M. V. Popov, V. F. Balakin, K. S. Belan
(National Metallurgical Academy of Ukraine)
balakin@inbox.ru

New processes and technologies in making tubes with improved strength and performance properties determined by a certain microplastic structure of metal

Despite the fact that metallic structural materials have passed test of many years along with their improvement and development, reserves of giving them new properties are far from being exhausted.

The improvements in strength and performance properties of structural materials in last decades were mainly determined by development of steels and alloys with new chemical and phase compositions. In the last years, new ways of formation of micro- and nanocrystalline structures resulting in alteration of physical and mechanical properties have taken shape.

One of the methods of formation of microcrystalline and sub-mictrocrystalline structures resulting in alteration of physical and mechanical properties is use of intense plastic strains such as those in torsion under high hydrostatic pressures, alternating bending, pilger rolling, equal-channel angular pressing. Disadvantage of these methods of nanostructure formation is impossibility of producing large-size test products having materially improved performance qualities (e.g. corrosion and irradiation-induced swelling resistance, high cyclic strength, etc.).

Consequently, the present-day foreground task of improvement of tube quality consists in the development of new technologies, deformation patterns and machinery for their realization based on the idea of intense straining.

In respect to the dislocation-and-structure analysis of deformations and fractures [1], higher strengths at a minimum fracture probability can be obtained through development of a structure enabling optimum homogeneity and intensity of deformation energy absorption by lattice and creation of such strain conditions at which a maximum number of slip planes could be enabled, i.e. to have a multi-directional forming pattern with a possible prevention of accumulation of a critical dislocation density (10^{14}) in individual micro-volumes.

Mechanical effect of the forming process brings about inhomogeneous energy absorption within the strained metal volume: fracture initiating discontinuities originate in local volumes having an extremely distorted lattice. To avoid this event, strain irregularity must be minimal at a minimal metal grain anisometry.

The results of dislocation-and-structure analysis and investigation of metal properties and structure changes (depending on the process and design parameters of pilger rolling [2]) have enabled development of physical and technological requirements for creation of new forming processes possessing deformation potentials considerably higher in comparison with ones used at present (e.g. rolling).

As a result, the following processes were developed and industrially tested:

1. Pilger rolling of tubes with a simultaneous diameter and wall forming at high unit pressures in two sequential instantaneous deformation zones (Fig. 1) and simultaneous superposition of thrust and torsion strains between them.

Two variants of such process were developed:

– for cold tube rolling mills with a fixed mandrel and a reciprocally moving stand;

– for mills with a stationary stand, i.e. for pilger mills with a short tapered or a long cylindrical mandrel.

Deformation ability of such process is by 2 to 4 times higher in comparison with the known processes and metal hardening is lower. Highly repeatable per pass elongation ratios are 6 to 19 for cold rolling of practically all known steels and alloys including titanium and zirconium based alloys. Elongation ratios μ= 6-19 in cold twin-row pilger rolling approach the values observed in the hot pilger rolling process and are by 2 to 3 times higher than those achieved in the world practice.

2. Cold pilger rolling in two instantaneous deformation zones of a mill with moving mandrel and stand ensures elongation ratios μ= 10-12, even in rolling tubes with micron wall thicknesses. They are 5 to 6 times as high in comparison with those obtainable in a conventional rolling on a fixed mandrel.

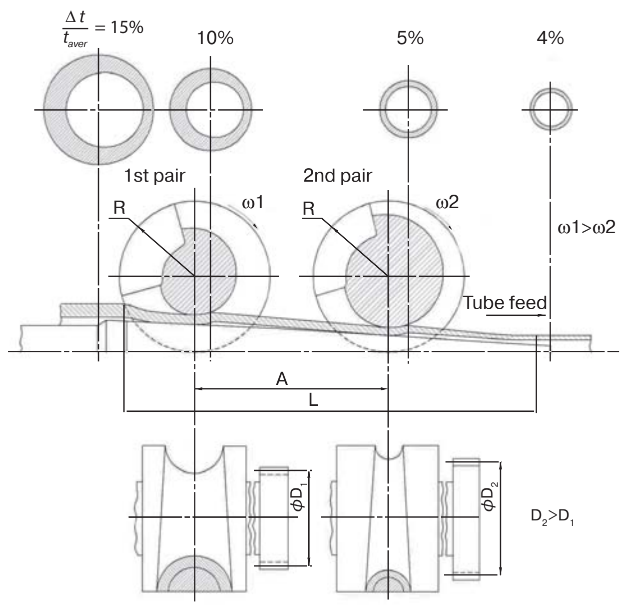

Fig. 1. The scheme of twin-row pilger tube rolling process

For example, rolling by pass schedule 21.5×0.5→20.0××0.05 mm in cold tube rolling mills of KhPTR 15–30 type has become feasible.

3. Roller-roll method of pilger rolling combining advantages of rolling in rolls and rollers and ensuring per pass elongation ratios = 10–12.

4. Pilger rolling + drawing method enabling high elongation ratios of 8 to 12 and making tubes with micron walls 63 × 0.03 mm; tubes with OD/WT = 2100 were produced in this way.

5. Two variants of pilger rolling method with stretching in the deformation zone: rolling at the entering angle larger than the friction angle, and rolling in a nonsymmetrical deformation zone using mismatch of peripheral velocities (diameters) of rolls. This rolling method combined with rolling in two simultaneous deformation zones makes it possible to obtain elongation ratios μ = 10–12 per pass in a cold condition.

The new cold rolling methods ensured an elongation ratio = 1200–1250 in rolling stainless steel (Kh18N10T) in several passes with no single heat treatment operation. It corresponds to deformation ratio of 99.9 % at which metal transforms to an amorphous state (as it was confirmed by the results of investigations carried out at Institute of Metallophysics of Ural branch of the Russian Academy of Sciences). For example, 5.5×0.1 mm tubes were rolled from 89×9 mm tube billets.

The new deformation methods have enabled development of new tube making technologies and improvement of existing ones. Production cycle number was reduced by 50 %, metal discharge rate reduced by 30–40 % and lower labor and energy inputs were achieved. High deformation ratios (more than by 2 times higher than the level achieved in the world practice) achievable now in rolling of thick-walled tubes assure a uniform fine-grained structure (grain anisometry not higher than 2–3 points) when manufacturing the following products:

1. Long (more than 30–40 m) boiler tubes that can be coiled. Such tubes feature longer service life and higher long-term strength and increase reliability and life of power units.

2. Bearing tubes including small diameter (28–32 mm) tubes having a uniform fine-grained structure improving contact strength of the bearing material and thus making higher efficiency and longer life of the bearings used in practically all machines and equipment units.

It is worth to be mentioned that rods can also be rolled using the new methods.

The above-mentioned rolling methods using very high strain levels have been developed by the tube manufacturer - Progressive Technologies JSC. At present time, this company (in cooperation with Frunze Sumy Scientific and Production Association JSC, the Ukrainian producer of cold tube rolling mills) is developing a new cold tube rolling mill using a twin-row scheme of rolling in tandem stands (Fig. 2) and modernizing operating equipment (cold tube rolling mills of KhPT or KhPTR type) to upgrade their capacity and reduce twice as much their working cycle number.

In cooperation with National Metallurgical Academy of Ukraine, the studies directed to further improvement of deformation schemes and clarification of their effect on physical, mechanical and operating properties of tubes are being carried out.

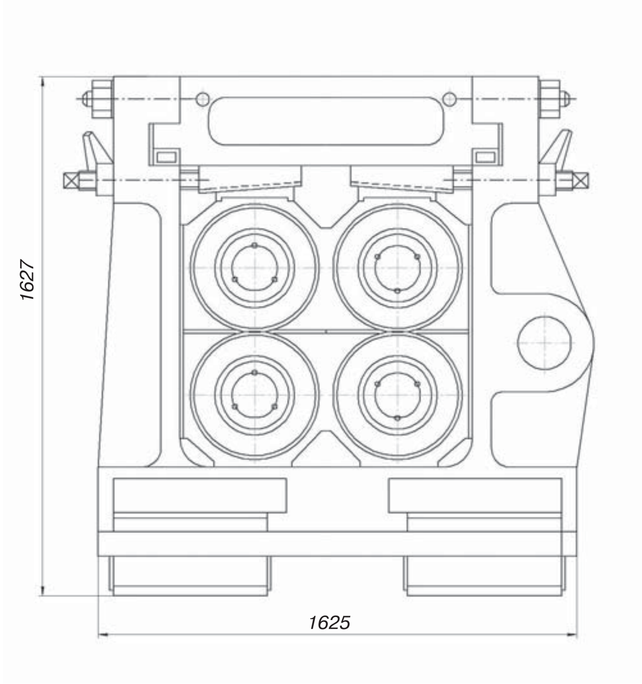

Fig. 1. KhPT mill with two-lane scheme rolling in tandem stands

One of such schemes is based on the scientific discovery "The Pattern of Plastic Behavior of Viscous-elastic and Viscous-plastic Media in the Conditions of Their Developed Vibroplastic Strain" (made by V. F. Balakin, V. N. Morozenko, R. P. Didyk, Ye. V. Kuznetsov)* the purpose of which is 10-50% reduction of metal resistance to plastic strain during its vibration-induced deformation at a frequency corresponding to the frequency of periodical elementary shifts of the concrete metal.

It should be pointed out that the mechanism of formation of dimensional accuracy during the tube making process has allowed to develop tool designs reducing cross-sectional and longitudinal wall thickness variation by 6 to 8 and 10 to 12 times respectively during the twin-row pilger rolling process (in two instantaneous deformation zones) that makes it possible to use stock material having high (up to 50 %) wall thickness variation for making precision tubes.

The achieved dimensional accuracy of cold-rolled tubes (for wall thickness, for diameter) is several times higher than it is required by all known international standards. Using the method of twin-row pilger rolling, more than 80,000,000 m of tubes of practically all known steels and titanium and zirconium based alloys have been rolled in new and modernized mills. Pilot lots of nuclear fuel cladding tubes have been produced at a two times smaller cycle number (4 instead of 8 passes and more than 120 process steps reduced).

* Discovery Application No. Ф-218 dated May 27, 1999, The Pattern of Plastic Behavior of Viscous-elastic and Viscous-plastic Media in the Conditions of Their Developed Vibro-plastic Strain, by V. F. Balakin, V. N. Morozenko, R. P. Didyk, Ye. V. Kuznetsov

The idea of the new experimentally substantiated and successfully applied technology consists in that all cold-rolled tubes of any steel or alloy grade, non-ferrous metals and titanium and zirconium based alloys can be produced in a diameter range of 14 mm and more using two passes instead of 3 to 5 passes as with the conventional technology.

Example:

89×10÷12 → 34÷38×4 mm (KhPT 90(75)-4B mill);

34÷38×4 → 30-14×1,5 ÷2,5 mm (KhPT-324B mill)

Productivity of the modernized mills is by 2 to 2.2 times higher, the product dimensional accuracy is by 2 to 3 times higher and the cycle number is reduced. KhPT-4B is the cold tube rolling mill modernized through the substitution of a 4-roll tandem stand for a 2-roll stand.

A great advantage of the method of pilger rolling in two instantaneous deformation zones is that it can be applied to operating mills of KhPT and KhPTR types after their modernization (substitution of a 4-roll stand with new connecting rods for a 2-roll stand). It ensures 2 to 2.5 times growth of productivity at a two times smaller cycle number, 25 to 35 % lower labor and power inputs and 2 to 3 times higher tube dimensional accuracy.

Review of “Chernye Metally” issues and supplements published in 2010

«Chernye Metally» No. 1-2010

The “Russian” section is presented by publications on foundry thematics. E. Rozhkova, A. Orekhova, V. Belov and T. Bazlova (Moscow Institute of Steel and Alloys) developed the method of ladle treatment of melts of chromium iron, allowing to change iron primary structure without varying content of chromium and carbon. Another paper of foundry specialists from the Moscow Institute of Steel and Alloys (S. Matveev, A. Orekhova, E. Chereshneva) is devoted to varying of the iron heredity using fullerene-based modifier.

In the framework of celebration of 150th anniversary of the Society of German Metallurgists (VDEh) we continue to publish reviews on different directions of development of metallurgical technologies. In this issue the readers can find the paper “Actual state of smelting-reduction processes in iron-making” by V.-P. Kepplinger.

Special collection of articles in this issue is devoted to new developments of control, measuring and testing devices in iron and steel industry. The papers of the Institute of Industrial Researches of VDEh, and several companies (Laser Analytical Systems & Automation GmbH, EMG Automation GmbH, Solving 3D GmbH) are presented.

In January 2010 Anatoly Brovko, the professional metallurgist, has been inaugurated as thenew governor of Volgograd region. This issue describes the report about this important event and gives the interview with A. Brovko in the coloured insert.

«Chernye Metally» No. 2-2010

The section of national metallurgy is presented by 3 publications/ The specialists of St. Petersburg Polytechnical University A. Rudskoy, N. Kolbasnikov et al. devoted their article (p. 8-14) to research of the structure and properties of TROP-steels. Physical simulation of different variants of heat treatment in combination with quantitative metallographic and X-ray structural analysis have revealed relationship between structural components required for obtaining the aimed structure with residual austenite.

The scientists of the Moscow Institute of Steel and Alloys A. Stomakhin, E. Lysenkova et al. investigated optimization of additives of nitride-forming elements in steel (p. 15-19). The new technique of calculation of optimal concentrations of these elements in steels allows to exclude complicated calculations and to restrict number of experimentally examined compositions. One more publication entitled “Optimal structural state of metal for railroad wheels and rails” is presented by I. Vakulenko et al. from Dnepropetrovsk National University of Railroad Transport (p. 20-23).

Among translated materials, the section “Power engineering and ecology” is the basic one in this issue. It includes 3 papers (p. 42-62) devoted to the problems of lowering emissions of greenhouse gases during steel making, decrease of energy consumption and increase of efficiency of energy usage, analysed on the base of experience of Tenova, RHI AG and Badische Stahl Ebgineering.

We hope that the readership interest will be also attracted to the surveys “Up-to-date development of basic oxygen and electric arc steel making” and “New testing devices for iron and steel industry”. In historical section the article “What is crucible steel?” is presented.

“Chernye metally” No. 3-2010

The section “Development of metallurgy in Russia and CIS countries” includes 3 articles devoted to tube production. Yu. Gulyaev et al. analyzed actual problems and devel-