Journal of Achievements in Materials and Manufacturing Engineering

VOLUME 18
ISSUE 1-2
September–October
2006

Numerical simulation of wear of basalt lava spinning rolls

A. Klimpel*, A. Lisiecki, D. Janicki
Welding Department, Silesian University of Technology,
ul. Konarskiego 18a, Gliwice 44-100, Poland
* Corresponding author: E-mail address: andrzej.klimpel@polsl.pl

Received 15.03.2006; accepted in revised form 30.04.2006

Manufacturing and processing

ABSTRACT

Purpose: of this paper: Results of the study of wear phenomena of cascade spinning rolls during stone wool production process are described.
Design/methodology/approach: The study was based on direct process observations, chemical analysis and temperature measurements of basalt lava, metallographic examinations of the spinning rolls deposits. It was showed that the deposits of spinning rolls are worn in very different way, depending on the roll position in rolls cascade.
Findings: Predominant wear phenomena of the fully austenitic Grade 310 deposit of spinning roll no 1 is molten basalt lava corrosion-oxidation accompanied by low and high cycle thermal fatigue, high temperature basalt lava erosion at low velocity of basalt lava stream impinging the working surface at high angle. Predominant wear phenomena of the austenitic-ferritic Grade S32304 deposit of spinning roll no 2 is high temperature basalt lava erosion at very high velocity of lava stream impinging the working surface at high angle what is the cause of much faster wear of then spinning roll no 1. High temperature erosion wear is accompanied by molten basalt lava corrosion-oxidation and low and high cycle thermal fatigue processes. Predominant wear phenomena of the austenitic-ferritic Grade S32304 deposits spinning roll no 3 and roll no 4 is high temperature basalt lava abrasion as sprayed by rolls no 1 and no 2 fibers of solidifying basalt lava impinge the working surface of spinning rolls no 3 and no 4.
Research limitations/implications: The mechanisms of high temperature erosion demands further investigations and detailed studies.
Practical implications: The wear resistance of basalt lava spinning rolls can be increased.
Originality/value: The mechanisms of surface layer wear of basalt lava spinning rolls were determined.
Keywords: Welding, Spinning rolls, Basalt lava

1. Introduction

Basalt is generic name for solidified lava poured out of the volcanoes. Basaltoid rocks are melted approximately in the temperature range 1500–1600°C. When this melt is quickly quenched, it solidifies to glass like, nearly amorphous, solid. Slow cooling leads to more or less complete crystallization, to an assembly of minerals [6]. Basalt rocks from dolomite stones were used as a raw material in production line of one company in Gliwice [1-8], Table 2.

During the stone wool production process stream of molten basalt lava is poured out from the nozzle of the molten lava ladle on the tapping spout. Next, molten lava during flow through the tapping spout is uniformly heated up by gas flame to the temperature approx. 1450°C, as shown in Fig. 1, and subsequently is poured out from the tapping spout to the spinning rolls system where rolls are spinning at 6000-7000 [rpm] and water cooled from inside (Fig. 1 and Fig. 2) [5-13].

As the result of various wear phenomena, the spinning rolls are heavily worn, particularly in the middle part and outside part of the working surface, as shown in Fig. 4, 5. Basic criterion of the work time of spinning rolls, demanding their replacement, is heavy wear (wash out) of the grooved surface projections of spinning rolls, causing weakening and subsequently disappearance of the action of stone wool spraying, Table 1, [12-19].

Table 1.
Dimensions, peripheral speed and work time of spinning rolls

Rolls no	Diameter [mm]	Wall thickness [mm]	Grooved surface width [mm]	Peripheral speed [m/s]	Work time [h]
1	190	33	125	59.66 – 69.59	220 - 250
2	245		145	76.90 – 89.70	100-120
3	370			117.75 – 135.50	75-80
4	370			117.75 – 135.50	75-80

Remarks: Grooved working surface of spinning rolls dimensions: groove width = 2.2 [mm] height of projection = 3 [mm], width of projection = 1.5 [mm], see Fig. 2 and 3.

Table 2.
The chemical composition (wt-%) of a weld metal deposit of cascade spinning rolls

Welding wire designation	C	Mn	Si	Cr	Ni
SG X 12 CrNi 25 4 austenitic-ferritic structure	0.08	1.2	0.8	25.7	4.5
SGX 12 CrNi 25 4 fully austenitic structure	0.12	3.2	0.9	25.0	20.5

Fig. 1. A view of stone wool production process. Basalt lava is poured out from the ladle on the tapping spout from which is poured out to the cascade spinning rolls

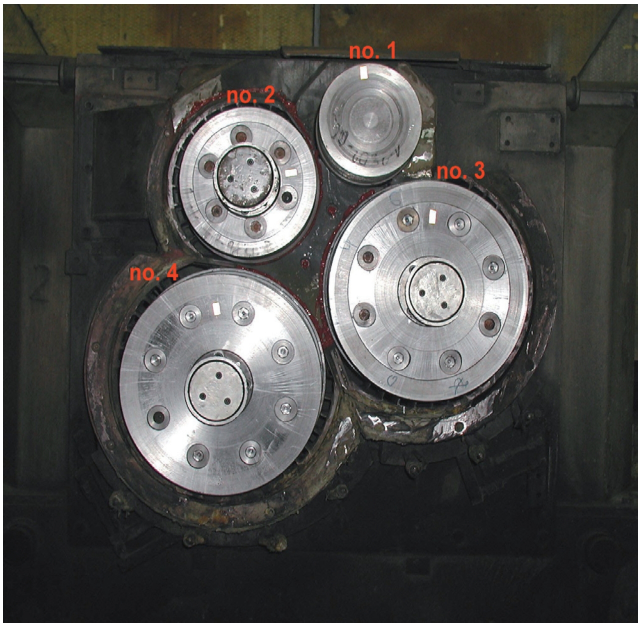

Fig. 2. A view of cascade spinning rolls of stone wool production apparatus of one company in Gliwice, Poland

Table 3.
Short time elevated temperature tensile strength of Grade 310 steel

Temperature, [°C]	550	650	750	850	950	1050
Tensile Strength, [MPa]	550	430	280	180	90	50

Remarks: Recommended Maximum Service Temperature (Oxidizing Conditions): Continuous - 1150°C, Intermittent - 1035°C.

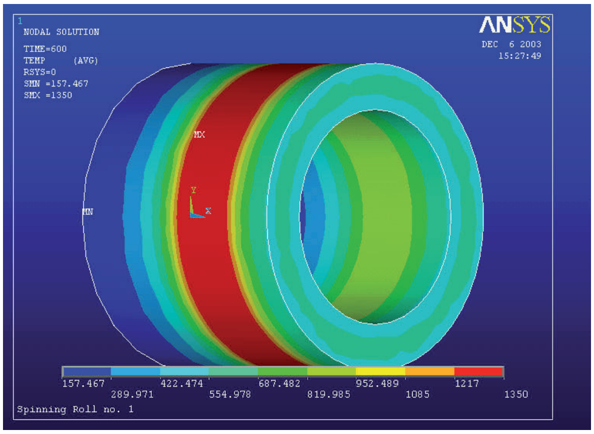

Fig. 3. Temperature distributions on outside and inside surfaces of spinning roll no 1 during stable stone wool production

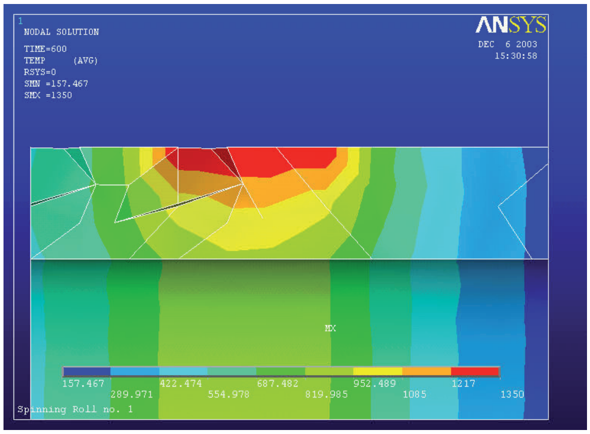

Fig. 4. Detailed temperature distributions in the middle part of cross section of spinning roll no 1 during stable stone wool production process

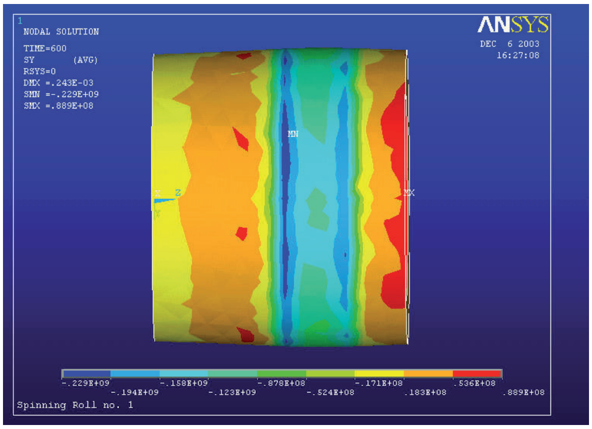

Fig. 5. Stresses and strains distributions on the outside surface of spinning roll no 1 during stable stone wool production process (max. tensile stress - 229 MPa – marine blue fields)

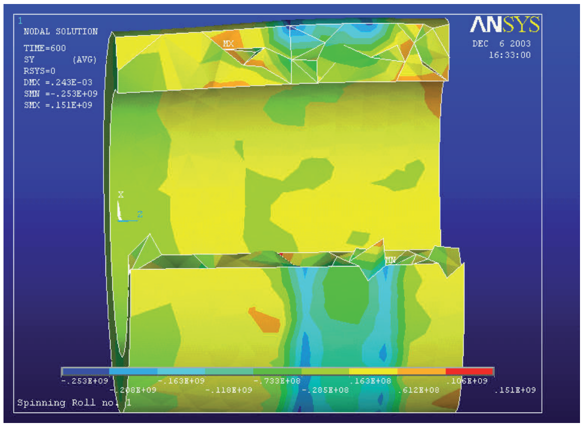

Fig. 6. Stresses and strains distributions in the cross section of spinning roll no 1 during stable stone wool production process (max. tensile stress - 253 MPa; marine blue fields)

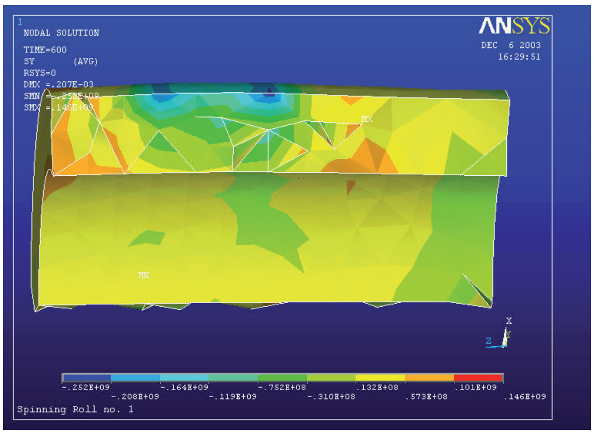

Fig. 7. Detailed stresses and strains distributions in the cross section of spinning roll no 1 during stable stone wool production process (max. tensile stress - 252 MPa; marine blue fields)

2. Mechanical properties analysis of the deposit of spinning roll no 1 by the finite element method

Finite element (FEM) calculation has been applied to analysis stresses and strains distributions in the deposit of spinning roll no 1 during stone wool production process. Spinning roll no 1 was chosen as it works under highest load basalt lava temperatures, as shown in Fig. 3 and Fig. 4. Basing on the thermovision temperature measurements and making an assumption of heat convection from inside surface of the roll by water cooling system, a model of temperature distribution on the cross section of spinning roll no 1 was calculated by means ANSYS program, as shown in Fig. 3 to Fig. 4. Results of numerical calculation of the stresses and strains distributions are shown in Fig. 5 to Fig. 7. It is proved that the maximum tensile stresses and strains are in the area of the surface layer of the deposit of thickness 3,0-5,0 [mm] and tensile stresses are in the range of 119 to 253 [MPa], much higher than the short time elevated temperature tensile strength of SGX 12 CrNi 25 4 steel in corresponding range of temperatures, as shown in Fig. 5 to Fig. 7 and depicted in Table 3.

3. Summary

From the study of wear phenomena of cascade spinning rolls of stone wool production process on the basis of direct process observations, chemical analysis and temperature measurements of basalt lava, finite element method calculation of stresses and strains distributions in deposits of spinning rolls, metallographic examinations and technical literature review, the following conclusions have been drawn:

- the deposits of spinning rolls are worn out in very different way, depending on the roll position in rolls cascade,
- predominant wear phenomena of the fully austenitic Grade 310 deposit of spinning roll no 1 is molten basalt lava corrosion-oxidation accompanied by low and high cycle thermal fatigue, high temperature basalt lava erosion at low velocity of basalt lava stream impinging the working surface at high angle,
- predominant wear phenomena of the austenitic-ferritic Grade S32304 deposit of spinning roll no 2 is high temperature basalt lava erosion at very high velocity of lava stream impinging the working surface at high angle what is the cause of much faster wear of then spinning roll no 1. High temperature erosion wear is accompanied by molten basalt lava corrosion-oxidation and low and high cycle thermal fatigue processes,
- predominant wear phenomena of the austenitic-ferritic Grade S32304 deposits spinning roll no 3 and roll no 4 is high temperature basalt lava abrasion as sprayed by rolls no 1 and no 2 fibers of solidifying basalt lava impinge the working surface of spinning rolls no 3 and no 4. High temperature abrasion wear is accompanied by high temperature basalt lava erosion and corrosion-oxidation.

References

[1] G.E. Linnert.: Welding Metallurgy Carbon and Alloy Steels. AWS. Miami, Florida, 1994. Ed. 4. Vol.1. Fundamentals. Chapter 6, s.628-633. Ed.4. Vol. 2. Technology. Chapter 10. s.100-107.

[2] A.M Fox.: Atomic and Lasers Physics.: www.shef.ac.uk/physics/teaching/phy332/laser_notes.pdf.

[3] J. Buława.: Application of laser in Polish Industry. Bulletin of Welding Institute, Gliwice, 5/2001.

[4] M. Banasik.: Molecular CO_2 lasers and welding application, Polish Welding Journal. no 9/2000.

[5] Publishing House The Chronicle. The Chronicle of Technique. Warszawa 1992.

[6] J. Kusiński.: Application of lasers in material engineering. Swietokrzyska Polytechnic. Mechanics. 2001.

[7] B.W. Schilling.: Encyclopedia of Optical Engineering.: http://www2.dekker.com.

[8] A. Cenian, E. Zaremba, M. Frankowski.: Lasers in medicine: http://www.imp.gda.pl/implaser/mat_szkol_r1.htm.

[9] T. Fiszer.: Action of laser.: http://www.ftj.agh.edu.pl/~fiszer/laser/lasery.htm.

[10] R. Aldrich.: Laser Fundamentals.: http://www.fas.org/man/dod-101/navy/docs/laser/fundamentals.htm.

[11] Properties of laser light.: www.biofiz.am.wroc.pl/instrukcje/c28.pdf.

[12] L Migliore.: Lasers materials procesing. Marcel Dekker Inc 1996.

[13] Laser Machining Processes - TEM Mode, Beam Diameter, Focal Spot Size and Depth of Focus. http://www.columbia.edu/cu/mechanical/mrl/ntm/level2/ch02/html/l2c02s07.html.

[14] A. Klimpel.: High power diode lasers in welding. Polish Welding Journal, no. 8/1999.

[15] T. Szulc.: Laser Cutting – opportunities and limitation. Polish Welding Journal, no. 8-10/2002.

[16] List of laser types.: http://en.wikipedia.org/wiki/List_of_laser_types.

[17] MEOS – CO2 laser work station.: http://meos.com/Downloads.htm..

[18] P.L. Smith.: A tiny package houses a powerhouse of a laser. American Machinist.: http://www.americanmachinist.com/304/Technologies/LasersPlasmaCut/Article/False/9141/.

[19] C.A. Walsh., H.K.D.H. Bhadeshia., A. Lau., B. Matthias., R. Oesterlein., J. Drechsel.: Characteristics of High-Power Diode Laser Welds for Industrial Assembly.: www.msm.cam.ac.uk/phase-trans/2001/carrie.pdf.