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Effect of Postdeformation Pause on Structure and Properties of Accelerated-Cooled Bearing Steel

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Effect of pause between rolling end and start of accelerated cooling on microstructure and properties of bearing steel bar rolled on mill 350 at JSC "Oskolsky Electrometallurgical Works" is investigated. It is recommended to reduce the pause as much as possible. For this purpose the accelerated cooling unit should be placed on the minimum distance from the last stand and it is necessary to start cooling from the first section and use the last mill stand as finishing one.

Keywords: ACCELERATED COOLING, SELF-TEMPERING TEMPERATURE, MICROSTRUCTURE, CARBIDE NETWORK, GRAIN SIZE, HARDNESS

Introduction

Industrial technology of thermomechanical treatment of rolled bearing steel with diameter 34-78 mm is applied on mill 350 at JSC "Oskolsky Electrometallurgical Works". The primary task of this technology is to decrease residuals of carbide network due to postdeformation accelerated cooling of rolled metal to self-tempering temperature (T_{st}) 690-630 °C.

Continuous cooling of rolled metal in four-eight sections of cooling device is carried out on the most of sizes. Interrupted cooling is used occasionally on average diameter bar during production of which it is necessary to use flying shears located between the fourth and fifth sections of cooling unit [1].

Presented technology enables to reduce size of carbide network residuals to 3 points without changing the basic technological parameters of rolling. Actual grain size of rolled metal also decreases in average from 6-7 to 7-10 points. With increase of rolled metal diameter these effects decrease, first of all, in the centre of bar cross-section, also the difference in size of carbide network residuals in the centre of rolled metal cross-section and surface layers increases.

Decrease of effect of accelerated cooling on structure and properties of rolled wire at its diameter increase is caused by following factors:

- increase of duration of postdeformation pause due to rolling rate reduction;
- drop of cooling rate in central layers;
- rise of self-tempering temperature and exceedence of required values of T_{st} for maximum diameter rolled metal products due to limited length of cooling unit.

Results and Discussion

Industrial experiments were carried out to investigate effect of mentioned-above parameters on structure and properties of bearing steel. During these experiments the value of postdeformation pause and duration of accelerated cooling of rolled metal were varied. It was achieved due to turning on several first (according to current technological instruction) or several last sections of cooling unit.

The temperature of end rolling was 990-1020 °C. Regimes of post-deformation accelerated cooling of rolled metal are resulted in **Table 1**.

The length of accelerated cooling path at change of duration of post-deformation pause differed a little in connection with different length of first and last four sections of cooling unit. So, it increased from 19 to 20 m or by 5 % on bars with diameter 34 and 48 mm, and on bar with diameter

62 mm - decreased from 29 to 27 m or by 7 %. This difference was compensated by change of water pressure in cooling sections so that the self-tempering temperature changed not more than by 5 %. As a result, self-tempering temperature was within 640-700 °C. Thus, duration of post-deformation pause for all bars increased approximately in 1.5 times - from 45 % on bar with diameter 34 mm to 64 % on bar with diameter 48 mm. Effect of post-deformation pause on actual grain size, residuals of carbide network, carbide liquation, carbide striation and hardness of metal was investigated. The results of investigation are presented in **Tables 2-5**.

Obtained data showed that prolongation of post-deformation pause at almost invariable temperature of self-tempering led to increase of hardness on the cross-section of rolled metal (**Table 2**). So, hardness of rolled metal with diameter 34 mm increased from 35-36.5 HRC to 51.5-56 HRC (i.e. approximately by 16-19 HRC), and in the cross-section centre - from 32.5-37 HRC to 55 HRC (i.e. approximately by 18-22 HRC). Hardness incrementation decreased with increase of rolled metal diameter, so on diameter 48 mm it was 8-10 HRC, and at diameter 62 mm - 4-7 HRC.

The prolongation of post-deformation pause promoted growth of actual grain size by 0.5- 1.0 point (**Table 3**, **Figure 1**).

This is indicative of partial recrytstallization process, as a result of which stability of austenite increased and temperature of γ - α transformation dropped.

Depth of thermomechanically-treated layer (hardened on martensite and tempered) increased from 0.3-0.4 to 1.3-1.4 mm at increase of rolled metal diameter from 34 to 62 mm (**Table 4**).

It is necessary to mention that the maximum increase of postdeformation pause for rolled metal with diameter 48 and 62 mm led to increase of carbide network residuals size to 4-5 points in some experiments (**Table 5**). Also it can be explained by secondary recrystallization process, as a result of which structure imperfection and amount of carbides precipitated inside grains reduced.

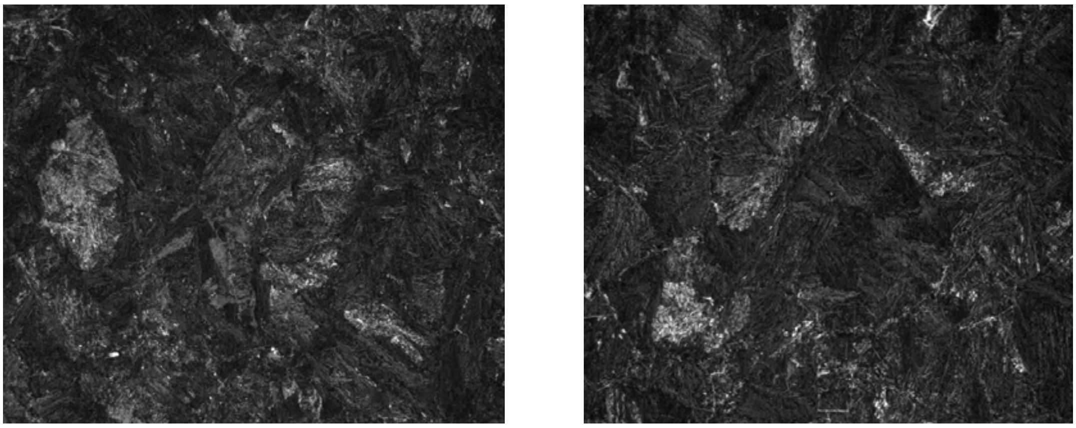
Effect of postdeformation pause duration on carbide liquation and carbide banded orientation has not been determined yet at change within stated limits.

Table 1. Regimes of post-deformation accelerated cooling of rolled metal

Rolled metal diameter, mm	Steel grade	Rolling rate, m/s	Last stand No.	Length of stand-cooling section, m	Post-deformation pause, s	Prolongation of pause, s/%
34_{TI}	ШХ15СГ-ПВ	5.000	16	30.8	6.2	2.76/45
34_{exp}				44.8	8.96	
48_{TI}	ШХ15-ПВ	2.503	14	22	8.8	5.6/64
48_{exp}				36	14.4	
62_{TI}	ШХ15- ПВ	2.500	14	22	8.8	4.2/48
62_{exp}				32.5	13	

Rolled metal diameter, mm	No. and length of cooling sections, m / Water pressure in sections, MPa								Length of cooling path, m
	005 3.5	006 3.5	007 3.5	008 3.5	001 5.0	002 5.0	003 5.0	004 5.0	
34_{TI}	1.6	1.4	1.3	1.2	1.5	---	---	---	19
34_{exp}	---	---	---	---	1.5	1.5	1.4	1.0	20
48_{TI}	1.6	1.4	1.3	1.2	1.5	---	---	---	19
48_{exp}	---	---	---	---	1.5	1.5	1.4	1.0	20
62_{TI}	1.6	1.4	1.3	1.2	1.5	1.3	---	---	29
62_{exp}	---	---	---	1.2	1.5	1.3	1.5	1.5	27

*TI- technological instruction,
exp - experiment



a b

Figure 1. Microstructure of steel ШХ15 rolled metal with diameter 48 mm after accelerated cooling according to technological instruction (*a*) and in the experiment (*b*)

Table 2. Rockwell hardness of rolled metal

Rolled metal diameter, mm	Thermomechanical treatment	Section	½ R, HRC	Center, HRC
34	TI	Head	36.5	32.5
		Center	36.5	35.5
		End	35.0	37.0
	Experiment	Head	52.0	55.0
		Center	56.0	55.5
		End	51.5	55.0
48	TI	Head	38.0	41.0
		Center	38.5	40.0
		End	38.0	40.0
	Experiment	Head	49.0	48.0
		Center	48.0	49.0
		End	49.5	41.0
62	TI	Head	38.5	33.0
		Center	39.5	34.0
		End	39.0	35.0
	Experiment	Head	42.5	40.0
		Center	43.0	41.5
		End	42.0	40.5

Table 3. Estimation of actual grain size by GOST-5639

Rolled metal diameter, mm	Edge, point	1/2R, point	Center, point
34_{Exp}	7	6,7	6
34_{TI}	9, 8	8	7
48_{Exp}	8	8, 7	7, 6
48_{TI}	8, 9	7, 8	7
62_{Exp}	7, 8	7, 6	5, 6
62_{TI}	7, 8	7	6, 5

Table 4. Depth of thermomechanically-treated layer

Rolled metal diameter, mm	Thermomechanical treatment	Section	Depth, mm	Characteristic of layer
34	TI	Head	0.4	Uniform
		Center	0.4	Uniform
		End	0.4	Uniform
	Experiment	Head	0.35	Nonuniform
		Center	0.3	Nonuniform
		End	0.35	Nonuniform
48	TI	Head	1.0	Uniform
		Center	1.0	Uniform
		End	1.0	Uniform
	Experiment	Head	0.9	Uniform
		Center	0.9	Uniform
		End	0.9	Uniform
62	TI	Head	1.4	Uniform
		Center	1.4	Uniform
		End	1.3	Uniform
	Experiment	Head	1.3	Uniform
		Center	1.4	Uniform
		End	1.4	Uniform

Table 5. Estimation of carbide network

Rolled metal diameter, mm	SEP 1520																	
	Head						Center						End					
	Technological instruction			Experiment			TI			Exp			TI			Exp		
	Center	1/2R	Edge	C	1/2R	E	C	1/2R	E	C	1/2R	E	C	1/2R	E	C	1/2R	E
34	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	5.0	5.0	5.0	5.0	5.0	5.1	5.0	5.0
	5.0	5.0	5.0	5.1	5.0	5.1	5.1	5.0	5.0	5.2	5.0	5.0	5.0	5.0	5.0	5.1	5.0	5.0
48	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.1	5.0	5.0	5,0	5.0	5.0	5.1	5.0	5.0
	5.1	5.0	5.0	5.1	5.1	5.0	5.1	5.1	5.0	5.1	5.0	5.0	5,0	5.0	5.0	5.1	5.0	5.0
																5.4	5.1	
62	5.1	5.0	5.0	5.0	5.0	5.0	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	5.1	5.1	5.0	5.1	5.1	~5.1	5.1	5.1	5.0	5.0	5.0	5.0	5.1	5.1	5.0	5.0	5.0	5.0

Rolled metal diameter, mm	GOST 801																	
	Head						Center						End					
	Technological instruction			Experiment			TI			Exp			TI			Exp		
	C	1/2R	E	C	1/2R	E	C	1/2R	E	C	1/2R	E	C	1/2R	E	C	1/2R	E
34	1;1	1;1	1;1	2;1	1;1	1;1	1;2	1;2	1;1	1;2; 3	1;1	1;1	1;1	1;1	1;1	1;2	1;1	1;1
48	3;3	1;2	1;1	3;4	3;3	1;1	2;3	3;3	1;1	4;5	3;4	1;1	3;4	1;2	1;1	4;5	2;3	1;1
62	3;3	2;3	1;1	3;4	2;3	1;1	3;4	2;3	1;1	3;4	2;3	1;1	3;4	2;3	1;1	1;3	1;3	1;1

Conclusions

1. Prolongation of postdeformation pause approximately in 1.5 times (from 6-9 to 9-14 seconds) at thermo-mechanical treatment of rolled bearing steel with diameter 34-62 mm leads to increase of:

- carbide network residuals by 1-2 points;
- hardness of hot-rolled metal by 5-20 HRC;
- depth of thermo-mechanically treated layer by 0.05-0.1 mm;
- actual grain size by 0.5-1 points.

2. Efficiency of accelerated cooling of roller-bearing steel rolled stock increases with reduction of postdeformation pause. When designing sections for accelerated cooling, it is necessary to place a cooling unit at the minimum possible distance from the last mill stand.

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Влияние последеформационной паузы на структуру и свойства ускоренно охлажденных подшипниковых сталей

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Исследовано влияние паузы между окончанием прокатки и началом ускоренного охлаждения на микроструктуру и свойства проката из подшипниковых сталей на стане 350 ОАО «ОЭМК». Рекомендовано максимально уменьшать паузу, для чего необходимо устройство ускоренного охлаждения располагать на минимальном расстоянии от последней клети, начинать охлаждение с первой его секции, в качестве чистовой использовать последнюю клеть стана.