Applied Mechanics and Materials Vol. 459 (2014) pp 330-334
Online available since 2013/Oct/31 at www.scientific.net

doi:10.4028/www.scientific.net/AMM.459.330

Fatigue Strength of the Rolls with Grooves

Željko Domazet, FranciskoLukša, MiroBugarin

Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, FESB-University of Split, RuđeraBoškovića 32, 21000 SPLIT, Croatia

zeljko.domazet@fesb.hr

Keywords: Fatigue strength, Hot rolling, Rolls with grooves

Abstract. In “Steelworks Split” failures of the rolls with grooves on the 3-high-roughing mill stand occurred four times. Detailed analysis of all the elements which influenced the failure was carried out. Stress analysis shownthatthe most critical area of the roll is the 7.a caliber what is corresponding with fracture positions. The fatigue strength of the material in the caliber groove for fatigue life prediction was missing and fatigue strength is determined by experimental testing.

Introduction

In “Steelworks Split” failures of the rolls with grooves on the 3-high-roughing mill stand occurred four times, Fig 1.

1.fracture - middle roll

2.fracture - middle roll

3.fracture - upper roll

4. fracture – lower roll

Fig. 1 Roll fractures

In “Steelworks Split” the 3-high-roughingmillstand was suitable for the hot rolling of the billet swith initial cross-section 100 mm square and 3 m initial length in 8 passes. Rolling mill production was 70 billets per hour. The mass of one billet was 230 kg. The rolling material is BSt 400 S according to DIN 488. Rolling temperature of the rolling material in the first pass is 1200°C.

Total length of the roll is 2300 mm, roll barrel length is 1400 mm and roll barrel diametar is 450 mm. Roll speed is 120 rpm. The material used for the rolls is nodular graphite cast iron with the pear litic base with hardness on the roll surface 380 HB. The pass schedule and corresponding dimensions are shown in Table 1. Fig. 2 shows the roll design and groove distribution with positions of the failures.

Table 1 Pass schedule & Experimental determined rolling forces

Pass No.		1	2	3	4	5	6	7	8
Pass shape		box	box	box	box	box	oval	square	oval
Groove dimensions [mm]		100x82	100x66	67x80	67x59	66x52	80x34	40	58x20
Cross-section [mm^2]	9850	8015	6474	5398	4032	3280	2286	1578	1075
Width [mm]	100	104	108	71	76	65	82,5	53,5	60,5
Initial height [mm]		100,0	82,0	108,0	80,0	76,0	52,0	82,5	40,0
Height after pass [mm]		82,0	66,0	80,0	59,0	52,0	34,0	51,0	20,5
Absolute draught [mm]		18,0	16,0	28,0	21,0	24,0	18,0	31,5	19,5
Absolute reduction [mm^2]		1835	1541	1076	1366	752	994	708	503
Coefficient of elongation		1,23	1,24	1,20	1,34	1,23	1,43	1,45	1,47
Working diameter [mm]		372,5	393,5	372,5	398,5	396,5	419,5	397,25	433
Length [m]	3	3,69	4,56	5,47	7,33	9,01	12,93	18,73	27,49
Length of arc of contact [mm]		57,84	56,10	72,08	64,68	68,97	61,44	79,10	64,97
Projected area of contact [mm^2]		5900	5947	4938	4754	4276	4531	3461	3265
Rolling time [sec]		1,58	1,74	2,26	2,65	3,53	4,65	6,92	9,52
Gap [sec]		3	3	3	3	3	3	3	3
Rolling temperature [°C]	1200	1198	1194	1188	1183	1176	1169	1159	1146
Determined rolling forces [kN]		356,1	494,6	356,1	524,2	346,2	544,0	286,8	445,1

Experimentally determined results of the rolling forces are used for numerical analysis of the local stresses by finite element method. FEM analysisshowedthatthe most critical area of the roll is the 7.a pass. Fig. 3 shows an example of FEM analysis of the rolling forces with caused stresses. The roll is loaded with rolling forces in the 4. and 8. calibers which causing maximum stress in the 7.a caliber.

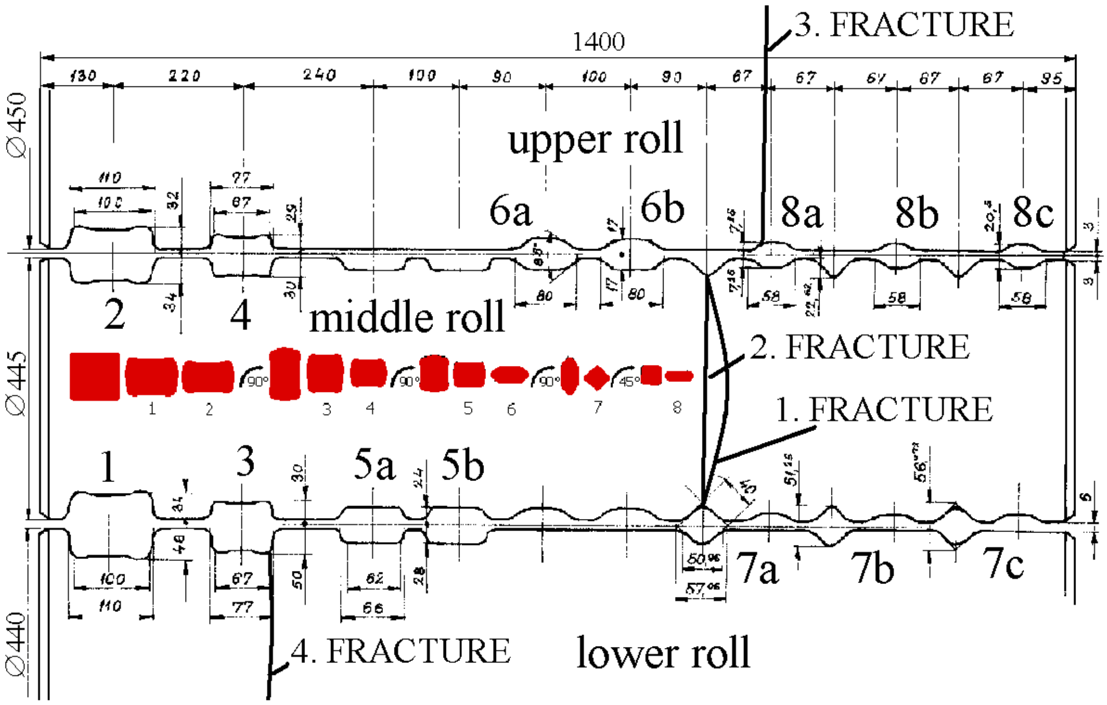

Fig. 2 Roll design and groove distribution with positions of the failures

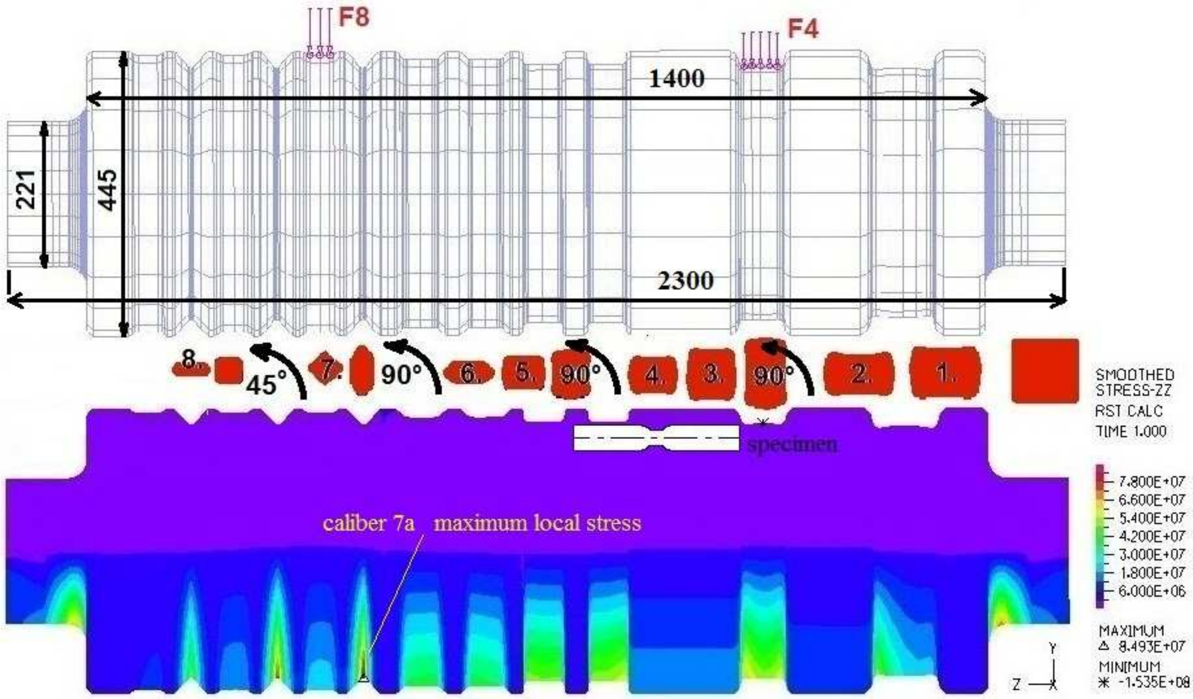

Fig. 3 Example of the rolling forces with caused stresses

For the fatigue life estimation is necessary to have fatigue strength of the material in the caliber groove. Analysis of available literature has discovered this information missing. Determination of the fatigue strength is very expensive and require a lot of time.Usually, roll manufacture catalogs contain data about chemical composition of the material, the roll hardness on the surface and hardness drop from the surface, tensile and bending strength of the core and the picture of metallographic structure of the material. Some catalogs contain information about fatigue strength of the material in the roll core.Different conditions of the cooling during the casting and heat treatment of the roll after casting cause different mechanical properties of the material on the roll surface and of the roll core what is visible in drop hardness from roll surface.

Roll basic data

The broken rolls of the 3-high-roughing mill had dimension ∅450 x 1400 mm and they made in steelworks "VALJI d.o.o", Slovenia. The mark of the roll is KGR-380-P. These rolls are nodular iron cast rolls with the pearlitic base and data are shown in the tables 2 and 3 and Fig.4.

Table 2 Chemical composition of the rolls [3]

Chemical element	C[%]	Si[%]	Mn[%]	P[%]	S[%]	Cr[%]	Ni[%]	Mo[%]
percent	3,4÷3,6	1,8÷2,2	0,5÷1	do 0,05	do 0,05	do 0,5	1,5÷3	do 0,2

Table 3 Hardness and strength of the rolls [3]

Roll mark	Hardness [HB]	Tensile strength of the core [N/mm^2]	Bending strength of the core [N/mm^2]
KGR-380-P	350÷420	325÷425	500÷700

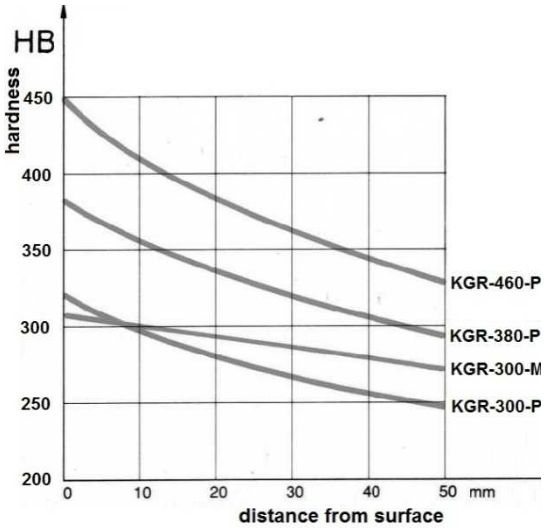

Fig. 4 Hardness drop

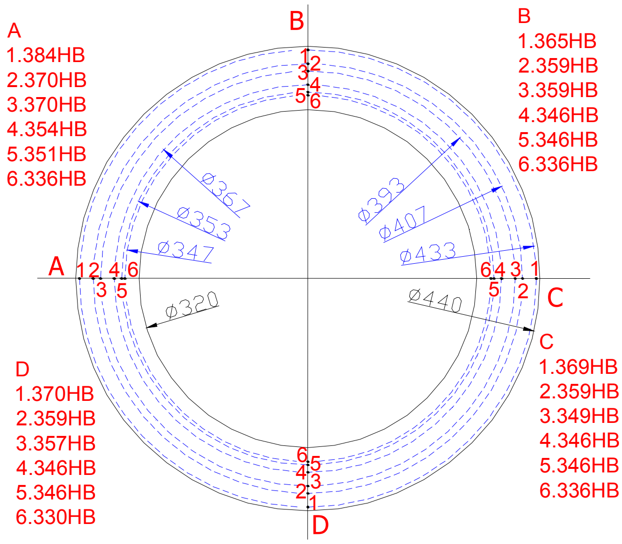

Fig. 5 Hardness measurement

Fatigue tests

Specimens, Fig. 6, were taken from the new roll dimensions ∅500 x 1500 mm with same characteristic like broken rolls. First was taken out by turning one ring dimensions ∅440x∅320x170. The hardness measurements were done on the four places, Fig. 5. Then, the specimens were taken from the ring by water cutting and final testing shape was made by grinding machine.

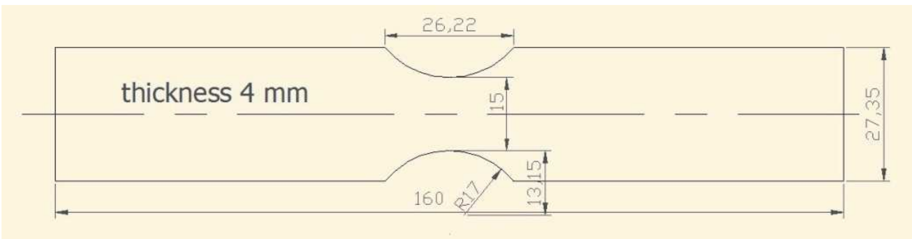

Fig. 6 Shape and dimensions of the specimen

Dynamic test were carried out in Laboratory of fatigue strength at Department of Mechanical Construction, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, University of Split. Tension/compression tests were performed on the servo hydraulic testing machine INSTRON 8801, Fig. 7. Bending tests were performed on the plane bending mechanical testing machine, Fig. 8.

Fig. 7 Servo hydraulic testing machine INSTRON 8801

Fig. 8 Plane bending mechanical testing machine

Tension/compression tests and bending tests were done on the various stress levels till specimen breakage with constant amplitudes and stress ratio R=-1, Fig. 9.

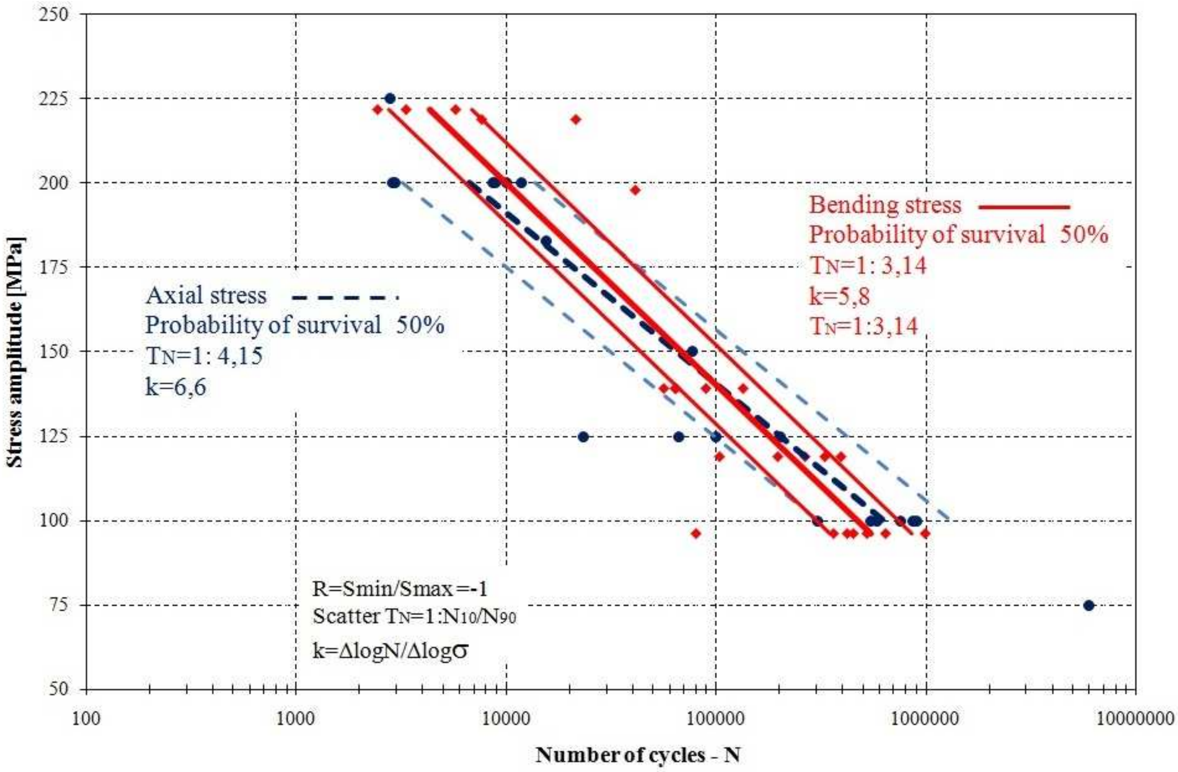

Fig. 9 Fatigue strength (S-N curves) for the axial and bending tests of the roll material

Conclusion

Tensile strength (325÷425 MPa) and bending strength (500÷700 MPa) of the roll material were known as well as hardness (350÷420 HB), see Table 3, but crucial material data for the fatigue life prediction – fatigue strength, was missing. Additional problem was heat treatment of the roll surfacewhich is rolls working area and the location of the fatigue crack origin. Because of that, large number of specimens was cut out from this region of the roll and tested in tensile and bending fatigue test machines. Obtained fatigue test data should be used for the rolls fatigue failures analysis as well as improvement of the rolls and rolling procedure in the future.

References

[1] F.Lukša; Investigation of the cause of the failures of the rools with grooves, Master Thesis, Universityof Split, Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture, Split, Croatia: 2005.

[2] Ž.Domazet, F.Lukša, M. Šušnjar; Failure analysis of rolls with grooves, Engineering Failure Analysis, Volume 14, Issues 6; September 2007, pages 1116-1174

[3] Valjid.o.o. Štore, Cast Iron rolls, catalog

[4] O.Buxbaum, V.Grubišić, H.Huth, D.Schutz; Betriebsfestigkeit, VerlagStahleisenmbH, Düsseldorf, 1986.

[5] E.Haibach; Betriebsfestigkeit-Verfahren und datenzurBauteilberechnung, VDI-Verlag GmbH, Düsseldorf, 1989.

[6] Technological rules "Steelworks Split", Split

[7] O.Buxbaum; Description of operational stresses for fatigue design, ZbornikradovasaSeminaraizPogonskečvrstoće, Split 1990.

Applied Mechanics and Mechanical Engineering IV
10.4028/www.scientific.net/AMM.459

Fatigue Strength of the Rolls with Grooves
10.4028/www.scientific.net/AMM.459.330