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The Organizational and Technological Diagram of Special-Purpose Precision Tubes Making under Conditions of Mini-Manufacture

Ju.N. Stasovskiy /D.Sc. (Eng.)/, **I.N. Lukash**

National Metallurgical Academy of Ukraine
4 Gagarin Ave., Dnipropetrovsk 49600, Ukraine

Abstract

Scientific and methodological foundations of technological model at the stage of preparation of innovative and investment project of high technology mobile mini-manufacture of competitive precision tubes have been worked out for the first time.

Keywords*: precision tubes, mini-manufacture, drawing mill, model, manufacture*

Development of priority branches of industry (instrument making, electronics, medicine, power mechanical engineering, aircraft industry and shipbuilding, etc.) causes a constantly growing demand in precision welded and seamless, especially cold-worked, fine tubing (with outside diameter less than 40 mm [1].

In CIS countries, the main volumes of seamless fine corrosion resistant steel tubing are made from a continuous tubular billet purchased from various manufacturers with the application of traditional technologies according to the scheme "hollow billet - hot pressing or rolling - cold or warm deformation - finishing - control – delivery" under conditions of specialized pipe plants. In Ukraine, the following can be as an example: JSC "Sentravis Production Ukraine", State Enterprise "Dnepropetrovsk Precision Tube Plant", State Enterprise "Nikopol Pipe Plant", JSC "Nikopol Steel Pipe Plant YuTiSt" - specialized industrial shops; in Russia – JSC "Pervouralsky Novotrubny Works", JSC "Sinarsky Pipe Works"; "MedSpetsTrub" Ltd. - industrial shops; State Enterprise "Moscow Electronic Engineering Plant "EMITRON" - specialized site.

Alongside with the development of seamless tube production, the demand for welded tubes grows every year. This tendency is proved by the fact that the new manufacturers of welded corrosion resistant steel tubes have been implementing the new equipment recently in CIS countries [2]. From the middle of 2008, the two new welded corrosion-resistant steel pipe plants – "IVIS Steel" (Dnepropetrovsk) and "Kompozit-STK" (Gulyaypole) started operating in Ukraine. In Russia, except for operating JSC "MTZ Filit" and Group of Companies "Arinoy", the plant "Marcegaglia.ru" (Vladimir) and "Izostal" (St.-Petersburg) are being built, and the latter is almost ready to be implemented. The first Ukrainian welded corrosion resistant steel pipe plant "IVIS Steel" specializes on making the tubes of round (outside diameter of 12 - 50.8 mm), square (10x10-40x40 mm) and rectangular (15x10-50x25 mm) sections with a wall thickness of 0.5-3 mm by means of TIG welding method without heat treatment. The full capacities are 250-300 tons per month, however, at present they are loaded on 7-10 %, and almost all the products are on export to Russia.

The other Ukrainian plant "Kompozit-STK", started in the end of May 2009, produces the tubes with diameter of 6-51 mm of 304, 304L, 321, 316L, 316Ti, 310S, 430 corrosion resistant steel grades with the application of TIG welding and heat treatment, mainly for food and petrochemical industry. Now, the full capacities of the plant are 125 tons per month.

In Russia, the most large-scale project is building of industrial shop in Vladimir by company "Marcegaglia" (Italy). The new plant will produce welded tubes of ferritic steel grades mainly with outside diameter of 10-64 mm (TESA TIG) and 40-159 mm (TESA HF) for enterprises of chemical, petrochemical, pharmacological and food-processing industry of Russia and CIS countries. The initial industrial capacities will make 300-350 tons per month. It is planned to increase the output up to 1.6-2 thousand tons per month (20-25 thousand tons per year) during two years.

In St.-Petersburg, the plant "Izostal" has been built and is ready to be implemented as well. This plant will produce longitudinal welded tubes of corrosion-resistant austenite steel grades with outside diameter from 90 up to 300 mm, moreover the tubes with diameter of 90-143 mm will be flexible, and the large-diameter tubes (150-300 mm) will be made in the form of straight lines. The output capacities of the line are 126 km/month.

All the listed welded pipe plants use a purchased cold-worked (sometimes precision) strip as an incoming billet.

At present, the main world trend at precision tube making of specified range of sizes is reduction of cold working amount due to obtaining a billet with sizes similar to the finished article (for example, the use of welded thin-walled tubular billet), intensification of cold working modes, increase in labor productivity as a result of application of highly productive processes of drawing.

Today, the most serious problem in precision corrosion-resistant steel tube making is the following. Seamless precision special-purpose tubes are produced on the same equipment as the general-purpose tubes made from purchased continuous round billet or tubular billet for further processing (at the above-mentioned specialized works or industrial sites). The traditional technologies applied at these works are featured by high cycling and labor input, which causes a high cost price of precision tubes and decrease in production efficiency at manufacturing low-tonnage batches (frequently several meters) from a wide range of materials. Therefore, the products manufactured by Ukrainian works are in most cases noncompetitive by quality and price (as the products are produced on the worn-out equipment with the application of imperfect energy- and labor-consuming local technologies, it is necessary to form the batches of tubes via selection method with significant consumption of resources, first of all, expensive metal) [1]. The up-to-date mobile mini-manufactures or mini-plants equipped with continuous technologies and high-efficiency equipment can have no drawbacks specified.

Welded tubes making in the limited range of sizes and of restricted spectrum of materials (based on the standard size of electric pipe-welded rig and welding method) is carried out on the available or specialized equipment implemented again. The quality of welded tubes, in view of the level of applied equipment and technology, can even correspond to "precision". The experts from Russia notice [2] that " … construction of new welded corrosion-proof pipe plants is an urgent need for country (Russian Federation). But the prospects of these plants directly depend not upon demand for tubes but on approaches to construction and upon purposes the owners have. If, at the stage of design, the plant owners do realize what they are going to produce, for what segment of the market, in what quantity, in this case, at first, they consider the necessary equipment and its good configuration. If the solution is not ready yet, or not new equipment with available set of elements is purchased, this plant will be reasonable only in the period of short supply and unless the "serious players" appear. Also, it is necessary to note that construction of the plants with a low number of tube-welding mills can be a success only in case of narrow specialization and limited pipe grades".

Currently, despite substantial domestic capacities and significant volumes of tubular goods export and owing to the problems stated above, such countries as Italy, Spain, China, India, etc. import the welded tubes made of stainless steels and alloys. There is a similar situation in Russia as well.

For the most part, these problems can be eliminated by means of creation of domestic mobile mini-plants or mini-manufactures equipped with the up-to-date highly-productive equipment and continuous resource-saving environmentally safe technologies (from obtaining the own high-quality cold-deformed strip till the welded tubes making, including precision ones, with subsequent advanced processing – manufacture of cold-deformed precision tubes of different grades from the welded billet).

In the welded thin-walled tubes making of a wide range of materials, the up-to-date methods of welding are applied: argon-arc (TIG - Tungset Inert Gas, welding by tungstic electrode in the inert gas, without filler metal), laser, microplasma (plasma-arc welding coupled with TIG), HF (high-frequency welding), electron-beam welding, etc. Now, it is considered that TIG or TIG coupled with plasma-arc welding make about 65 % of all the

European welding manufactures, while approximately 30 % is accounted for HF welding and the rest – for laser welding. Actually, there is no competition between various welding systems but, as a rule, the requirements for welding technology depend on the sphere of welded tubes application.

At present, a cold-rolled corrosion-resistant strip of required dimension is used as an incoming billet for welded tubes making. It is this strip from which a tube of required diameter is formed on the welding-and-forming mill and is welded by one of popular methods of welding, for example, laser or TIG welding. Choosing a welded tube with a wall thickness close to thickness of finite sized tube and applying the regulated variation of deformation-speed modes in the process of drawing, we obtain a total relative degree of deformation up to 95-97 % (for example, for steel 12Cr18Ni10T). The welded tubes in coils or cut lengths are used both as finished marketable products and round billet for subsequent cold drawing.

The analysis of basic research works in chosen tendency has shown the following.

In paper [3], there are practical recommendations regarding implementation of continuous technology in precision tubes making from a welded billet, foundations of the new method of technological scheme construction according to continuous resource-saving technologies; approaches to choice of criteria for determination of unified dimensions of tubular billet for precision tubes making; the new concept of precision tube mini-plant.

The disciples of Moscow scientific school [4, 5] present a technique of comparative efficiency evaluation of alternative technologies of tubes mini-manufacture [4] and computation procedure of investment projects efficiency at implementation and development of capacities by stages [5].

The techniques of technological scheme construction in precision tube making by continuous technologies have been unavailable for a long time. The existing techniques consider the finishing stages of tube making in details, and making of necessary billet for further processing is not well-considered.

The disciples of Ural scientific school [6, 7] describe the system for automated analysis and designing of multi-operational technique of cold-deformed tubes making, which provides the minimal operating costs under specified technical and economic restrictions and standardized quality of production. The foundation of this system is economic and technological model of processes with application software for technological and technical-economic computations of rational processes of tube making [7].

However, the approaches suggested in works [6, 7] ensure finished precision tubes making at the finishing stage that is only a part of continuous technology.

From the middle of 70s of the 20-th century, the disciples of Dnepropetrovsk scientific school have started carrying out the research works in this area.

For implementation of continuous technology in precision tubes making, there was a necessity for a new method to be developed concerning design of continuous technological schemes of the whole technological process in view of the basic and auxiliary operations, to which metal is subjected during manufacture (from melting the liquid metal with proper quality to manufacture of products of required quality and with specified operational characteristics)[3].

As a matter of experience, to produce the precision tubes with specified wall thickness and with necessary tolerance (from +/-0.005 up to +/-0.02 mm) it is reasonable to apply the following methods of drawing: sink drawing (through 2-3 drawholes); moving-mandrel drawing that ensures substantial deformation across the wall (for some materials reduction ratio reaches 4.0); fixed-plug drawing that is reasonable to apply for enhanced quality tubes making, and also for finishing drawing of finished tubes; floating-plug mandrel drawing that is reasonable to apply, first of all, for parcel drawing of lengthy tubes [1].

In precision tube making, the important condition is the necessary up-to-date process equipment that provides high quality production with the minimal resource consumption and has the minimal effect upon environment [1].

At present, despite the considerable world experience related to production of welded and cold-deformed stainless steel tubes, the developers of numerous plants and companies aim their efforts at the creation of new and advancement of operating technologies and equipment for precision tube making. Thus, there is almost no technological and economic model of precision tubes making by continuous technology.

The purpose of work presented is creation (scientific substantiation) of some stages of scientific and methodological foundations, in particular, organizational and technological scheme of manufacture at the stage of preparation of innovative and investment project as a basic component of professional approach to designing by the example of development and implementation of technological and economic model of competitive precision tube making under conditions of mini-manufacture [8].

Within this scientific work, the authors offered a feasibility report of mini-manufacture of precision fine tubing made of corrosion-resistant steels of austenite class (grades 08Cr18Ni10T, 12Cr18Ni10T) as an example. The output is 1000 tons per year, including (Figure 1): cold-deformed tubes with the use of seamless billet 250 t; cold-deformed tubes with the use of welded billet 500 t; welded tubes 250 t.

The range of sizes of precision tubes is following:

- welded tubes of diameter range according to technological capabilities of specialized equipment (Ø 10-60 mm on electric pipe-welded rig (EPWR) 10-60; Ø 10-50 mm on EPWR 10-50; Ø 5-16 mm on EPWR 5-16);
- cold - deformed tubes with the use of welded (or seamless) billet of diameter from 5 up to 60 mm with a wall thickness of 0.5-3.5 mm (different methods of drawing); and also capillary tubes of diameter less than 5 mm (down to 0.1 mm) with a wall thickness less than 1.0 mm (down to 0.017 mm and less) (drawing).

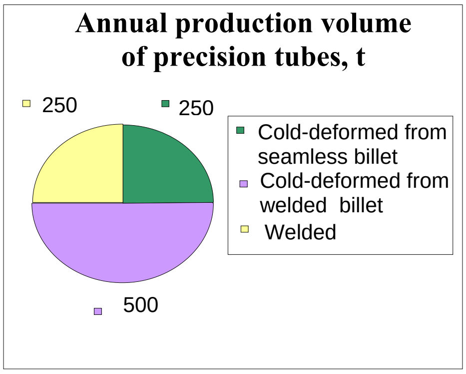

Figure 1. Planned production volume of precision fine tubing made of corrosion-resistant steel

Production volume, range of sizes and the main methods of precision tube making are resulted in Figure 2. Substantiation of the choice of range of precision tube sizes at the new mini-manufacture is presented in Figure 3.

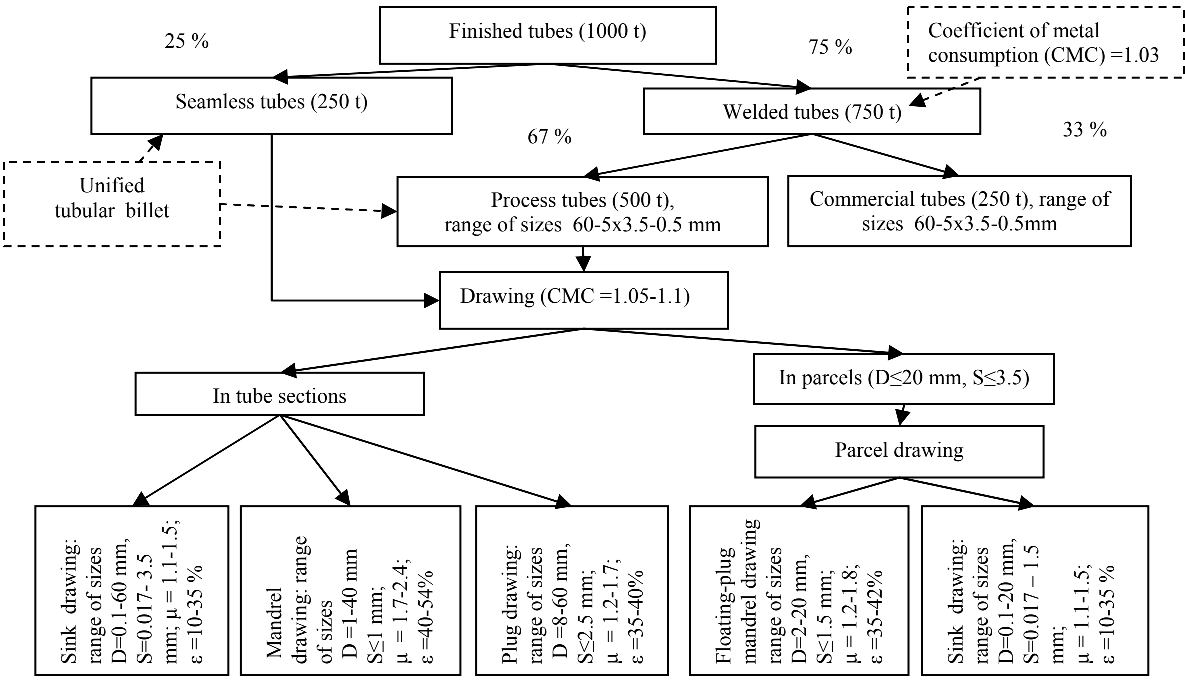

Figure 2. Production volume, range of sizes and methods of precision tubes making

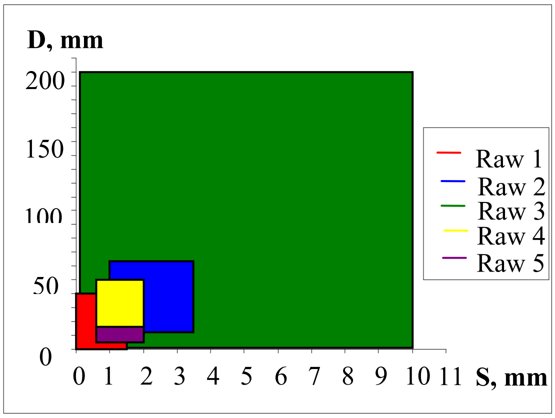

Figure 3. Comparison of ranges of sizes of precision tubes

The range of welded precision tubes produced in the world at the moment is rather extensive (outside diameter D = 1-200 mm, wall thickness S ≥ 0.1 mm that is marked by green color in Figure 3). The most widespread range of sizes of precision tubes for today is D ≤ 40 mm, S ≤ 1.5 mm (red-colored in Figure 3). The tubes of smaller dimensions (D < 5 mm) are planned to be produced by means of different methods of drawing.

At the planned use of EPWR 10-60 (dark blue zone in Figure 3), EPWR 10-50 (yellow zone) and EPWR 5-16 (violet zone), it is possible to produce the welded commercial tubes, which also can be used as a process tubular billet for the subsequent manufacture of cold-deformed tubes with the use of drawing at mini-plant. At the point where the red zone crosses with dark blue, yellow and violet zones, both welded tubes and cold-deformed commercial tubes are produced. Only cold-deformed commercial fine tubes are produced from the welded billet by means of drawing (on the rest of red zone in the chart).

The offered precision tube production schemes are diagramed in Figure 4. The scheme of arrangement of industrial sites (blocks, modules) and of capital equipment and stages of new mini-manufacture implementation are presented in Figure 5.

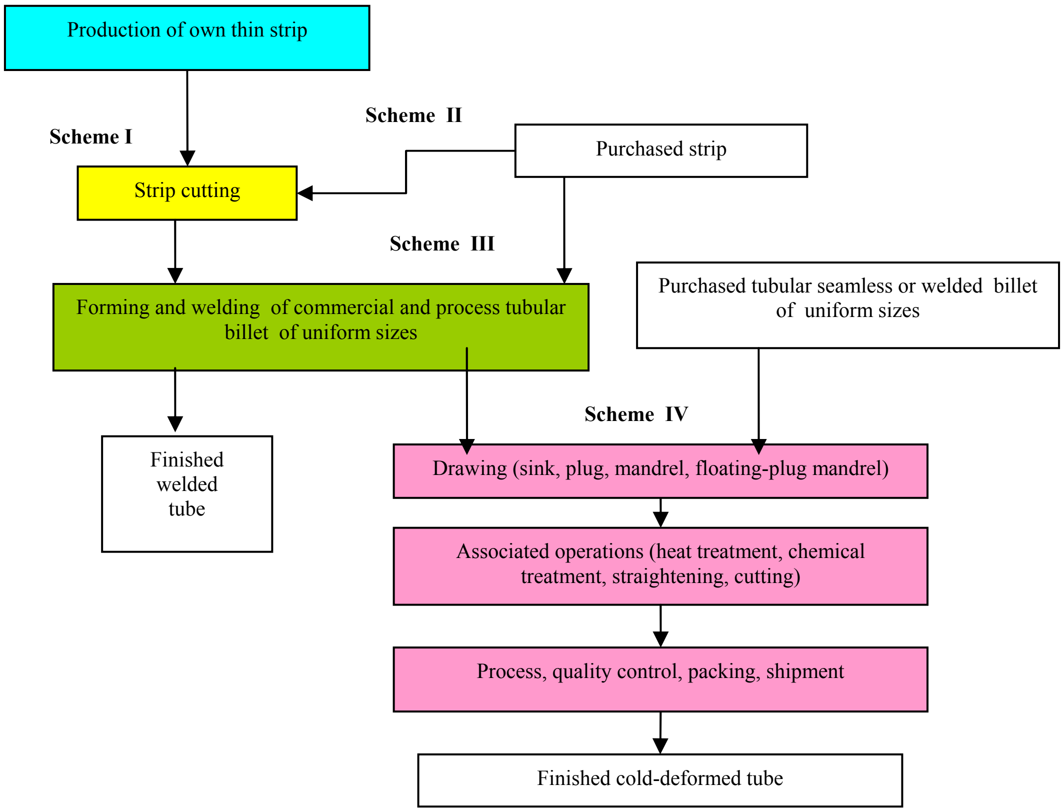

Figure 4. Precision tube production schemes

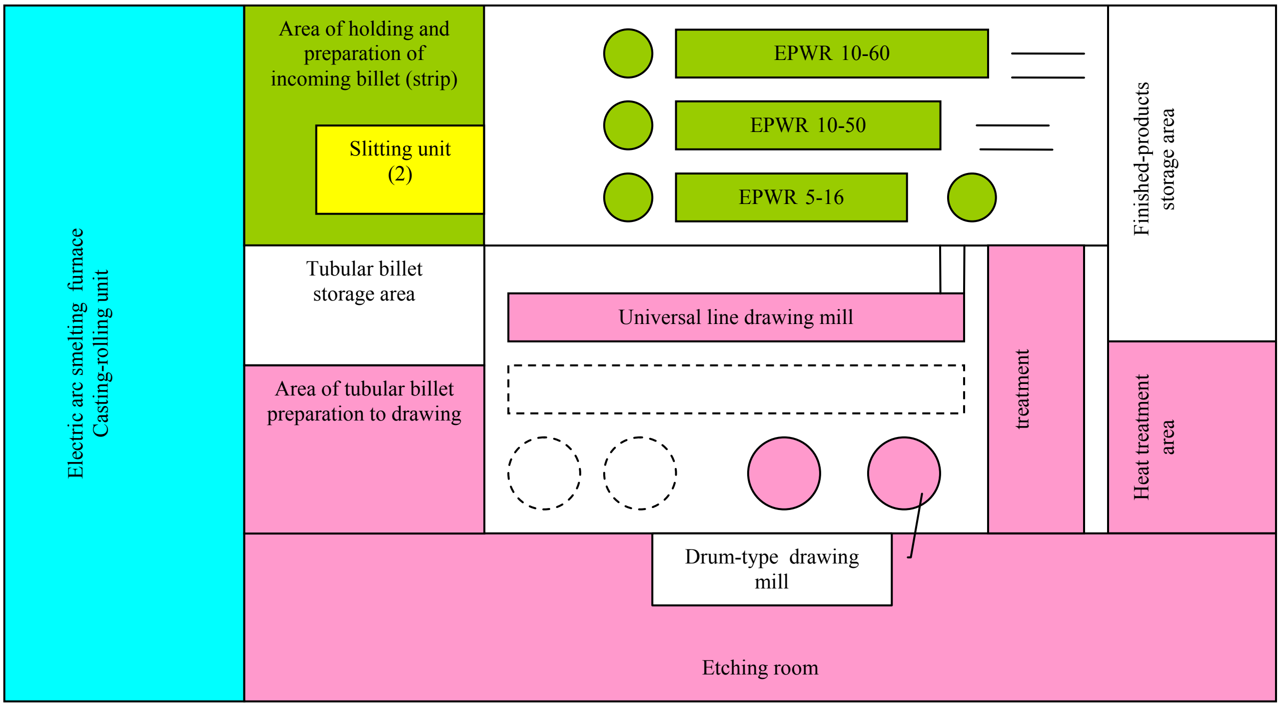

Figure 5. Scheme of arrangement of industrial sites and capital equipment at a mini-plant

The offered precision tube production schemes at a mini-plant being founded are as follows:

Scheme I: production of own strip with necessary final characteristics (geometrical dimensions, surface condition, mechanical properties, chemical composition, etc.) → cutting-to-width → skelping and welding of commercial and process tubular billet of uniform sizes → finished welded tube or → drawing → secondary operations → processing → finished cold-deformed tube.

Scheme II: purchased strip → cutting-to-width → skelping and welding of commercial and process tubular billet of uniform sizes → finished welded tube or → drawing → secondary operations → processing → finished cold-deformed tube.

Scheme III: purchased strip of required width→ skelping and welding of commercial and process tubular billet of uniform sizes → finished welded tube or → drawing → secondary operations → processing → finished cold-deformed tube.

Scheme IV: purchased tubular seamless or welded billet of uniform sizes → drawing → secondary operations → processing → finished cold-deformed tube.

Implementation of new mini-manufacture is planned stage by stage:

Stage 1. Implementation of scheme IV (purchase and installation of the combined drawing line and tube finishing).

Stage 2. Implementation of scheme III (purchase and installation of tube-welding machines with equipment for laser and TIG welding of tubes).

Stage 3. Implementation of scheme II (purchase and installation of longitudinal cutting units that enable to purchase a wider strip).

Stage 4. Implementation of scheme I (purchase and installation of the melting electric furnace and casting-rolling unit that will enable to melt the metal of required chemical composition and to produce a strip of necessary thickness).

The new mini-manufacture as one of the possible options can be equipped with the following equipment [1, 3, 8]:

- the universal line drawing mill that operates with the application of all methods of drawing (to produce the tubes of measured length of diameter from 0.1 up to 60.0 mm);

- drum-type drawing mill (for tubes of diameter from 0.1 up to 20.0 mm in parcels).

Except for listed capital process equipment for deformation of tubes, the up-to-date manufacture is equipped with auxiliaries: machines for shaping the tube ends before drawing (rotary swager – RS, radial-clamping machine – RCM), furnace for "light" annealing, rotary reeler, unit for tube straightening by means of "pure bending", cutting devices (saws), baths for washing the finished tubes, etching baths, finishing equipment, equipment for tube quality control (flaw inspection, ultrasonic control), equipment for packing the finished tubes, etc.

When choosing a drawing grease, the environmentally safe grease is preferable. From this point of view, the most effective are water-soluble greases developed, for example, by domestic experts of Scientific Research Institute "MACMA" (Kiev). In case of parcel drawing of tubes without intermediate heat treatment, chlorinated paraffin wax of grade ХП-600 is often used as a grease for outside tube surface, and in case of ironing – grease DF-M manufactured by Japanese Company "Duraran" is used for inside tube surface.

On the offered EPWR 10-60, EPWR 10-50 and EPWR 5-16 it is planned:

- to form tubular billet by means of technological tool (rolls), pass design of which is executed in view of the up-to-date method of "W-bend formation" (suggested by the experts of Company " NAKATA ", Japan);

- to weld tubes with the use of two welding methods – laser and TIG welding.

For slitting of the rolled metal, the new manufacture will be equipped with slitting units (SU).

Also, the electric arc melting furnace and casting-rolling plant are planned to be installed at the last stage that will satisfy the base enterprise's requirements for incoming billet to produce welded tubes in the volumes required. A certain volume of high-quality strip will be produced for the further development of branches (affiliated mini-plants) or of marketable products for sales to other consumers who are not welded tubes manufacturers.

The manufacture does not require great production facilities and carrying out of special labor-consuming construction work. For example, 150-500 m^2 is enough for tube cold deformation area depending upon the chosen configuration of equipment. The basic energy carrier is electric power, and self-contained power supply is possible. Water is used in the closed cycle. The options of process equipment designs and technological schemes provide the vertical shop design (for example, double-level shops) [8].

The offered continuous technology is environmentally sound as has a minimum influence upon environment and is almost non-waste. The use of energy carriers (electric power, water, compressed air, vapor) is minimized, etching of metal is practically absent, the application of intermediate annealing is excluded or reduced as much as possible. Reduction of metal consumption index, decrease in labor intensity and in cycling process of technological process enable to reduce production expenses [8].

The subject of research presented and its urgency were determined by the following issues:

1) The objective necessity to solve a problem of combination of two components (technological and economic) in the up-to-date manufactures at the design stage as a basis of their perspective operation in the pipe&tube production and in metallurgy as a whole under conditions of the market economy formation;

2) The absence of necessary scientific and methodological maintenance at the stage of preparation of innovative and investment project.

In particular, these scientific research results can be a basis of the effective operation of up-to-date mini-manufactures in Ukraine in the near future. In authors' opinion, it will enable to reduce substantially or to refuse import of production, to satisfy the home market needs and to raise an export potential of precision fine tubing manufacturers.

When founding an up-to-date mini-manufacture, it is necessary that "three whales" (technology, economy and marketing) were in the constant interrelation, interdependence and interference ("3I").

At all the stages of implementation of innovative and investment project (from a plan till the complete adoption and successful functioning of new manufacture), the qualified marketing research provide and create a base for informed and correct decision making [8].

Summary

The organizational and technological production scheme as one of the components of the concept of technological and economic model that reveals the purposes, problems and foundations of precision tubes "know-how" is offered. This scheme considers the market condition of high technology precision tubular goods. The real scheme of stage-by-stage implementation of new precision tube mini-plant is resulted.

References

1. Ju.N. Stasovskiy Pretsizionnye truby (*Precision Tubes*) // Metal i litye Ukrainy. - 2008. – No.1-2. – P. 24-28.

2. Novye proizvoditeli svarnykh nerzhaveyuchshikh trub v SNG I ikh perspektivy na rynke (*New Manufacturers of Welded Corrosion-Resistant Tubes in CIS countries and Their Prospects in the Market*)// Metal-curiyer. Tsvetnye metaly. - 2009. – No. 27 (128). - P. 12-13.

3. Ju.N. Stasovskiy Nauchnye osnovy resursosberegayuchshikh tekhnologiy proizvodstva pretsizionnykh trub malykh razmerov primenitelno k usloviyam mini-proizvodstv s ispolzovaniem tonkostennoy svarnoy zagotovki (*Scientific Foundations of Resource-Saving Technologies of Precision Fine Tubing Making Relating to Conditions of Mini-Manufactures with the Use of Thin-Walled Welded Billet)* // Suchasni problemy metallurgii. Naukovi visti. Plastychna deformatsiya metaliv. Teoriya I tekhnologiya vyrobnutstva trub (Ukrainian). – Dnipropetrovsk: Systemni technologii, 2008. – V. 11. – P. 377-384.

4. A.M. Rytikov, O.A. Shashlova Sravnitelnaya effektivnost alternativnykh tekhhologiy mini-proizvodstva trub s intensifikatorom teploobmena (*Comparative Efficiency of Alternative Technologies of Tube Mini-Manufacture with Heat Exchange Intensifiers*) // Tsvetnye metally. – 2000. – No. 5. – P. 102-107.

5. A.M. Rytikov , O.A. Shashlova Raschet effektivnosti investitsionnykh proektov pri vvode i osvoyenii mochshnostey ocheredyami (etapami) (*Computation of Investment Projects Efficiency under Implementation and Adoption of Capacities Stage-by-Stage*) // Tsvetnye metally. – 2000. – No. 11-12. – P. 9-12.

6. A.A. Bogatov, N.A. Smirnov, V.V. Kharitonov, V.A. Solomein Sistema avtomaticheskogo proektirovaniya protsessov kholodnoy deformatsii trub (*Automated Design Engineering System of Tube Cold Deformation Processes)* // Proizvodstvo prokata. - 1999. – No. 2. - P. 28-30.

7. N.A. Smirnov, A.A. Bogatov, V.V. Kharitonov Razrabotka struktury avtomatizirovannoy sistemy tekhnologicheskogo proektirovaniya trubnykh tsekhov (*Structure Development of Automated Design Engineering System of Pipe Shops*) // Proceedings of Scientific and Technical Conference “*Theory and Technology of Plastic Deformation Processes*”. - M.: Moscow Institute of Steel and Alloy, 1997. - P. 330-335.

8. Proektorivaniye sovremennykh proizvodstv obrabotki metallov davleniyem (*Development of Up-To-Date Methods of Metal Forming*) / Textbook // Yu.N.Stasovskiy, Yu.S.Krivchenko, G.S.Babenko; edited by J.N.Stasovskiy. – Dnepropetrovsk: Monolit, 2009. – 746 p.

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Организационно-технологическая схема производства прецизионных труб целевого назначения в условиях мини-производства

Стасовский Ю.Н. /д.т.н./, Лукаш И.Н.

Впервые разработаны научно-методологические основы технологической модели на стадии подготовки инновационно-инвестиционного проекта наукоемкого мобильного мини-производства конкурентоспособных прецизионныхтруб.