THERMAL FATIGUE BEHAVIOR AND CRACKING CHARACTERISTICS OF INDEFINITE CHILL IRON ROLLS

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Introduction

Thermal fatigue can be defined as the gradual deterioration and eventual cracking of a material by alternating heating and cooling during which free thermal expansion is partially or fully constrained. Thermal fatigue is considered as a low-cycle failure mechanism that occurs due to the operating conditions [1].
Cooling process of the work rolls is one of the most difficult tasks during hot rolling. Their surface is exposed to rapid temperature change due to the contact with hot rolled material and cooling with water sprays. If cooling is not intensive enough, wear of rolls and fire cracks appear. Fire cracks can appear after only a few turns of rolls, starting on the surface and grow perpendicular to the surface of the rolls. Intensity of growth and depth of cracks mostly depend on temperature gradient during alternating heating and cooling.

Experimental

Experimental test

To study nucleation and growth of cracks, a special test was developed as a part of thermo-mechanical simulator of metallurgical processes, Gleeble 1500, (Fig. 1), [2,3]. Specimens (Fig. 2) were tested at similar conditions found on surface of rolls during hot rolling. Specimens were heated to four different temperatures, 400, 500, 600 and 700 °C and then rapidly cooled with water. Two series of experiments with 500 and 1000 cycle repetitions were carried out, each cycle being composed of three phases: heating, water cooling and cooling of the specimen with air, all in duration of 4.8 s.

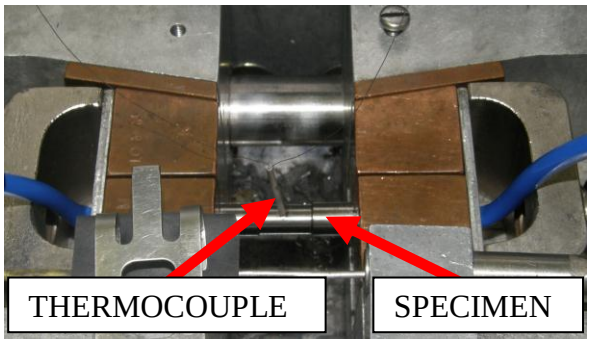

Fig. 1 Test cell with specimen.

Material

Specimens were electric-discharge machined from an indefinite chill roll, quality CIN-N-80, in foundry Valji, ltd. These type of roles are usually used for roughing and finish mills and Steckel rolling mills, [4].
Metallographic examination of steel showed that outer shell of the roll consist of matrix of dendrite grains from bainite and martenzite (B+M), ledeburite (Fe_3C) and some free graphite.

Specimens

Specimens were of cylindrical shape with ϕ10 mm by 71 mm in length (Fig. 2). Through the specimens in longitudinal direction a ϕ4 mm borehole was machined. Specimens were cooled trough the borehole with stream of water and air. In the middle of the specimens a reduction of diameter was machined which enable greater temperature gradients during heating and cooling stage of experiment. A thermocouple which controlled the

experiment was mounted in the middle of reduced part of specimen, (Fig.1).

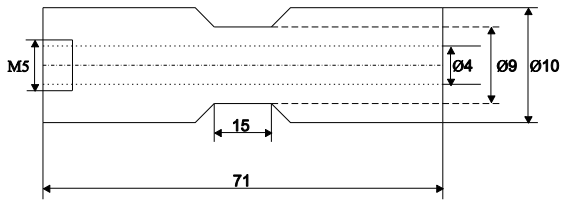

Fig. 2 Dimensions of the specimen (mm).

Results and Discussion

During the testing thermal fatigue cracks appeared on all of the specimens. With higher maximal temperature during a single cycle and greater number of cycles, cracks become wider and deeper, but lower in density.

At the temperature of 400 °C, 5.1 cracks/mm formed on average. At the temperature of 700 °C, the density of cracks was reduced to 2,8 cracks/mm. In the 2,5 mm thick wall of specimens cracks reached a depth between 300 µm and 1500 µm, (Table 1). Cracks start to grow on cooled surface of the specimen on the phase boundaries between grains of bainite and martensite and grains of ledeburite, (Fig. 3). Cracks propagate in depth of specimen mostly through the ledeburitic phase, (Fig. 4).

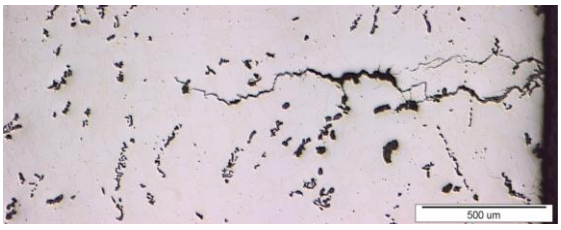

Fig. 4 Image of crack after 1000 cycles at heating temperature 700°C, longitudinal direction.

Table 1 Depth of the deepest cracks found in the specimens, (µm).

	Temperature (°C)	400	500	600	700
Cycles	500	300	700	1200	1500
	1000	300	900	1400	1500

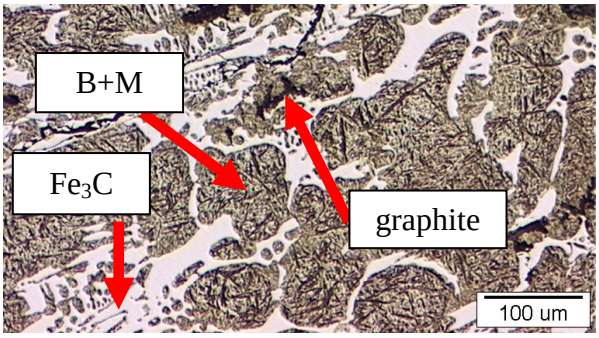

Fig. 3 Microstructure of specimen tested at 700°C for 500 cycles, perpendicular direction.

Conclusion

The developed test enables simulation of thermal fatigue during hot rolling. Formed cracks appear on cooled surface on the phase boundaries. With increasing number of cycles cracks become deeper and wider. Crack density decrease with higher test temperature.

References

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