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COMPARISON OF LOCAL STRESS VALUES OBTAINED BY TWO MEASURING METHODS ON BLAST FURNACE SHELL

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This paper describes measuring of time behaviour specified for local stress increments on the blast furnace shell that were performed using strain gauge sensors. These results are compared with values obtained by means of the second specific measuring method. There is also presented in this paper a commentary and discussion concerning the measured time behaviour obtained from the both measuring methods. This article presents results from another of experimental analysis series concerning the blast furnace shell in one concrete metallurgical plant.

Key words: blast furnace, measuring, stress, sensor, strain gauges

INTRODUCTION

The blast furnace is always a specific technical and technological phenomenon, which represents a wide interdisciplinary research area covering various branches of engineering and technology. Taking into consideration our solution of the given research task, which was focused on a concrete blast furnace situated in a metallurgical plant, there were already published relevant publications, e.g. describing a control of blast furnace iron-making process [1], numerical simulation of blast furnace [2] as well as simulation of blast furnace thermal processes [3-5].

This article describes a long term measuring of stress increments in the selected points on the shell of the blast furnace BF2 hearth. The measuring was performed during three operational regimes of the blast furnace, namely during starting, rising of operation and full operation. This measuring is a supplement to the previous analyses, which were realised on the shells of the blast furnaces BF1 and BF3 [6] in a metallurgical factory, whereas this measuring is already the third in the performed measuring sequence. There are some differences among these blast furnaces in their construction, e.g. they have different cooling systems, diameters of the blast furnace hearth, tuyere armatures etc.

The diameter of the blast furnace BF2 is 14 362 mm, the BF3 blast furnace diameter is 11 996 mm and in the case of the BF1 the diameter value is 12 943 mm.

The shell of the blast furnace BF2 is a welded shell construction made from the normalized steel S355J2G3 with the next values of mechanical characteristics: the yield point 363 MPa, the tensile strength 471 ÷ 608 MPa, the ductility 22 %, and the notch toughness 49 Jcm^{-2} [7].

According to the torque-less theory of the rotating shells [7] there were measured increments of relative deformations in the selected points of the shell, together with related stresses in the circumferential directions.

A suitable method for this kind of measuring task is application of a ‚half-bridge' interconnection of the stress gauges together with a thermal compensation. The thermal compensation was realized by means of another unidirectional strain gauge sensor placed in a vertical direction.

The arrangement of sensors in 13 measuring points in the area of the BF2 blast furnace hearth is illustrated in the Figure 1.

There were applied during the whole measuring process the strain gauges 1-LY11-6/120 made by the com-

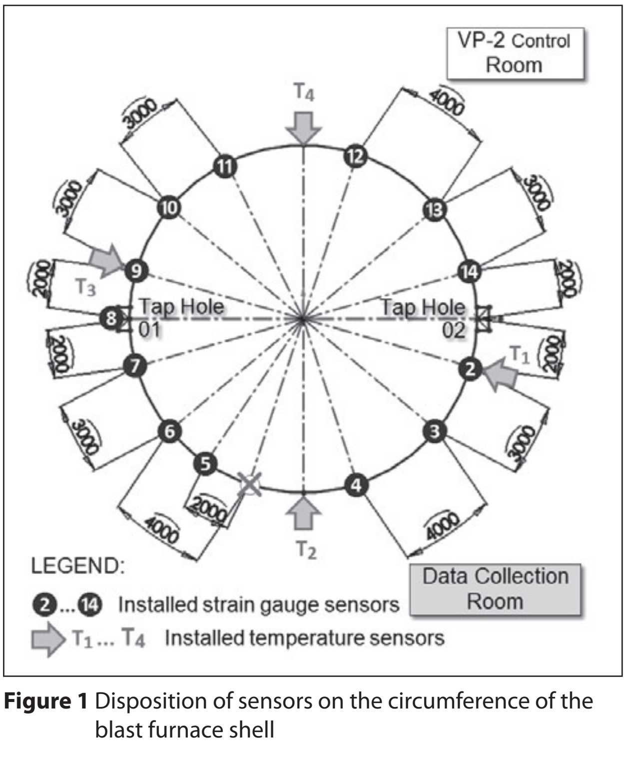

Figure 1 Disposition of sensors on the circumference of the blast furnace shell

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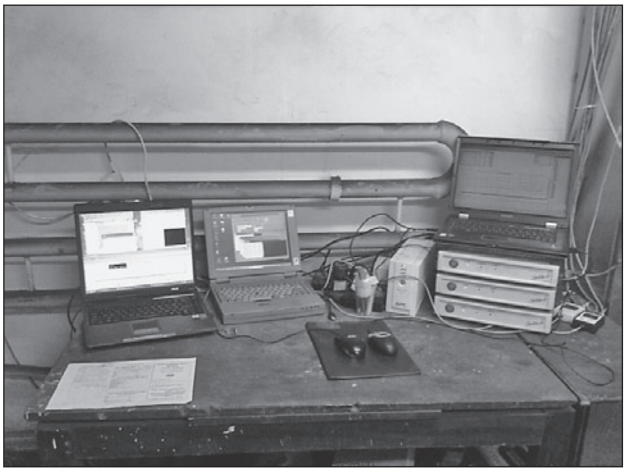

Figure 2 Measuring standpoint

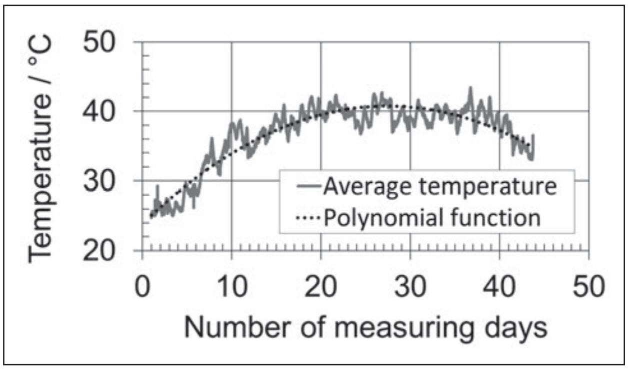

Figure 3 Calculated average temperature on the shell of the blast furnace hearth BF2

pany HBM. The gluing operation was performed using the two-part glue X60, which is specified for the strain gauge application and following process of the glue hardening requires normal temperatures. The strain gauges installed on the blast furnace shell were insulated against the external influences by means of a silicon sealant and the compensational strain gauges were insulated using the silicon rubber SG250. The applied measuring device consists of the modular measuring amplifiers equipped with the A/D converters SPIDER 8. The software CATMAN, which is a product of the company HBM, was used for the measured data collection, data processing and their final evaluation. The working standpoint arranged for measuring and evaluation of the obtained data is illustrated in the Figure 2.

MEASURING OF THE TEMPERATURE

The temperature values were measured during 43 days by means of the electronic equipment G – RECO TEA produced by the company ELSO Philips Service, Ltd. and using the temperature sensors PT 1000. The Figure 1 illustrates the real placement of the temperature sensors, which are described $T_1 \div T_4$. The time behaviour of the average temperature value is presented in the Figure 3. This time behaviour was calculated according to the data obtained from the abovementioned four temperature sensors (stochastic behaviour) using a correlation analysis, which corresponds to a calculated polynomial of the 3rd order.

MEASURING USING STRAIN GAUGE SENSORS

The measuring sequence of the stress increments in the 13 sensor application points (according to the Figure 1) was performed during 43 days. The measuring process started on the 21st of August 2013 at 09:15 PM and it was finished on the 3rd of October 2013 at 4:00 PM There were applied together 13 active sensors and 13 thermal compensational sensors for measuring of the circumferential stress increments. The Figure 4 is a time behaviour of the recalculated circumferential stress increments in the measuring points 2 ÷ 14 (see Figure 1), which involves the whole measuring time period.

MECHANICAL MEASURING

On the level 500 mm below the applied strain gauge sensors there was wrapped a steel band (strap, tape) around the shell of the hearth according to the Figure 1. This band was fixed by means of an extension spring and tensioning screw. The free end of the band was connected to a shifting traveller of the potentiometric sensor, whereas the fixed part of this sensor was anchored to the blast furnace shell (Figure 5).

The resulting time behaviour of the band extension during the whole measuring period is presented in the Figure 6.

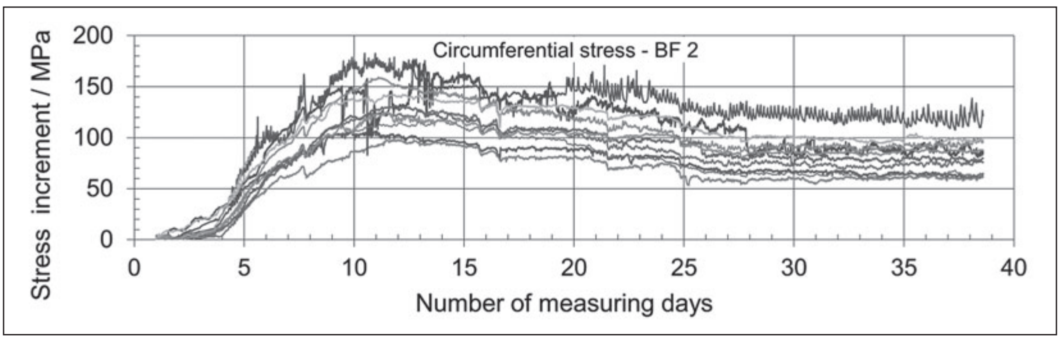

Figure 4 Time recording of the circumferential stress increments

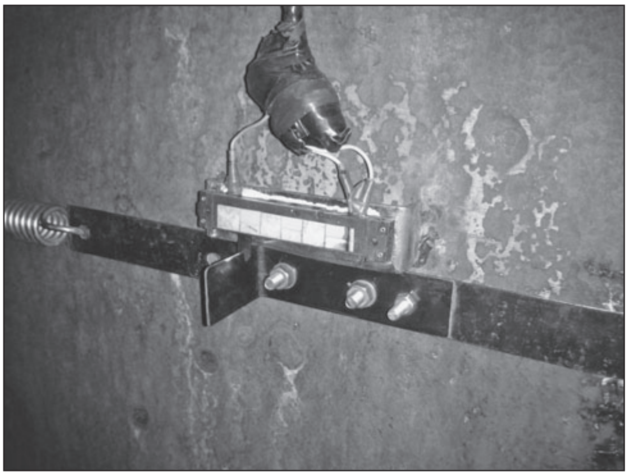

Figure 5 View on the measuring sensor of band extension

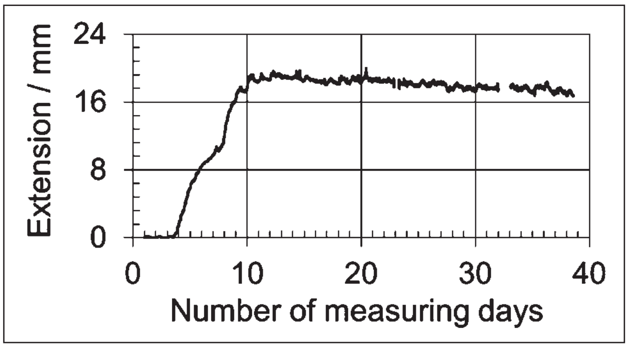

Figure 6 Time behaviour of the band extension measuring

COMPARISON OF THE RESULTS

The Figure 7 illustrates time behaviour of the average value of the circumferential stress increments obtained from the strain gauge sensors. This time behaviour is developed according to the values obtained from the diagram in the Figure 4.

It is visible from the graph in the Figure 7 that the maximum value of the circumferential stress increments is approximately 130 MPa. The Figure 8 represents time behaviour of the recalculated circumferential stress, which corresponds to the measured extension of the wrapped band (according to the Figure 6) taking into consideration the temperature time behaviour from the Figure 3. The maximum stress value, which is resulting from this graph, is approximately 125 MPa.

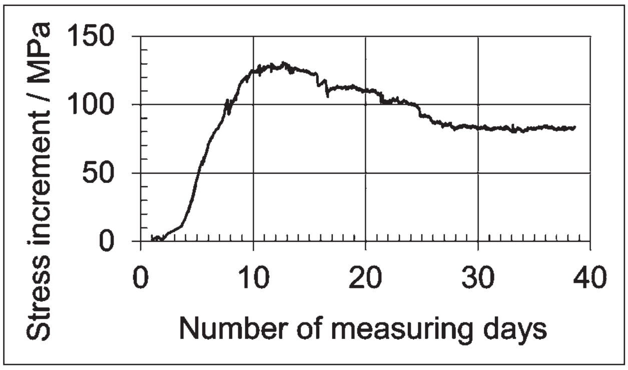

Figure 7 Time behaviour of average value of the circumferential stress increments

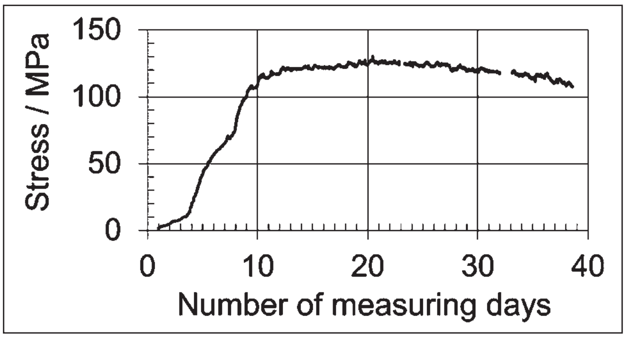

Figure 8 Time behaviour of the circumferential stress value of the hearth shell calculated from the measured band extension

The final comparison between the time behaviour of the stress increments obtained from the strain gauge sensors (average values, Figure 7) and the calculated time behaviour of the band extension (Figure 8) presents only an insignificant difference between the both maximum stress values, namely approximately 5 MPa.

CONCLUSION

This article is a continuing of the previous articles written by the authors [6]. There are defined in the Table 1 the critical values of the circumferential stress increment, radial displacement and circumferential extension of the blast furnace with the diameter approximately 14 000 mm, according to the [8].

Table 1 **The defined critical levels**

Circumferential Stress Increase / MPa	< 165	165 - 220	> 220
Extension in Circumferential Direction / mm	< 40	40 - 55	> 55
Radial Displacement / mm	< 6	6 - 9	> 9

- no action is required
- watch very closely, also watch rate of increase
- reduce blast volume and blast pressure

In our case the diameter value of the blast furnace BF2 is also approximately 14 000 mm. The measured circumferential stress increase is less than 160 MPa and the extension in circumferential direction is approximately 20 mm. It is possible to state finally, taking into consideration the measured data and after comparison of them with the Table 1 that the measured values do not require any action, i.e. they belong to the 1st column in the Table 1, according to the conditions defined in the [8].

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Note: The responsible translator for English language is Ing. Jana Vargová, Košice, Slovakia