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UDK

SOLUTION OF STAINLESS STEEL PIPE CALIBRATION LUBRICATION PROBLEM

Abstract

In the calibration operation while pulling the basic material through the matrix there is a great energy accumulation in the grate of the basic material. Therefore the oil has to fulfill certain requirements such as the heat conductance which should be fast enough to prevent formation of cracks while cooling of the basic material. The oil also serves for lubrication of the matrix. To conclude we can say that the basic function of the oil in the calibration process is lubricating of the matrix in order to reduce wear and the heat conductance for avoiding cracks.

1. Introduction

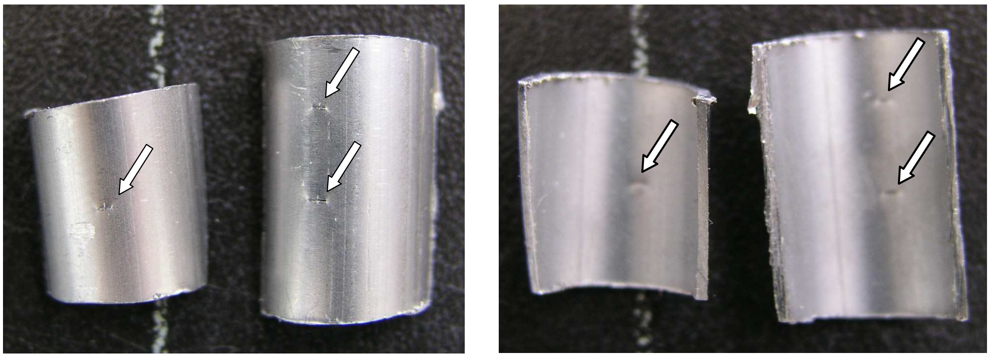
The use of stainless steel is quite widespread. It is an irreplaceable material in the food, pharmaceutical and other industries. Pipes made of this material are becoming the irreplaceable material which is very much in demand in most of the industrial sectors. Therefore, one of the challenges the manufacturers face is efficient, cheap, and quality production of stainless steel pipes in order to be more competitive in the market. Furthermore, all these demands are accompanied with the development and improvement of the pipe production technology. Today the most commonly used procedures include bending of steel sheets, welding, heat treatment and calibration of pipes to the desired diameter.

By these procedures and this order we are able to produce pipes of different diameters continuously with the same input material and the same parameters of bending, welding and the caliber changes. During this procedure the critical spot is certainly the calibration process since the great energy accumulation in the crystal grate of the basic material, due to high deformation degree, can cause errors on the pipes. All these technological parameters of continuous production of welded pipes have to be coordinated and well adjusted in order to have a constant production without any interruptions and errors.

2. Problem description

In the process of the production of stainless steel pipes marked 304L we can witness damages in the form of transversal cracks, Figure 1 a and b.

Figure 1: Parts of pipes with cracks: a) outside, b) inside



a) b)

The cracks emerge in irregular intervals after the calibration procedure and they do not appear by any pattern. The cracks and their detection interrupt the whole production process when these damaged pipes need to be cut and discarded. Apart from this waste of the material and time, there is also a loss of the pipe continuity since they usually need to be produced in one piece of a certain length. Due to the direct and indirect costs caused by these errors and interruptions, a manufacturer is eager to find out what causes them and to prevent them in the future.

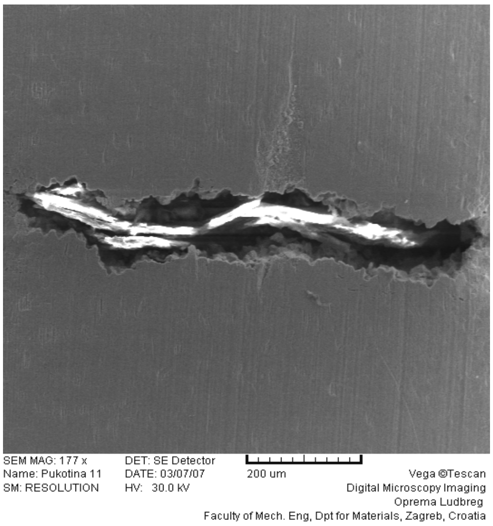
The analysis of the cracks showed their two possible causes. One may be an error in the material structure and another one is a problem in the lubrication during the pipe calibration.

3. Testing pipe material

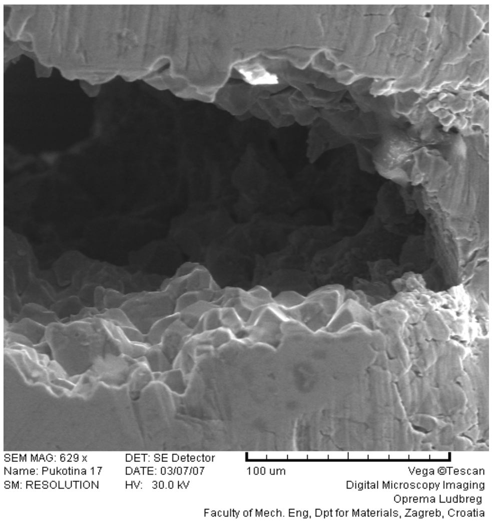
In order to determine errors in the structure of material which caused the cracks, the cracked parts have been tested under laboratory conditions.

The tests included the analysis by a scanning electron microscope, the microstructure analysis and the microhardness analysis. The samples were prepared before the test by cutting the parts of pipes and cleaning in ultrasound cleaner in alcohol for 5 minutes. The damaged parts were analyzed by the scanning electron microscope TESCAN VEGA TS5136LS under high vacuum, at 30 kV with the use of the SE detector (detector of secondary electrons). A typical crack and a detail of the surface around it are shown in Figures 2a, 2b, 2c, 2d.

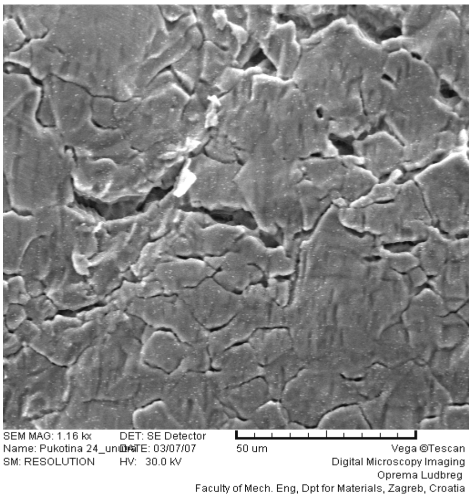
Figure 2: SEM pictures of the crack, SE detector: a) the whole crack, b) a crack edge c) a crack edge, magnified d) the basic material near the crack



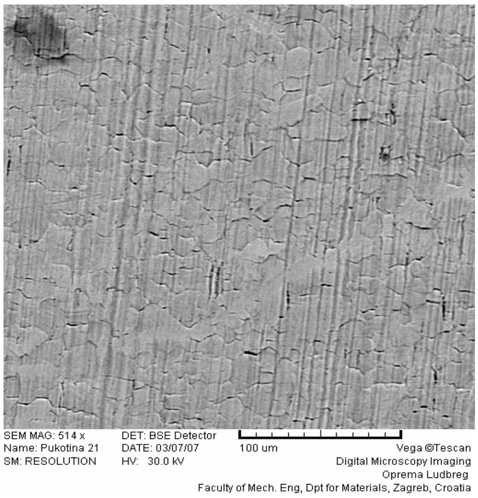
a)



b)



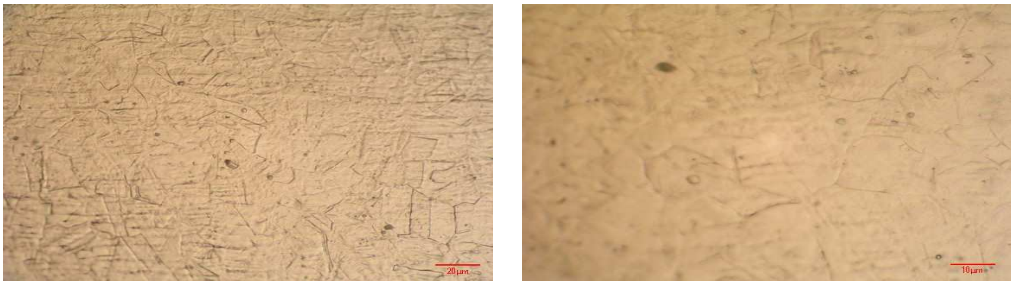
c)



d)

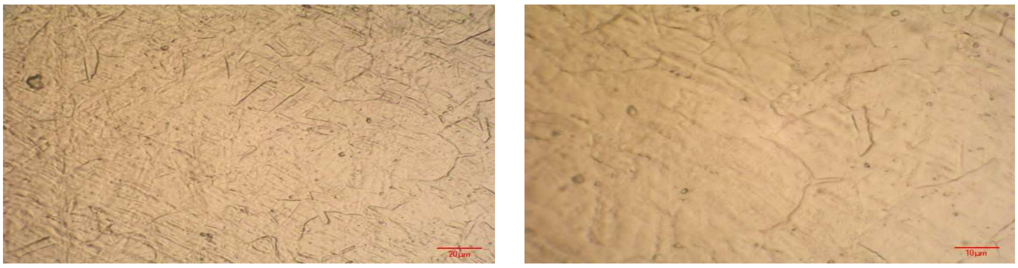
The analysis of the damaged pipe surfaces showed the transversal cracks 1, 2 mm long at grain boundaries. At the both ends of all the cracks one can see the material deformation in a recess form. There is a net of cracks spreading in range of few millimeters from the end of a crack towards the basic material and these cracks are visible over the entire deformed surface. After the surface analysis of the samples by the use of SEM, we also analyzed the material microstructure of the delivered pipe samples with and without cracks at the transversal cut. The samples were received for the analysis according to the recommendations for stainless steel: they were cut under the intensive cooling conditions, roughly and finely ground, polished and electrolytically etched by chromium acid.

Figure 3: Microstructure of the pipes with cracks in the transversal cut: a) lower magnification, b) higher magnification



a) b)

Figure 4: Microstructure of the pipes without cracks in the transversal cut: a) lower magnification, b) higher magnification



a) b)

The microstructures of pipe materials with cracks in the transversal cut are shown in Pictures 3a and b, and the microstructure pipe materials without cracks in Fig. 4a, b. The analysis of the material microstructure of damaged and undamaged pipes in the transversal cut did not show any significant difference. Both samples have homogeneous austenitic microstructure which is typical for this kind of material.

The material microhardness of both samples was measured. The measurements were conducted at the transversal cuts of the delivered pipes on the inside surface, in the middle of the cuts and on the outside surface. The measurement procedure was performed by the hardness measurement device using the Vickers method (HV) under a load of 1 N which matches HV 0,1. The average values of five measurements are shown in Table 1.

Table 1: Average values of five hardness measurements on the delivered pipe samples

Sample	HV 0,1		
	Inside surface	In the middle	Outside surface
Pipe with cracks	185	188	185
Pipe without cracks	154	157	157

By measuring the microhardness no differences have been noticed in regard to the measuring spot in the transversal cut of the pipe: the values of the microhardness on the inside surface, in the middle and on the outside surface are pretty much the same. The microhardness of the pipes without cracks is significantly lower, which could be the consequence of a difference in the deformation degree during the calibration and a temperature difference in the supplementary heat treatment of the pipes.

The tests performed on the pipe material showed that there is no irregularity or structural error to cause the cracks. The analysis results with SEM and microhardness values indicate that the cause of it is stress, which means that the cracks emerged due to the outside stress becoming greater than material strenght. This means that the cause of this crack is detected within the most critical procedure of pipe production technology, the pipe calibration.

4. Lubrication during pipe calibration

The technological process of the pipe production includes producing a pipe with the starting diameter of 10 mm and a subsequently diameter reduction, so called calibration, if required by a customer. For the successful calibration, the matrix (the caliber) needs to be made of high quality material and it needs to be extremely well lubricated (Figure 5). Due to extremely high deformation degree during the calibration process, the material needs to be properly lubricated to provide the lubricating film between the matrix material and the pipe material, to prevent the wear of the material and to conway developed heat.

Very stringent requirements for the lubricant used in this process can be met only by a lubricant which is specifically developed for this technology. So far the original lubricant recommended by the manufacturer of the pipe production line was used. Nevertheless, the cracks caused the reconsideration of the efficiency of this originally recommended lubricant as well as the request for the substitute lubricant with better properties. Beside the lubricating efficiency, another reason for seeking a substitute lubricant is ecological awareness, since the original lubricants contain some additives which proved to be ecologically harmful.

Table 2 shows the basic characteristics of the lubricant used from the beginning of the pipe production and which was recommended by the manufacturer of the equipment for this kind of the production.

Figure 5: Pipe calibration (a detail)

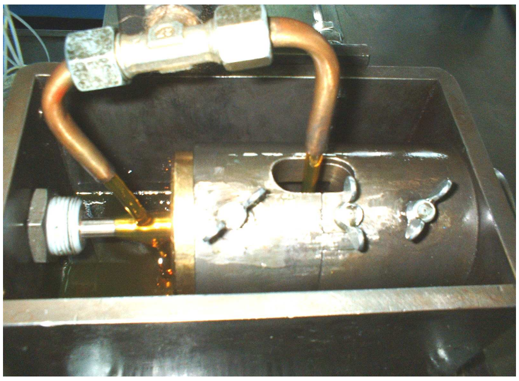


Table 2: Basic characteristics of the used lubricant

PROPERTY		CONTENT	
Kinematic viscosity, 40° C mm^2/s	170	Sulphur (S)	+
4-ball rig, ASTM D 2783:		Phosphorus (P)	-
Welding point, N	8000	Chlorine (Cl)	+
Mean wear scar, mm	0,86	Natural ester	+
Wear surface, mm^2	2,1	Synthetic ester	+

Table 3: Basic characteristics of new lubricant formulations

PROPERTY	OIL FORMULATION								
	1	2	3	4	5	6	7	8	9
Kinematic viscosity, 40 °C mm^2/s	90	130	170	160	150	160	160	160	160
4- ball rig, ASTM D 2783:									
Welding point, N	8000	8000	>8000	>8000	>8000	>8000	>8000	5000	5000
Mean wear scar, mm	0,56	1,19	0,35	0,98	1,08	1,21	1,12	0,46	0,46
Wear surface, mm^2	2,2	4,3	3,2	3,6	3,85	3,15	4,15	2,8	2,8
CONTENT									
Sulphur (S)	+	+	+	+	+	+	+	+	+
Phosphorus (P)	+	-	+	+	+	+	+	+	+
Chlorine (Cl)	-	-	-	-	-	-	-	-	-
Natural ester	+	+	+	+	+	+	+	-	-
Synthetic ester	-	-	-	-	-	-	-	+	+

Based on the requirements from the production, knowledge and experience, nine new oil formulations were made. Their basic characteristics are shown in Table 3. All the oil formulations were tested under actual conditions in the production of pipes.

Out of all these formulations, the one marked as 2 showed the best characteristics. This formulation passed the complete pipe coil production (500 m) without any problems, while there were damages, scores and sticking with all other formulations even after as low as 60 m of produced pipe. The rough surface of the produced pipes were supplementary measured. The results are shown in Table 4.

Table 4: Surface roughnes of pipes with particular oil formulation

	OIL FORMULATION								
	1	2	3	4	5	6	7	8	9
Ra, µm	1.05	0.31	0.45	0.58	0.68	0.38	1.19	1.75	1.01

Conclusion

During the production of stainless steel pipes, have cracks on pipes been noticed in irregular intervals, after the calibration process and no regularity in their appearance has been noticed. The analysis of the cracks resulted in two possible causes of these cracks. One being an error in the material structure and another problem may be in the lubrication during the pipe calibration.

The tests in the pipe material showed that there is not any irregularity or structural error to cause the cracks. The analyses results with SEM and microhardness values indicated that the cracks are caused by some kind of stress. The critical moment for cracks emerging is the calibration, i.e. the lubrication during the deformation.

Nine new oil formulations were tested, out of which the oil under the mark 2 demonstrated extremely appropriate properties for this technological process: good heat conductance, good lubrication, high quality pipe surface, i.e. low surface roughness. In addition, this new oil formulation is ecologically acceptable.

UDK	ključne riječi	key words
621.774.7 : 669.15'24'26-194.3	kalibracija cijevi od legiranog nehrđajućeg Cr-Ni čelika	calibration of alloy Cr-Ni inox steel tubes
621.892.09	mazivo prema grani namjene	Lubricants according to sort of application
.002.3	gledište formulacije sastava	formulation of constituents viewpoint

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