pel, V.A. Chubenko, SHEE "Kryvyi Rih National University." Appl. 02.05.2015, publ. 07.10.2015, bull. No 13.

7. Berezhnoy N.N., Chubenko V.A, Khinotskaya A.A., Chubenko V.A. (2015) The increase in efficiency of strips production process in foundry and rolling mill stand. *Metallurgical and Mining Industry*. No 12, p.p. 296 – 300.

Experimental studies of complex influence of temperature and deformation parameters of rolling on the mechanical properties of metal

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Abstract
The experimental study of the joint influence of temperature at the start of rolling and the various deformation modes on the mechanical properties of the samples of steel St3 (semikilled steel) was performed. The tests to determine the yield stress, tensile strength, percentage of elongation, and impact hardness for the samples rolled at nine rolling modes were carried out. Analysis of the data confirmed the possibility of control the mechanical properties of rolled products by changing the temperature and deformation process conditions. These results can be implemented in existing production conditions without significant change in technology and equipment by introducing the billet rolling technologies with reduced heating temperature.
Keywords: HOT ROLLING, HEATING TEMPERATURE, DEFORMATION MODE, YIELD STRESS, TENSILE STRENGTH, PERCENTAGE OF ELONGATION, IMPACT HARDNESS

Improving the mechanical properties of rolled section is one of the main demands of the modern market of metal products. It allows reducing the weight of steel structures [1] and increase enterprise-producer competitiveness by improving the quality of rolled products [2]. For a long time improvement of chemical composition of the steel produced by alloying has been the main way to control and improve the mechanical properties of rolled products. However, this trend has a number of limitations associated with the development of smelting technologies and high cost of alloying elements. The second direction developed considerably in recent years is the improvement of rolled metal products properties by developing thermoplastic processing in the mill line by regulating the temperature and strain -time rolling modes [3, 4]. Researches in this area are mainly devoted to processes of controlled rolling of sheet and plain rolled section made of alloyed steels [3, 5, 6, 7]. At the same time area of improving the mechanical properties of shaped sections made of steels with ordinary quality remains insufficiently studied [8]. Therefore, relevant studies are aimed at determining possible influence on the mechanical properties of rolled products by adjusting the temperature and deformation parameters typical for section rolling conditions.

The aim of this work is the experimental study of complex influence of start rolling temperature and deformation conditions on the mechanical properties of rolled products.

When developing plan of experiment the following variants for changing the degree of deformation by passes have been considered (Fig. 1): rolling of billets with the same degree of deformation in each pass, with decreasing and increasing degree of deformation and mixed mode. In this paper, the first three modes are considered.

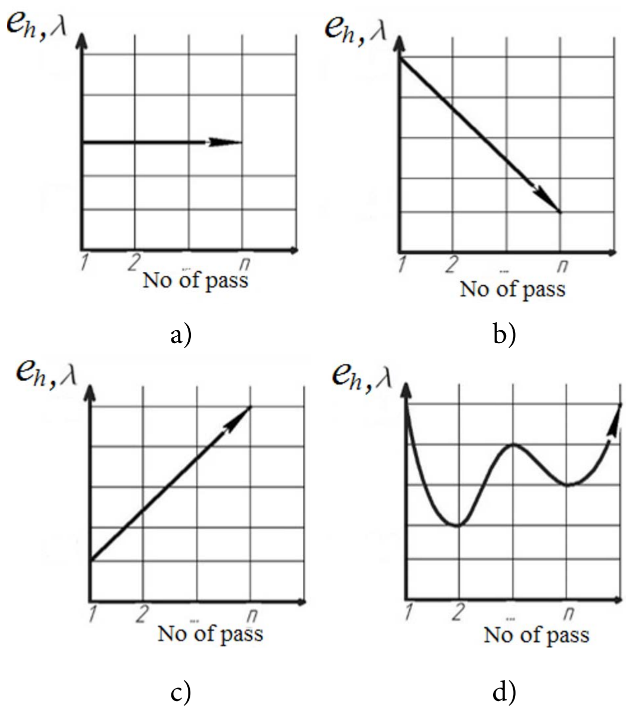


Figure 1. Possible deformation modes:
a - equal, b – decreasing, c – increasing, d – mixed

The research of influence of rolling temperature regime was implemented by reducing the heating temperature of billet before rolling. Another variant of temperature regime changing of rolling is decreasing of rolled products temperature in between-deformation periods [5].

The study was conducted in the laboratory of NMetAU metal forming department and central plant laboratory of PJSC "Petrovsky Evraz - DMP". Heating of samples before rolling was carried out in the laboratory chamber of electric furnace SNOL 2,5.4.1,4/11-I1. After heating, rolling was carried out on a single-stand reversing mill 200 (the engine power of 30 kW). The presence of transmission in the wire line of the mill allows adjusting the number of revolutions in the range from 2.8 to 52 rev/min. Leveling of samples was carried out on hydraulic press 2PG-125. Measuring the dimensions of the samples was performed with an accuracy of 0.01 mm. After leveling and measuring the samples were transferred to PJSC "Petrovsky Evraz–DMP" for mechanical tests.

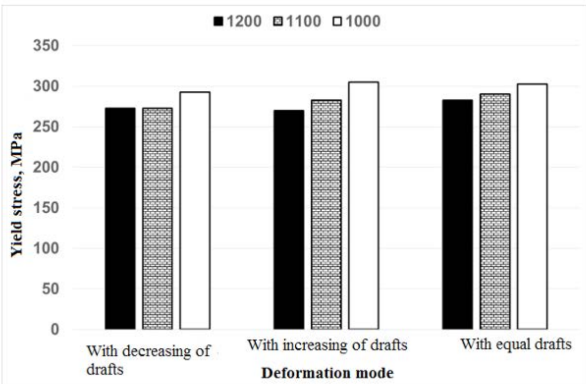
Experiments on rolling the square billets rolled on smooth rolls without turning were performed. Steel St3 (semikilled steel) used as the material for billet. Billet dimensions were 25 × 25 × 200 mm. Rolls diameter was 205 mm. The roll body length was 400 mm. The roll rotational speed was 12.5 rev/min.

The deformation of the samples was carried out in 4 passes on the modes given in Table 1. The implementation of a particular mode of deformation was carried out in 2nd and 3d pass. The first pass was intended for leveling the rolled products height and imitated the reducing pass (in modes with decreasing and increasing of drafts). The fourth pass was finishing. The high and medium deformation zones (l_d/h_{av}=0.7...1.8) typical for sections rolling were observed in all passes.

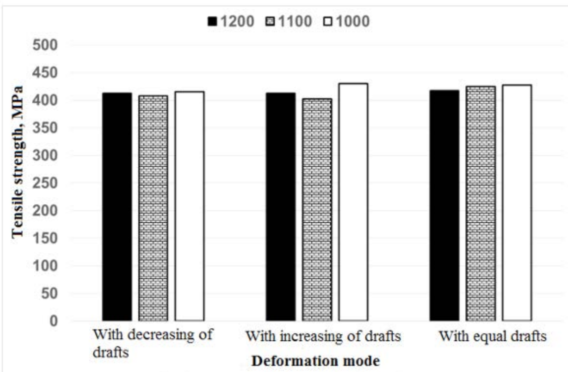
Table 1. distribution of the deformation by passes

Deformation mode	Deformation degree, %				Gap between rolls, mm			
	1 p.	2 p.	3 p.	4 p.	1 p.	2 p.	3 p.	4 p.
With decreasing of drafts	30	30	10	10	17	12	10	9
With increasing of drafts	30	10	30	10	17	15	10	9
With equal drafts	10	30	30	10	22	15	10	9

Rolling was carried out at three start temperatures: 1200 °C, 1100 °C and 1000 °C. For each mode 3 sample were rolled. The sample temperature before each pass, rolling force by the passes, the moment of rolling on top and bottom rolls were recorded. For all samples, tests on tensile strength and impact bending were performed. Figure 2 shows a histogram comparing the average values of the strength and ductility indicators for above rolling modes.



a)



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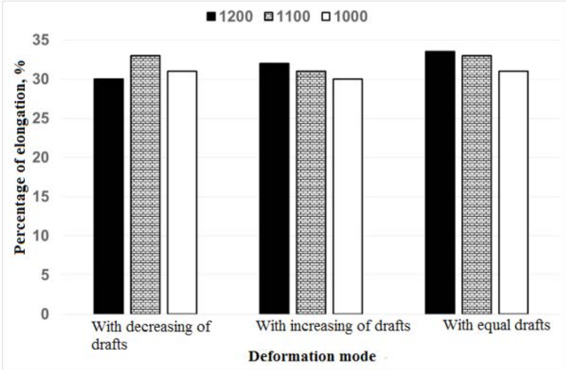
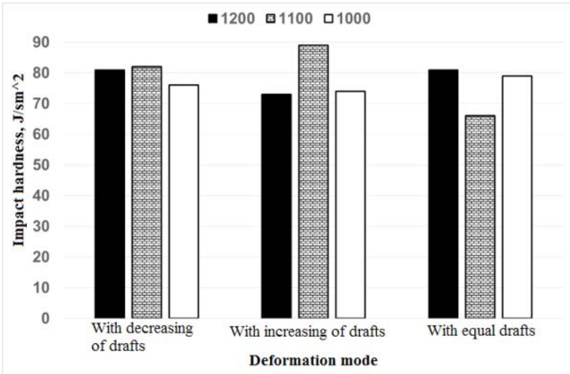


c)



d)

Figure 2. Comparison of the average values of the mechanical properties:
a - yield stress, b - tensile strength, c – percentage of elongation, d - impact hardness

At start rolling temperature of 1200 °C the application of various modes of deformation has no significant effect on the yield stress, tensile strength and impact hardness, but allows increasing the percentage of elongation. When start rolling temperatures of 1100 °C and 1000 °C changing of the mode leads to an increase of the strength and ductility values. The highest values of yield stress and tensile strength obtained at T_{sr}=1000 °C and increasing deformation mode. Maximum impact hardness values obtained at T_{sr}=1100 °C and increasing deformation mode.

Table 2 compares the maximum and average values of the mechanical properties with a base mode. The rolling mode with decreasing of deformations and start rolling temperature of 1200 °C has been adopted as the base and the most common mode in domestic enterprises. Modes investigated have shown the possibility of increasing the strength indicators by 4 ... 13% and ductility indicators by 10 ... 13% compared to the base ones.

Table 2. Comparison of obtained mechanical properties values

	Yield stress, MPa	Tensile strength, MPa	Percent. of elongation, %	Impact hardness, J/ sm^2
	Maximum values			
Base mode	275	415	31	81
Experimental modes	310	435	34	89
The difference between exp. and base modes	35	20	3	8
	Average values			
Base mode	273	413	30	81
Experimental modes	305	430	34	89

The difference between exp. and the base. modes	32	17	4	8

These results may be implemented in existing production conditions without significant change in technology and equipment by introducing the billets rolling technology with reduced heating temperature.

Conclusion

The experimental study of the influence of temperature and deformation modes of rolling the billets made of steel St3 (semikilled steel) on mechanical properties of steel was carried out. Applications of various combinations of start rolling and deformation modes temperatures in the laboratory allowed increasing strength indicator values by 4 ... 13% and ductility indicators by 10 ... 13%.

References

1. Bolshakov V. I. *Termicheskaya i termomehanicheskaya obrabotka stroitelnyih staley* [Thermal and thermomechanical processing of structional steel], Dnepropetrovsk, Sich, 1994, 232 p. – ISBN 5-7775-0484-1.
2. Bergeman G. V. Ways to improve the mechanical properties of shaped sections made of carbon steel of ordinary quality, Plastic deformation of metals: collective monograph, Dnepropetrovsk, Aktsent PP, 2014, P. 56-65. – ISBN 978-617-7109-18-0.
3. Tarasevich Yu. F. Formation of structure and properties of billets and ferrous rolled stock, *Results of science and technology*. Series: Rolling and drawing production, Vol. 13, Moscow, VINITI, 1985, p.p. 69-135. – ISSN 0202–7771.
4. Rudskoy A. I. Thermo-mechanical treatment of rolled section in the flow of rolling mills, Plastic deformation of metals: collective monograph, Dnepropetrovsk, Aktsent PP, 2014, p.p. 56-65. – ISBN 978-617-7109-18-0.
5. Poluhin V. P., Bernstein M. L., Peshkov V. A. (1983) Influence of controlled rolling conditions on structure and mechanical properties of steel, *Steel*, No 9, p.p. 68-71.
6. Pogorzhelsky V. I. *Kontroliruemaya prokatka nepreryivnolitogo metalla* [Controlled rolling of continuously cast metal], Moscow, Metallurgy, 1979, 184 p.
7. Minaev A. A. *Kontroliruemaya prokatka sortovoy stali* [Controlled rolling of profiled steel], Moscow, Metallurgy, 1990, 176 p. - ISBN 5-229-00296-4.
8. Borovskikh V. A., Mulko G. N., Savinykh N. G (1981) Application of the planned experiment in the study of controlled rolling of angle steel, *Steel,* No 9, p.p. 54-55.