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Influence of Rolling Temperature on Fatigue Life of Calibrated Rolls

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Abstract. In the hot rolling process calibrated rolls are used for the production of various simple and complex profiles. Rolling temperature is an important parameter of technological process which has great influence on energy costs, scale formation and rolling forces. In order to reduce the cost of energy, an analysis of the rolling temperature influence on fatigue life of the rolls has been carried out.The fatigue life estimation is carried out according to the fatigue life stress concept based on the local stress.Stress spectra in critical areas are determined for three different temperatures. The analysis shows that although lowering of the initial rolling temperature causing decreasing the fatigue life of the roll, the stresses caused by the rolling at thelowest temperature should not lead to roll fracture.

Introduction

In hot rolling, the rolling temperature is an important parameter of technological process. The increasingof temperature increases energy costs and scale formation. Lowering of the temperature increases rolling force and subsequently reduces fatigue life of the rolls.In order to reduce the cost of energy, an analysis of the rolling temperature influence on fatigue life of the rolls has been carried out on 3-high-roughing mill stand in "Steelworks Split".

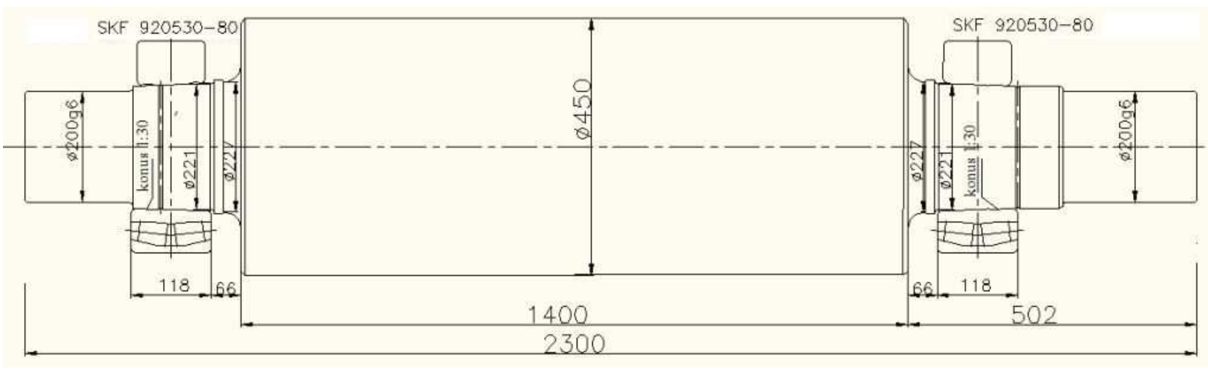
3-high-roughing mill stand was suitable for hot rolling of the billets with initial cross-section 100 mm square and 3 m initial length in 8 passes. The rolling mill production was 70 billets per hour. The mass of one billet was 230 kg. The rolling material was BSt 400 S according to DIN 488.The initial temperature in first pass was 1200 C°.The lowering of initial temperature from 1200°C to 1150°C and 1100°C is assumed.

The total length of the roll was 2300 mm, the roll barrel length was 1400 mm andthe roll barrel diameter was 450 mm. The roll speed was 120 rpm. The material used for the rolls was nodular graphite cast iron with the pearlitic base with hardness on the roll surface 380 HB. The roll machining due to wearing was estimated after 4000 rolling tons of steel.

Fig. 1 shows the roll design and groove distribution. The pass schedule and corresponding dimensions are shown in Table 1.

Rolling forces were determined by the analytical calculation and experimental testing. Monitoring of the rolling temperature was carried out using digital pyrometer. Experimentally determined rolling forces and temperature of the rolling material are shown in Table 1.

Fig. 2 shows analytically and experimentallydetermined rolling forces.



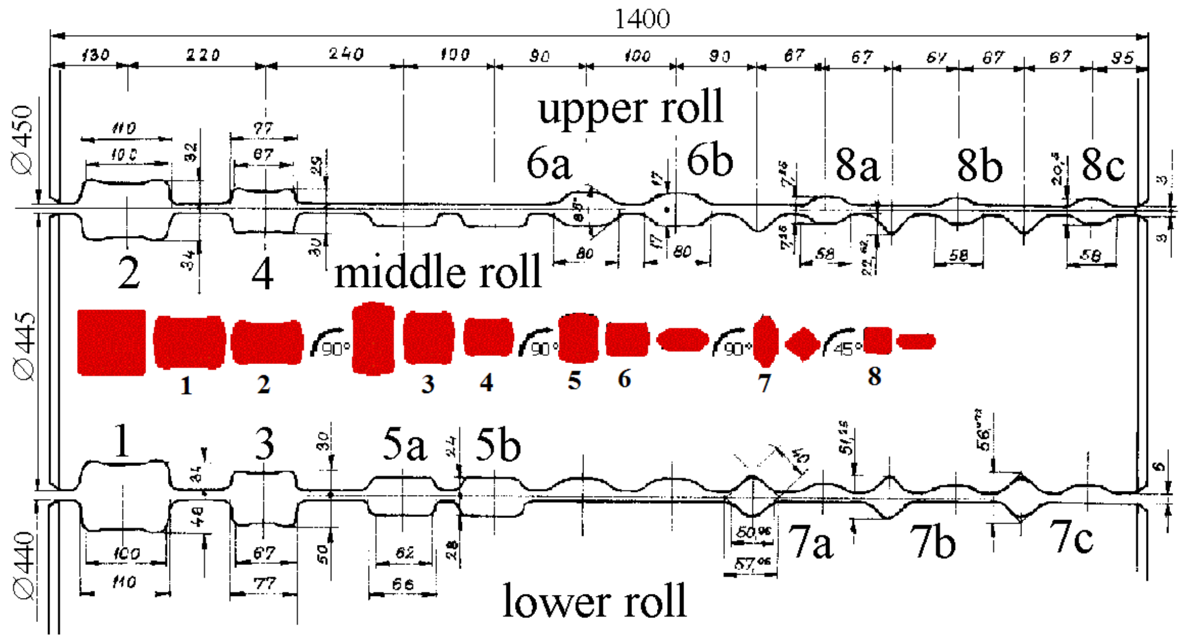


Figure1 Roll design and groove distribution

Table 1 Pass schedule &experimentally 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
Elongation coefficient		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
Projected 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 [s]		1,58	1,74	2,26	2,65	3,53	4,65	6,92	9,52
Pause [s]		3	3	3	3	3	3	3	3
Deformation speed [s^{-1}]		7,9	9,5	7,4	12	9,6	15,5	10,5	18,7
Rolling temperature [°C]	**1200**	**1198**	**1194**	**1188**	**1183**	**1176**	**1169**	**1159**	**1146**
Experimentally determined rolling forces kN		**356,1**	**494,6**	**356,1**	**524,2**	**346,2**	**544,0**	**286,8**	**445,1**

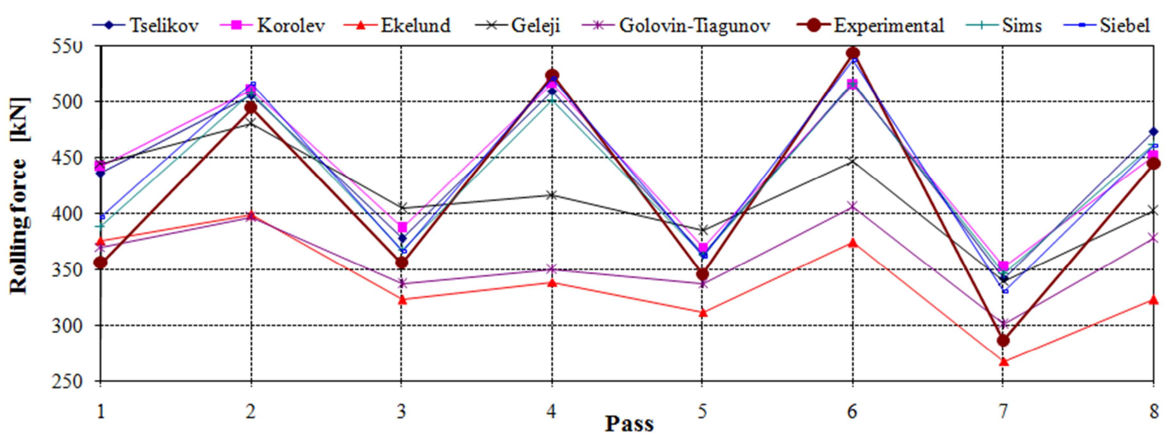


Figure2 Analytically and experimentallydetermined rolling forces

The obtained experimental results of rolling forces are used for the numerical analysis of local stresses by the finite element method. The linear elastic model with 3D solid elements with eight DOF per nodes was used. The complete numerical analysis included 30 cases according to the rolling schedule. The FEM revealed that there are 3 critical areas of the roll: roll neck, pass groove 3-4 and pass groove 7a. Fig.3 shows the FEM model ofthe middle roll with stock positions in pass grooves2 and 6.

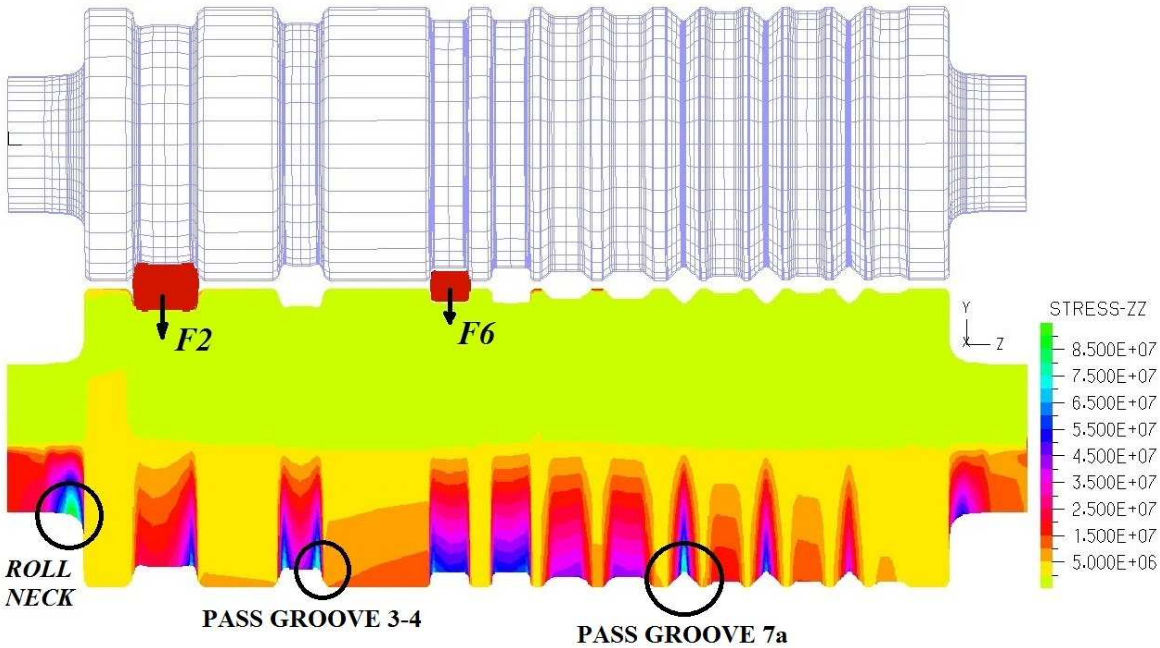
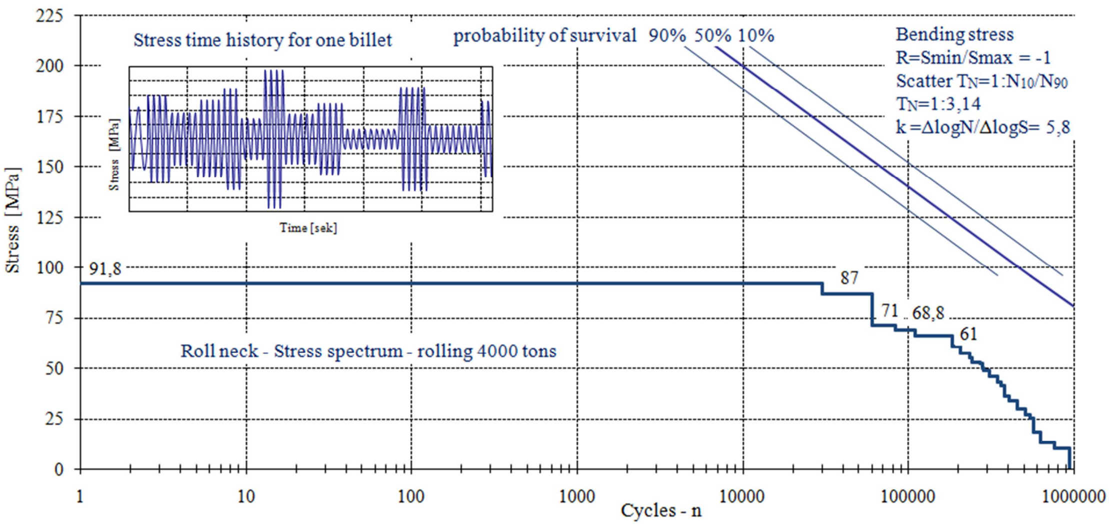


Figure3 Numerical analysis

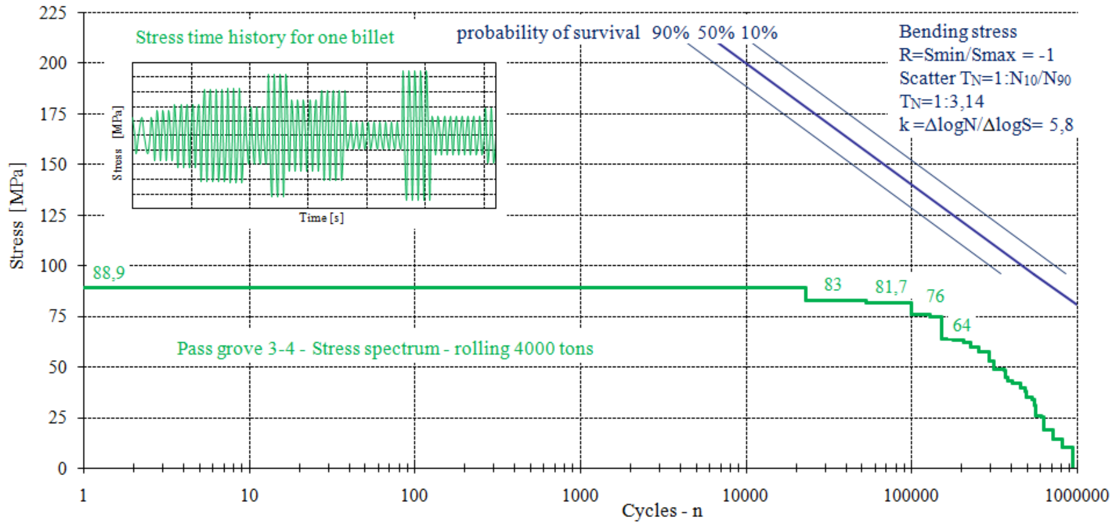
Stress time history of the individual local stress and stress spectra are obtained from numerical analysis and pass schedule. Fatigue strength of the roll material in the pass groove was missing and fatigue strength was determined by experimental testing.

Fig.4 shows experimentally obtained fatigue strength of the roll material under constant amplitude in the pass grooveand stress spectraof three critical areas: on the roll neck, pass groove 3-4 and pass groove7a for 4000 rolling tons.From the comparison of the presented spectrait can be seen that themost critical area of the roll is pass groove 7a.

a) Roll neck



b) Pass grove 3-4



c) Pass grove 7a

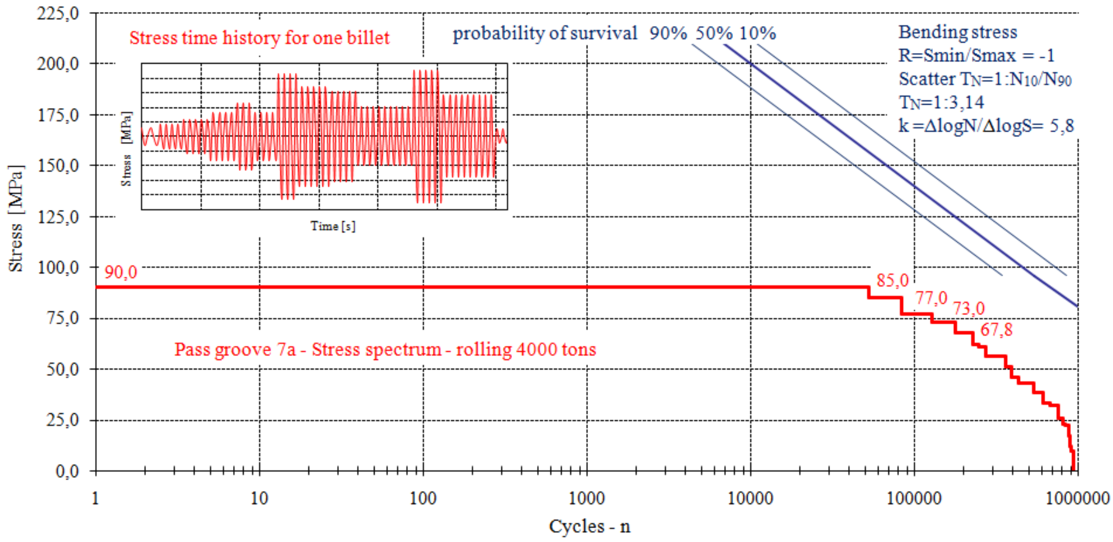


Figure4 Stressspectra for critical areas

Resistance to deformation

Main parameter to describe rolling force is resistance to deformation of rolling material.Resistance to deformation depends of the rolling temperature, deformation speed and deformation size. Fig.5shows experimentally obtained diagram of A.A.Dinnik [4],deformation resistance of low carbon steel St3 for the reduction size 30% and different deformation speed. For another reduction on the same diagram correction factor ***a***is used. The diagram shows speed range for this technological process.

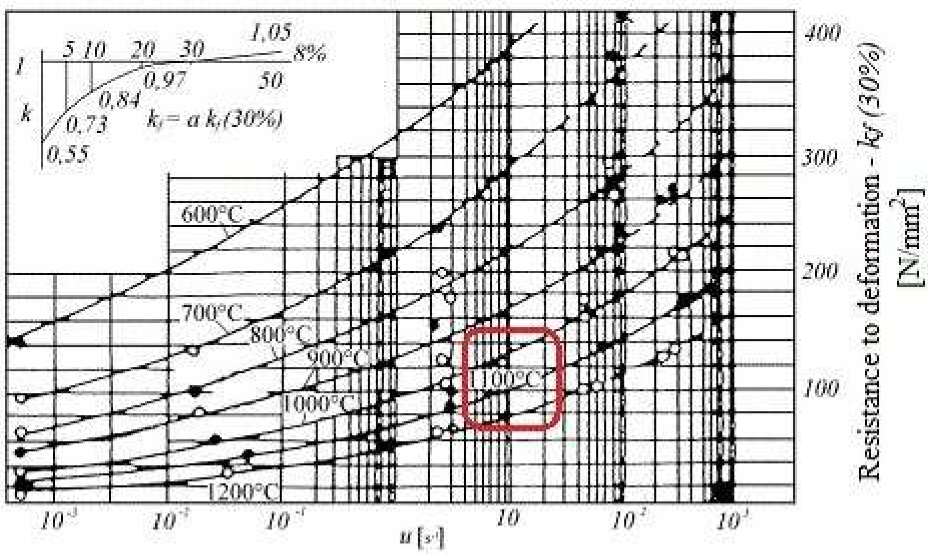


Figure5 Resistance to deformation of low carbon steel St3, A.A.Dinnik [4]

Resistance to deformation for 3 different initial temperatures in each pass is determined from diagram ofA.A.Dinnik, Fig. 5. The influence of initial rolling temperature on the resistance to deformation is shown in Fig. 6.

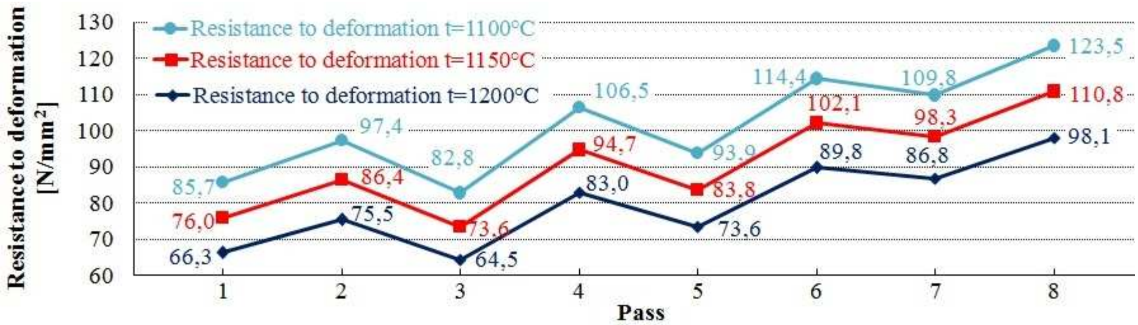


Figure 6 Influence of initial rolling temperature on the resistance to deformation

Influence of rolling temperature on rolling force

Rolling forces in passes were obtained fromformulae of eightauthors. Values obtained for rolling forces calculated according to A.I.Tselikov, A.A.Korolev, R.B.Sims and E.Siebel followthe experimental results. Rolling forces for 3 different temperatures in the first pass were obtained according to these four authors.

Based on this data it is obvious that the rolling forces increment is about 15% for lowering initial rolling temperature from 1200°C to 1150°C and about 30% for lowering initial rolling temperature from 1200°C to 1100°C.

Influence of rolling temperature on fatigue life

The obtained experimental values of rolling forces with an increase of 15% and 30% are used for numerical analysis of local stresses by the finite element method. Stress spectra for the initial rolling temperatures 1150°C and 1100°C determined from numerical analysis and pass schedule are shown in Fig. 7.

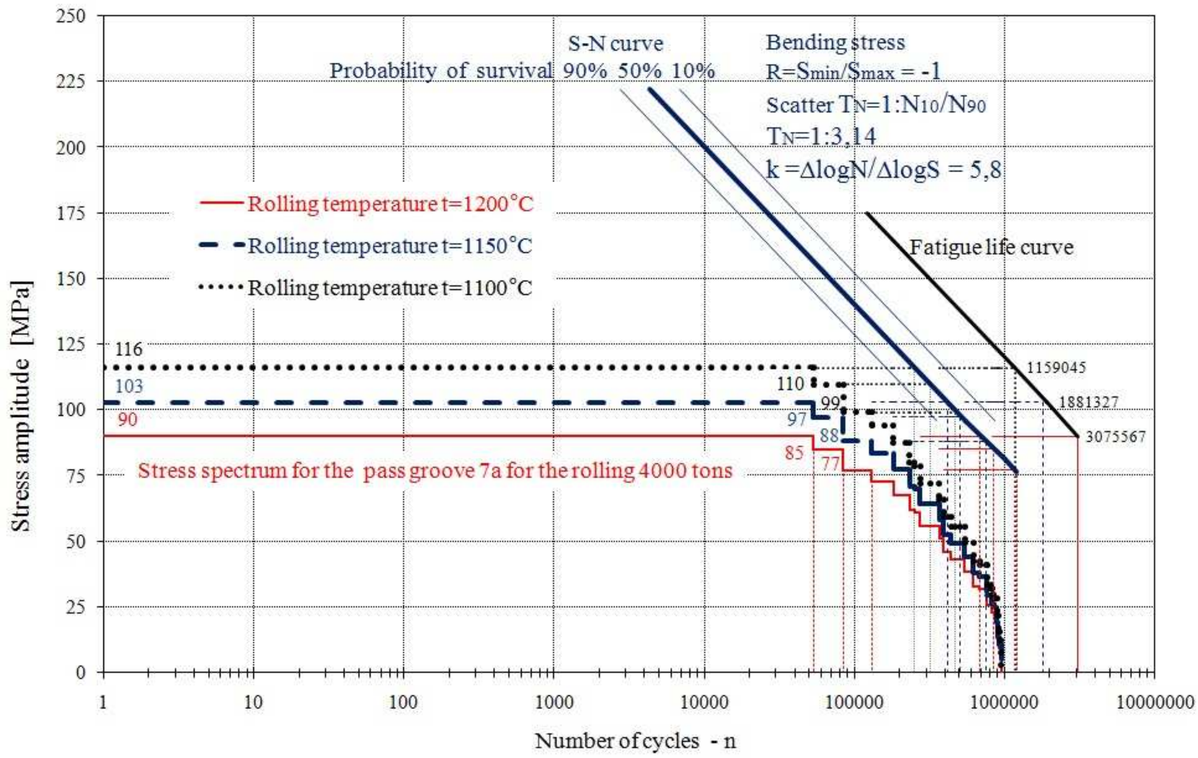


Fig. 7 Influence of rolling temperature on fatigue life

Summary

Lowering the initial rolling temperature from 1200°C to 1150°C causes increasing rolling force 15% and reduces the fatigue life of the roll about 40%, lowering the initial rolling temperature from 1200°C to 1100°C causes increasing rolling force 30% and reduces the fatigue life of the roll about 60%.Although loweringthe initial rolling temperature which causes decreasing of the fatigue life of the roll, the stresses caused by rolling at the temperature of 1100°C should not lead to roll fracture for the rolling 4000 tons.The analysis of rolling temperature effects on calibrated rolls fatigue lifeshows that some particular rolling temperature loweringin order to reduce energy cost will not have effect on roll fatigue life.

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