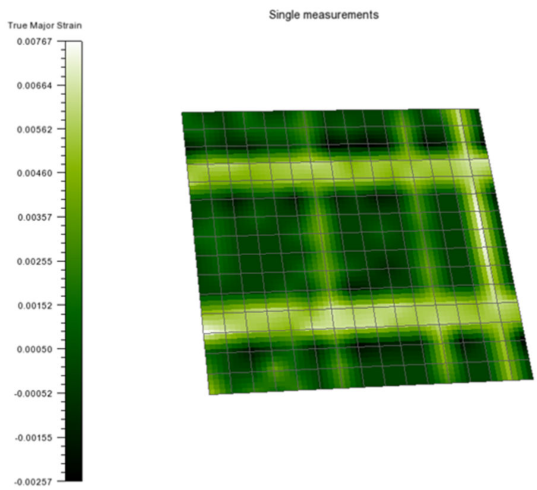

Fig. 13 X-Y direction 50MPa

V. FEM Modelling

Nowadays we are able to follow the stress state of the formed material in every point during the forming with FEM based simulation system. We can calculate the stresses more accurate than ever. We used the AutoForm system (at the University of Miskolc) to calculate the stresses during forming the sheet metal. Fig. 14 illustrates the new combination of experimental testing and FEM modeling.

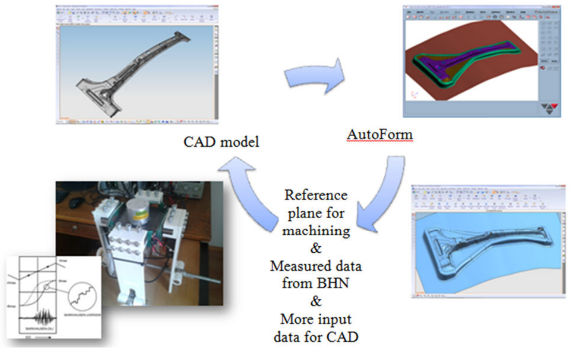

Fig. 14 New methodology

VI. Results

We've applied three different techniques on the same sample and model. In elastic deformation zone of the material the measured and calculated data showed good correlation. The effect of different (incremental) bi-axial stresses on the Barkhausen-noise can followed on Fig. 15.

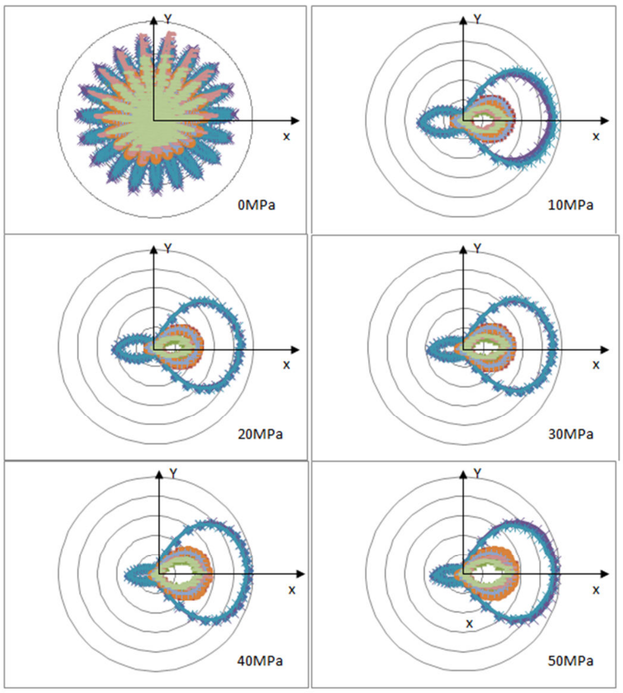

Fig. 15 Bi-axial stress state effect on BHN

VII. Conclusion

Combination of different techniques to investigate the effects on the same phenomena is usually a good practice to find new measureable parameters or find new way of dependencies. We will combine the BHN technique with other different remaining stress measurement techniques to get more accurate measurement results and find dependencies between the stress state and the noise avalanche shape.

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