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PERFECTION OF PROCESSES OF SEAMLESS STEEL TUBES PRODUCTION

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The article first give a review more of hundret years long history of seamless steel tube production, especially during the last 15-20 years of the 20^{th} century. Prolongation, article give technological indices for 4 mills (automatical, continuous mill, pilger, Assel), and perfectation of processes seamless steel tubes production at the begining of 21^{th} century.

Key words: semless steel tubes, pipes mills, production, development

Usavršavanje postupaka proizvodnje čeličnih bešavnih cijevi. Prvo, članak daje pregled više od sto godina duge povijesti proizvodnje bešavnih čeličnih cijevi, naročito u posljednjih 15-20. godina 20. stoljeća. Nastavak članka daje, uz tehnološke parametre za 4 valjaonice i usavršavanje postupaka proizvodnje bešavnih čeličnih cijevi početkom 21. stoljeća.

Ključne riječi: bešavne čelične cijevi, valjaonice cijevi, proizvodnja, razvitak

INTRODUCTION

Various hot rolling methods remain to be the most widely used methods of making *seamless* steel tubes.

The more than a hundred year long history of development of technology of seamless tube production can be conditionally divided into three stages (till 2000.y.). [1-3]

1. From the middle of 1880 y. to the middle of 1930 y., six basic processes of rolling shells into seamless tubes have been developed: pilgrim rolling; longitudinal plug rolling in Stiefel plug mill; mandrel drawing of shells thru a system of rings in Erhard push bench; longitudinal full-floating mandrel rolling in Fassel and Kellog multi-stand (7 and more stands) tube rolling mills; helical floating-mandrel rolling in a three-roll Assel mill and helical disk reeling in a Diescher mill. By the end of 1930 y., rolling schemes using plug and pilgrim mills were used most widely. Small quantities of tubes were produced using push benches and Assel and Diescher mills and continuous mandrel rolling was not actually used. Cast and forged ingots or rolled billets were used as a starting material in the tube manufacture.

2. In the period from the middle of 1940 y. to the middle of 1980 y., hot tube working processes were strongly perfected. First of all, it should be mentioned that a third hot working step has been introduced into virtually all known processes: sink rolling in sizing or stretch-reducing mills. Just due to the use of sink rolling as a final hot working step, continuous full-floating mandrel longitudinal rolling mills with 7 to 9 stands have got a wide-spread use. Beginning from 1960 y., due to the development of new lubricants, hot extrusion method has become commercially used in the production of tubes from hardly-deformed alloy steels and alloys. By the middle of 1980 y., continuous mills with retained and semi-floating mandrels have won recognition. At the same time, a process of making tubes at push benches by drawing tubes thru a roller cartridge instead of rings has been developed. Continuously cast round ingots were then used as a starting material.

3. During the last 15 – 20 years of the 20-th century, the following technologies have become commercially used - Table 1. [4]

a) elongation of hollow shells by helical rolling in 3-roll planetary mills;
b) reeling shells in modernized Assel mills with adjusted feed angles and Diescher mills (in various variants, including rolling with discs and driven skew rolls, so-called Accu-Roll process);
c) continuous longitudinal retained mandrel rolling in two-roll stands (MPM mills);
d) elongation of shells in push benches with roller cartridges where press piercing of solid billets into shells was replaced with helical piercing in mills with tapered rolls (CPE process).

The aim of this article give perfection of processes of seamless steel tubes production.

Perfection of processes is an essential reserve of raising efficiency of pipe and tube production.

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Table 1 **Development tendency at production of seamless tubes during the last 15-20 years of the 20th century [4]**

CHARGE	ROLLING	FINISHING, COLD FORMING, HEAT TREATMENT
Continuous casting of round sections Continuous cast hollow shell The charge with the improved possibility for hot and cold forming and superior surface quality Application of centrifugal cast raw pipes and high alloy steel pipes	PPM (Press piercing mill) - pressure rolling mill for longitudinal charge piercing MPM (Multi stand pipe mill) - continuous mill with the mandrel retention device - Ital. variant MPM-SL (Multi standless pipe mill) - continuous mill (without stands) with the common housing and a mandrel retention device - Ital. variant NEUVAL process -French variant of MPM with the retained mandrel by which a tube blank was previously -pierced at the cross rolling stand MPM -Aetna Standard Co. - Continuous rolling mill with a free, half-retained and retained mandrel, example: "VBC SUMITOMO" MRK-S (Mannesmann Rohrkontiwalzwerk mit Striperverfahren) - Mannesmann-variant of MRK with a stripper and half-retained mandrel MRK-AR (Mannesmann Rohrkontiwalzwerk mit Ausziehrohrwalzwerk) - Mannesmann-variant of MRK with a mandrel-retention device with a drawing stand CPE (Crossroll picrcing elongation) - piercing by cross rolling with an elongation at the push bench CPD (Crossroll piercing Diescher elongationl -piercing by cross rolling with an elongation at the Diescher stand with the mandrel retention ACCU-ROOL (Procedure similar to CPD) - piercing by cross rolling with an elongation at the cross rolling stand by Diescher's discs with the retained mandrel, developed by Aetna Standard Co. in 4 versions PSW (Planeten -Schrägwalzerk) -planetary cross rolling stand for pipes	Development of non-destructive testing procedures High-efficiency devices for development Plastic coating, internal grinding Continuous cold rolling of pipes Application of multi-drawings resp. tandem-and multiple cold and pilger machines High-efficiency cold pilger stands

TECHNOLOGICAL INDICES FOR 4 MILLS WITH GREATEST DISTRIBUTION IN A WORLD (IN 20TH CENTURY)

Tube rolling mill installations with automatical, pilger, continuous mill and three-roll reeling (Assel) mills for production of hot-rolled seamless tubes have received (in 20th century) the greatest distribution in a world. These installations differ on the technological indices.

As for instance, Table 2 give the performance for this mills. Table 3 give the change of indices by production hot rolling of seamless tubess.

The installations with automatical and pilger mill have the broadest sort. The installations with continuous and three-roll reeling mill are applied to production of small and angle diameter tubes, the first -for rather thin-wall, and the second - for heavy-wall tubes.

The modern installations with continuous mill (mandrel mill) have top performances. Seamless tube rolling mill installation with three-roll reeling mill ensures deriving tubes in a split-hair accuracy, in 1,5 to 2,0 times superior an exactitude of tube than on other installations.

Allowing, that the expenditures on metallurgical process on all seamless tube rolling mill installations compound 15 to 40 % from product cost, and 60 to 85 % are necessary for the cost of metal, the major value is acquired by (with) such an index, as account coefficient, which is the greatest on installations with pilger (in connection with availability pilger head) and three-roll (considerable end pop and necessity a turning of tubes) reeling mill.

Besides seamless tube rolling mill installations with pilger and three-roll reeling mill at the least share of a dead time in rhythm of rolling the continuous unsteady stages of process of an expansion have.

The analysis of technological indices of production of tubes on different seamless tube rolling installations allows defining reference directions of improving of the "know-how" of tubes encompassing by following:

- heightening of an exactness of tubes on installations with self-acting. mandrel and pilger mill,
- expansion of a sort of installations with three-roll reeling mill and heightening of their productivity,

Table 2. **Performance of seamless tube mill [4, 5]**

Indexes	The type reeling mill			
	auto-matical	continu-ous mill	pilger	three-roll reeling (Assel)
Sort:				
- diameter of rolled tubes / mm	57 - 426	30-102	22-700	34-200
- a ratio D/S	4,45	10 - 13	6 -40	4,12
Supposed aberrations: / %				
- on diameter	± 1	± 1	± 1	± 0,5
- on wall thickness	± 12,5	± 12,5	± 12,5	± 6,0
Productivity, thousand tonn annually	70-340	110-600	190 - 340	22 - 230
Account coefficient	1,08-1,14	1,075-1,090	1,193-1,227	1,175-1,257
Share of time in rhythm of rolling:				
- engine %	20 - 25	1 50 - 60	75 - 80	80 - 85
- supplementary %	80 - 75	50 - 40	25 - 20	20 - 15
- unsteady stages %	1	1	15 - 18	2 -3
Coefficient of an extract:				
- at weaving	1,3 -5,2	1,8 -3,0	1,3 -2,1	1,3 -2,1
- at an expansion	1,2 -2,1	3,0 -6,5	3,0 -15	1,8 -3,2

– decrease of account coefficient on installations with pilger and three-roll mill,
– abatement of a dead time in rhythm of rolling on automatical and continuous mill,
– abatement of time of unsteady stages of processes of an expansion on pilger and three-roll mill.

At a solution of the question about perfecting production it is very important to have an opportunity to institute influencing technology, design and organization - engineering measures on a production efficiency. It will allow selecting for introducing those measures, which can most contribute a production efficiency.

Table 3 **Change of indices by production hot rolling of seamless tube [4,5]**

Indexes	All	Including:		
		Opening-up of performs	a strain (defor-mation)	finish
Losses of metal at production of tubes %	5-60	1 - 25	2 - 10	2 - 30
Capital of an expenditure / %	100	2 -15	20 - 70	25 - 50
The cost 1 hour of operation of installations / %	100	2 -15	30 - 70	15 - 60
Annual working time fund of installations / hour		7500-8100	6500-7500	7500-8100
Annual working time fund of installations / hour		100-800	1000-25 000	1000-25 000

For complex examination of process of deriving hot-rolled of tubes irrespective of an expedient of a strain and used inventory the universal mathematical model of production linking technological parameters of process, design features of installations, performance of performing process and ready tubes with measure of an estimation of an economic efficiency is created.

PERFECTION AT THE BEGINNING OF 21ST CENTURY

At the beginning of 21st century, because of toughening of customer requirements to the product and service quality and globalization and aggravation of international competition, the majority of hot-rolled tube producers faced the problem of modernization of the existing equipment and building new production lines. [6-8]

From a large number of ideas of improvement of technologies and equipment for making hot-worked seamless tubes, it is worth to mention the idea of orientation of the mass production planning predominantly toward the technologies using continuous MPM mills with two-roll stands and continuous FQM and PQF mills with three-roll stands as the main reeling units. It is supported by a successful experience of operation of about 20 MPM mills built at the end of the 20-th century and commissioning of MPM, PQF and FQM units in China, Belarus, Japan, Russia, Kazakhstan in the last years. At present, installation of continuous mills at a number of tube works in Saudi Arabia, China, Ukraine and other countries is carried out or planned. It should be pointed out that MPM mills were initially equipped with press piercing mills but the modern continuous mills use skew roll piercing mills with tapered rolls and guide discs. Taking into consideration the fact that two or three billet sizes are rolled at a same piercing mill, the future design of the roll piercing mills will possibly provide for their possible operation both with the guide discs (in piercing small diameter billets) and shoes (when switching to piercing large diameter billets). At the same time, mills with horizontal roll arrangement should be preferred because shoe installation is much easier in this case.

It is not excluded, what further continuous mills will complete from two-roll “entrance” stands and three-roll (or four-roll) “exit” stands.

Of all promising innovations in the field of manufacture of hot-rolled tubes that can be used in production conditions in the nearest future, shell rolling in a stretch-reducing mill (CPS process) should be distinguished as the most promising process. The CPS process is a two-stage process where there is no second, main forming operation, i.e. there is no a mandrel tube rolling mill. Billets are subjected to helical piercing at elongation ratios up to 12 in a mill with a vertical arrangement of tapered rolls. The pierced billet is fed directly into a stretch-reducing (sizing) mill. Advantages of this process consist in that due to absence of a mandrel tube rolling mill, main equipment list is reduced and consequently investments get smaller. Such technology can be used above all in the production of conventional tubes.

At the present-day requirements to quality and dimensional accuracy of the final products, the processes of sizing or stretch reducing tubes as the final steps of the hot working process have a paramount importance [9-13]. Continuous sink rolling as the final production step in the majority of rolling patterns, determines quality of finished hot rolled tubes to a great extent. Based on the trends of development of the process of continuous sink rolling, it can be predicted that in the nearest future this process will be grounded on the idea of using three-roll stands. Stands must have individual drives ensuring flexible adjustment of roll rpm both in the course of rolling individual tubes (to reduce the length of thick ends) and from tube to tube rolling (to compensate for wall thickness variation in the mother tubes coming from the mandrel mill). Beside the roll rpm, roll pass shape plays an important role in ensuring quality of OD and ID surface of the sized (especially, stretch-reduced) tubes, and so the tool preparation stations should be equipped with modern machines for individual machining of the roll groves.

The continuous sink tube rolling process is usually carried out in mills in which roll pass of each subsequent stand is turned at angle $\frac{\pi}{n}$ (where n is the number of rolls in the stand) relative to the preceding stand roll pass. It is not inconceivable that this concept will be revised in the nearest future basing on the theoretical evidences worked out at State Scientific Research Tube Institute and Dnepropetrovsk Metallurgical Institute (Ukraine) as long ago as 1980 y. The calculations have shown that a substantially lower level of cross-sectional wall thickness variation can be achieved when using a mill which has two stand groups and the stands in each group are turned at a traditional angle $\frac{\pi}{n}$ but with the stand groups turned at angle $\frac{\pi}{2n}$ relative to each other. For the first time, this idea was realized in production conditions by designers of EZTM JSC (Russia) at their mill installed at Dnepropetrovsk Tube Works (Ukraine) in 2008.

In the improvement of the tube making processes, equipping process lines and individual units with computer-aided control systems is of especial urgency at present. Practically all modern tube rolling installations are already furnished or being furnished with the means of objective control of main process and product parameters. CARTA (Computer Aided Rolling Technology Application) process control system developed by SMS Meer has become a widely known and applied system currently. The system task consists in ensuring a high level of product yield and quality in the tube manufacture. Smaller diameter and wall thickness variations result in metal saving and cost reduction both in the course of production and during subsequent tube processing. [12]

At present, the problem of application of on-line tube dimension control systems is of high urgency. Obviously, practically all processing units will be furnished with systems for measuring tube wall thickness and diameter in the nearest future. Multichannel sensors measuring linear dimensions and allowing not only recording of the mean wall thickness variation during the tube travel along the process line but also determining the character of cross-sectional wall thickness variation will be given preference despite their relatively high price.

CONCLUSION

1. From a large number of ideas of improvement of technologies and equipment for making hot-worked seamless tubes, it is worth to mention the idea of orientation of the mass production planning predominantly toward the technologies using continuous MPM mills with two-roll stands and continuous FQM and PQF mills with three-roll stands as the main reeling units.

2. It is not excluded, what further continuous mills will complete from two-roll "entrance" stands and three-roll (or four-roll) "exit" stands.

3. Of all promising innovations in the field of manufacture of hot-rolled tubes that can be used in production conditions in the nearest future, shell rolling in a stretch-reducing mill (CPS process) should be distinguished as the most promising process.

4. At the present-day stage, development of the drawing processes is aimed at the growth of cost effectiveness and intensification of speed parameters.

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Note: The responsible translator for English language is lecturer from National Metallurgical Academy of Ukraine, Dnipropetrovsk, Ukraine.