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Wear phenomena of spinning rolls for stone wool production

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ABSTRACT

Purpose: 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 were based on direct process observations, chemical analysis and temperature measurements of basalt lava, metallographic examinations of the spinning rolls deposits.
Findings: It was showed that the deposits of spinning rolls are worn in very different way, depending on the roll position in rolls cascade. Predominant wear phenomena are high temperature erosion, molten basalt lava (molten salt) corrosion, high temperature corrosion-oxidation, high temperature metal-ceramic abrasion wear, thermal fatigue of the working surface of spinning rolls.
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

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, 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. The stream of molten basalt lava of the diameter 30-40 [mm] and at a temperature in the range of 1300-1390°C, impinges with the gravity drop speed of 3,0-3,5 [m/s] on a working surface of spinning roll no 1, at the position 5 minutes to 12 hours, Figure 2. The stream of basalt lava is accelerated on the surface of spinning roll no 1 to the velocity in the range of 60-70 [m/s] and impinges at much higher force the surface of roll no 2, as shown in Figure 2. At the same time, a thick layer of solidifying basalt lava covers and adheres to the grooved surface of the spinning rolls no 1 and no 2, as shown in Figures 1 and 2.

2. Spinning rolls

Spinning rolls of stone wool production installation are forgings produced from austenitic steel X2CrNi19-11 – Grade 308 (roll no 1) and low alloy steel S235JR and S355NL (rolls no 2, no 3 and no 4), Table 1. Working surface of spinning rolls is surfaced by automatic GMA process and normal thickness of the deposit is approx. 12-15 [mm]. Spinning roll no 1 is surfaced by means of solid wire ϕ 1,0 [mm] dia., from fully austenitic steel SGX 12 CrNi 25 20 - BUHLER Co (Grade 310). Surfacing of spinning rolls no 2, no 3 and no 4 is done by means of solid wire ϕ 1,2 [mm] dia. from duplex austenitic-ferritic steel – SGX 12 CrNi 25 4 - BUHLER Co (Grade S32304). Hardness of deposits is in the range of 200-230 HV10, as shown in Figure 3. After GMA surfacing process, the working surface of spinning rolls is grooved by machining, Figure 1. Results of weld metal chemical composition tests are presented in table 2. 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. All worn spinning rolls are usually reclaimed four times and next scraped.

Fig. 1. A view of grooved working surface of spinning roll no 2. Grooved surface dimensions: groove width = 2,2 mm height of projection = 3,0 mm, width of projection = 1,5 mm

3. Wear phenomena of spinning rolls

Results of visual and metallographic examinations of the worn spinning rolls have indicated that their working surfaces are worn due to various wear phenomena. Just rolls no 3 and no 4 are worn in very similar way. Figure 3 shows that projections of roll no 1 are partially or almost totally removed in the middle and outside part of the working surface of approx. width 70-75 [mm], where a low velocity stream of molten basalt lava hits at high angle the working surface, as shown in Figure 2, but last three outside projections are almost untouched by wear. The middle and outside part of the working surface - approx. width 45-60 [mm], contains a lot of large and deep pits and cracks, perpendicular and parallel to the roll spinning direction, as shown in Figure 3. Projections of inside part of the working surface (adjoined to the power transmission) of the width 40-45 [mm], are almost untouched by wear.

Figure 3 and 5 shows the worn area of working surface of spinning roll no 2, covered by pits and crack like defects, perpendicular or parallel to spinning direction. Projections of spinning roll no 2 are almost totally removed in the middle part and outside part of the working surface of approx. width 90 [mm], where a high velocity stream of molten and partially solidified basalt lava impinge at high angle the working surface, as shown in Figure 2. Projections of inside part of the working surface (adjoined to the power transmission), are almost not worn, as in this area has almost no contact with a high velocity steam of molten and partially solidified basalt lava.

Solidified stream and fibers of basalt lava accelerated and sprayed by spinning roll no 1 and no 2 impinge almost whole working surface of spinning rolls no 3 and no 4, as shown in Figure 2, and both rolls are worn in very similar way. The working surface of spinning rolls no 3 and 4 present uneven, and wavy shape of wear and almost all projections of working surface are less or more removed, Figures 3 and 6.

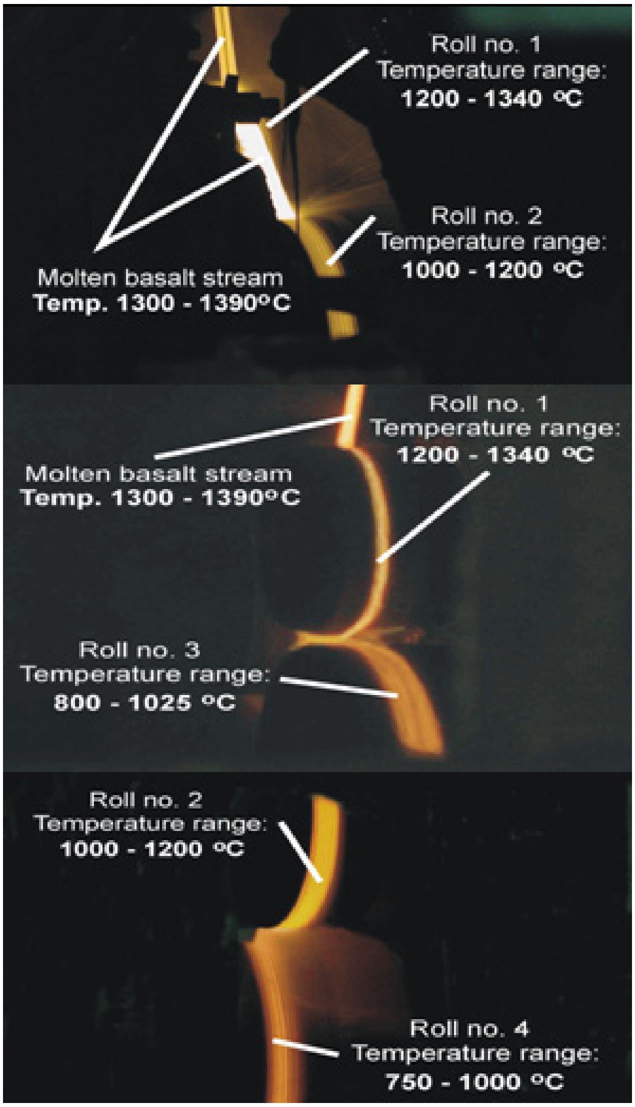


Fig. 2. Pictures of molten basalt lava stream impinging at working surface of spinning rolls and results of basalt lava temperature distribution measurements

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

<table>
<tr><th>Rolls No</th><th>Diameter [mm]</th><th>Wall thickness [mm]</th><th>Grooved surface width [mm]</th><th>Peripheral speed [m/s]</th><th>Work time [h]</th></tr>
<tr><td>1</td><td>190</td><td rowspan="4">33</td><td>125</td><td>59.66 – 69.59</td><td>220 - 250</td></tr>
<tr><td>2</td><td>245</td><td rowspan="3">145</td><td>76.90 – 89.70</td><td>100-120</td></tr>
<tr><td>3</td><td>370</td><td>117.75 – 135,50</td><td>75-80</td></tr>
<tr><td>4</td><td>370</td><td>117.75 – 135.50</td><td>75-80</td></tr>
</table>

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

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

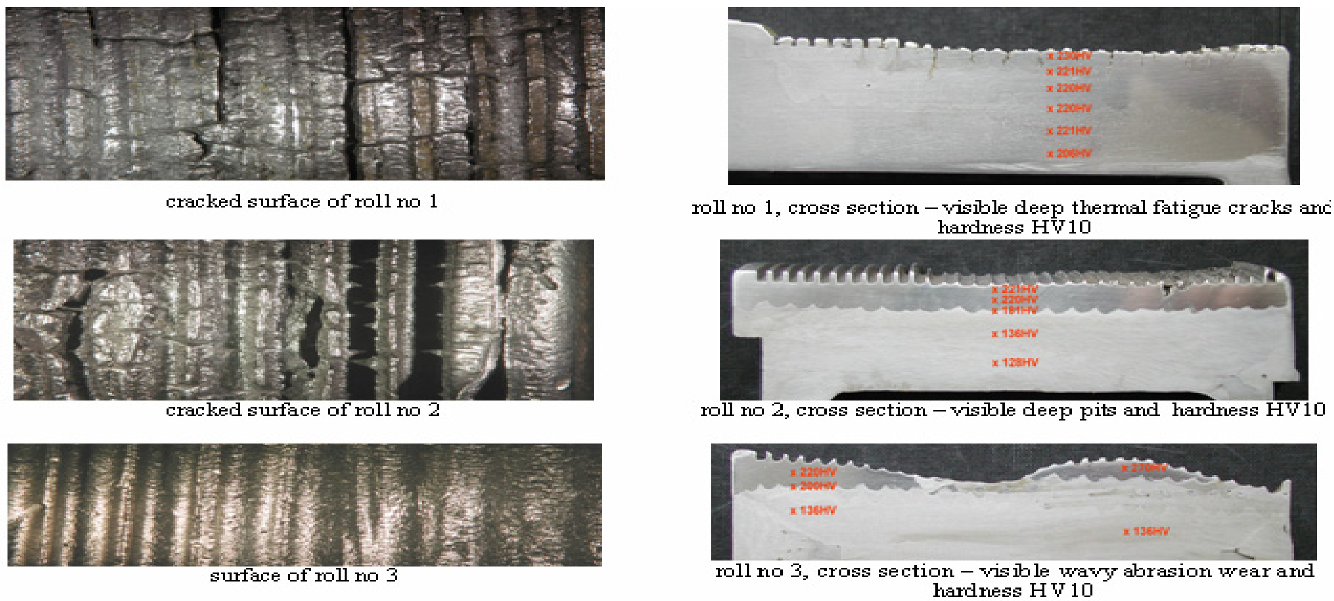


Fig. 3. Views of worn working surface of spinning roll no 1 after 240 hours, roll no 2 after 120 hours and roll no 3 after 80 hours of work time

4. 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, metallographic examinations and scientific literature review [1-15], following conclusions have been drawn:

- the deposits of spinning rolls are worn 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.

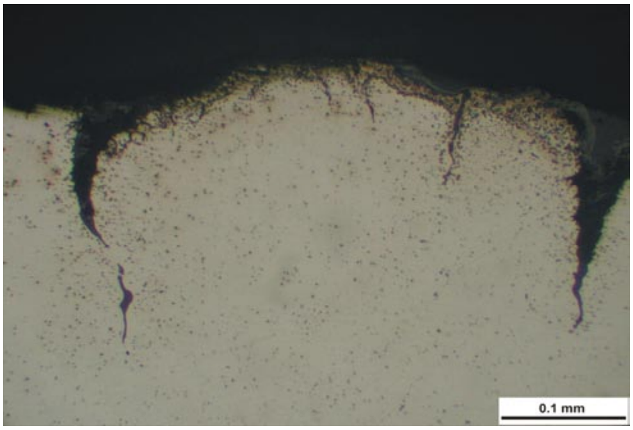
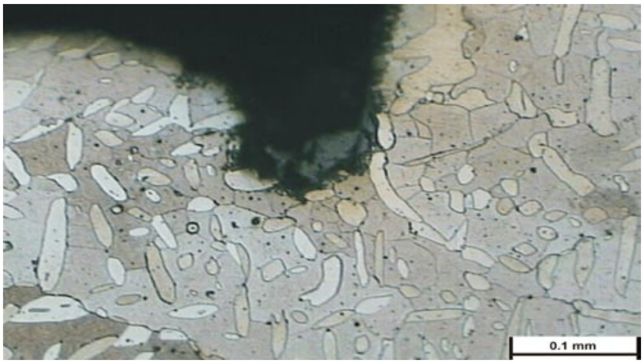


Fig. 4. Micrographs showing shape of a surface and fatigue cracks and fully austenitic microstructure of the corrosion-erosion and thermal fatigue worn spinning roll No 1



shape of the bottom of a pit

Fig. 5. Micrographs showing shape of a surface and the bottom of a pit and austenitic-ferritic microstructure of the erosion-corrosion worn deposit of spinning roll No 2

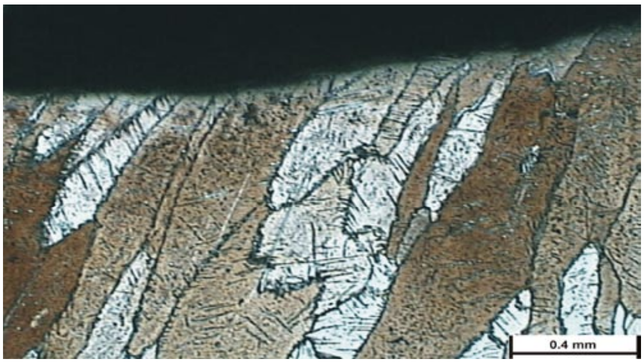


Fig. 6. Micrographs showing shape of a surface and microstructure of abrasion worn deposit of spinning roll No 3

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