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IMPROVING THE PROCESS FLOWSHEET OF FLAT-BULB PROFILES PRODUCTION IN UKRAINE

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Abstract

The study of production techniques and quality estimation of flat-bulb profiles (made of continuously casted ingots) have shown that Ukrainian iron & steel companies are capable of producing high quality ship steel which meets the international requirements. For the first time in Ukraine flat-bulb profiles were made of continuously casted ingots. These profiles have better mechanical properties, higher ductility and plasticity if compared to the profiles made using traditional methods.

Keywords: flat-bulb profiles, continuously casted ingots, ship steel, process flowsheet

While discussing the problems of section-rolling industry reconstruction in Ukraine we should consider a great variety of rather contradictory factors. The most important of them are the following. First, nowadays about 75 % of metal products made in Ukraine are exported to neighboring and distant foreign countries; so Ukraine is one of the world's leading metal exporters [1]. Second, the tendencies at the world metal market show that the consumption of metal will not grow considerably in the nearest future [2, 3]. Third, market economy presupposes the following purposes of such reconstruction:

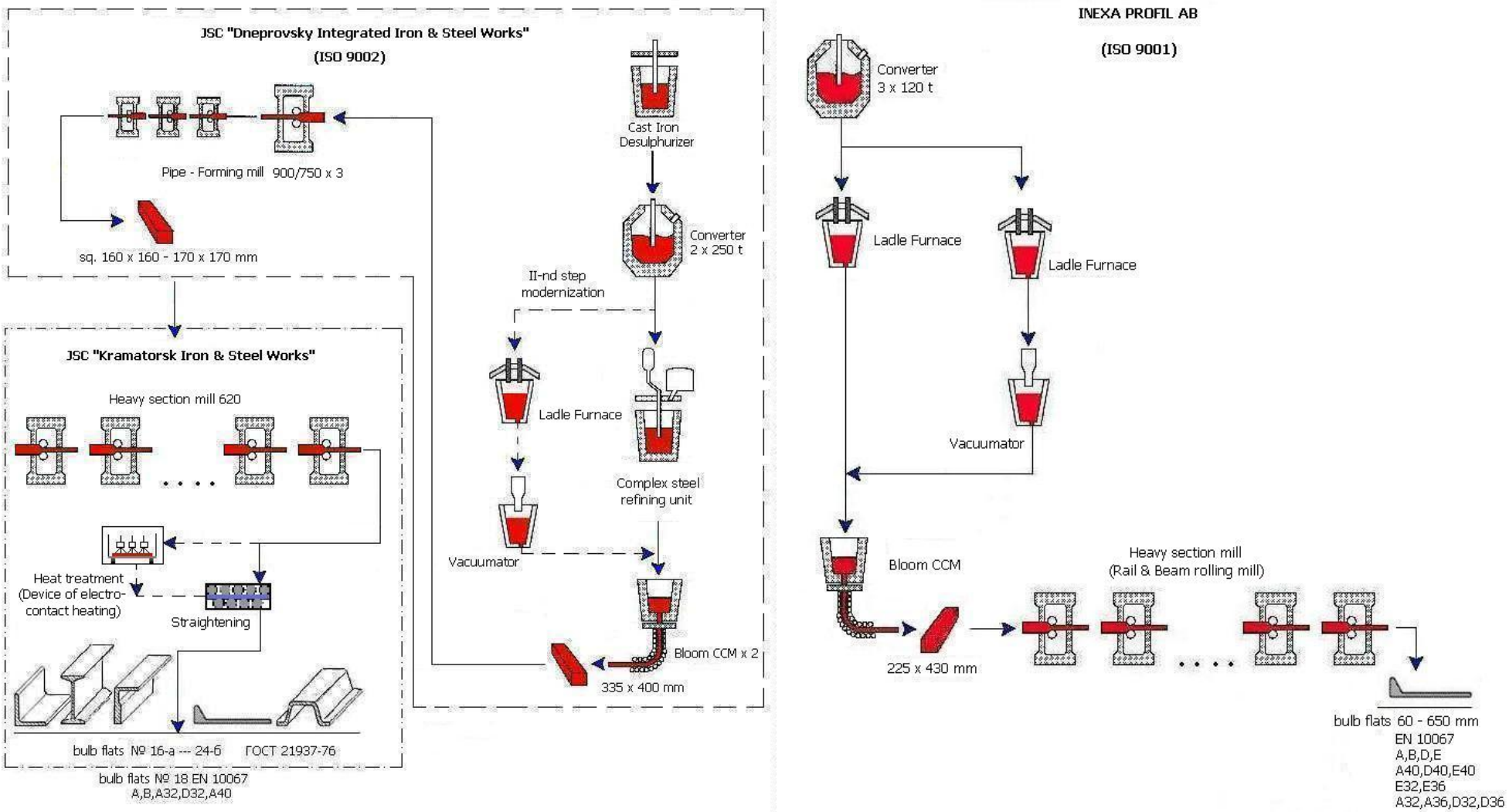
- a high quality product which would satisfy the consumer and help to oust the competitors from the market;
- a low cost price of this product;
- the shortest possible payback period.

Ferrous metallurgy is one of the major branches of Ukrainian industry. So its reconstruction should be regarded as a part of the program aimed at involving the country in the process of European integration. Moreover, a comprehensive realization of this program requires a much higher quality of engineering industry products, but it is hardly possible without improving the quality of rolled section steel and sheet metal. The world experience shows that such problems are most successfully solved by means of applying advanced steelmaking techniques and continuous casting methods.

Continuously casted billets with sections 150x150 mm to 200x200 mm are of great importance in producing a great variety of special shaped profiles (on heavy and medium section rolling mills). First of all such billets are used for producing flat-bulb profiles which are widely applied in shipbuilding industry (State Standard 21937-76, State Standard 9235-76). In the former USSR Ukraine was actually the monopolist in this particular kind of metallurgy, with 90% of all its products being concentrated on six rolling mills. At the same time, nowadays all Ukrainian flat-bulb steel is still being produced on the basis of ingots re-rolling.

Flat-bulb profiles are widely used in ship structures, so there are certain requirements to their quality. The basic properties of a flat-bulb profile are high ductility and toughness, which will guarantee its strength and resistance to the influence of multi-cyclic dynamic and thermal loads. The items of such quality can only be obtained if we select proper materials and apply the best production techniques which include steel melting and casting as well as deforming and thermal strengthening of the finished items. The analysis of flat-bulb profiles production schemes in EU countries leads us to the following conclusion. In Ukrainian metallurgy the most rational way of improving such production schemes will be the integration within the common project of several companies.

These companies must have up-to-date steelmaking facilities on the one hand and long experience in producing a great variety of such items on the other hand. In terms of economics the most prospective flat-bulb profiles production schemes are similar to those implemented by *Inexa* (the leading European producer of such items, Sweden) at metallurgical works INEXA PROFIL AB in Lulea (see the flowsheet in Figure 1).



a b

Figure 1. Flow sheets of flat-bulbs profiles production: a – JSC "Kramatorsk Iron & Steel Works", (Ukraine)
b – INEXA PROFIL AB, (Sweden)

At the end of 1999 JSC "VIZAVI", JSC "Dneprovsky Iron & Steel Works named after F.Dzerzhinsky" and JSC "Kramatorsk Iron & Steel Works named after V.Kuibyshev" started the common project aimed at flat-bulb profiles production on the basis of continuously-casted metal. Donetsk National Technical University and GERMANISCHER LLOYD Classification Society also took part in this project. In many ways the collaboration of these two iron & steel works has been conditioned by their unique production capabilities and it is much similar to the processes taking place at analogous enterprises all over the world (namely, billets for re-rolling are made by means of up-to-date steelmaking facilities and, consequently, the quality of finished products is higher).

At JSC "Dneprovsky Iron & Steel Works named after F.Dzerzhinsky" there is a "rolled-steel" process stage certified by the standard ISO 9002 and based on a modern oxygen-converter plant (OCP). Steelmaking technology applied at OCP presupposes the separation of steelmelting and refining processes and further steel teeming by blooming and combined continuous casting machines (CCM). This plant (OCP) has a unique combined CCM designed for simultaneous steel casting into blooms with section 335x400 mm (4 strands) and into billets for re-rolling with section 335x400 mm (4 strands). Simultaneous implementation of these two processes allows comparing the quality of steel billets (with similar sections) obtained using different techniques:

1) Blooms with section 335x400 mm are casted on a curvilinear CCM. Then the blooms are rerolled into billets with square section 170x170 mm on the mill 950/750-3.

2) Square billets (with section 160x160 mm) are casted on a curvilinear CCM.

It is worth mentioning that JSC "Kramatorsk Iron & Steel Works named after V.Kuibyshev" has 40 years experience in producing heavy flat-bulb profiles for shipbuilding industry of the former USSR. It is distinguished for a wide assortment of the produced items (asymmetrical flat-bulbs of 10 sizes out of 19, i.e. 52,6 %). The items are made according to State Standard 21937-76 B. This plant is unique due to its special equipment and heat treatment systems which allow producing ship steel of all ranks from A to E.

Besides, there are certain possibilities for improving this plant within the Standard 21937-76 B and EN 10067. It allows creating specialized production facilities aimed at providing shipbuilding companies (both Ukrainian and foreign) with flat-bulb profiles which would meet the highest requirements of the metal market.

All the facts mentioned above made possible the following researches (carried out in 2000-2001):

- Experiments aimed at defining such sections of cast billets which will ensure the highest quality of rolled metal products in accordance with common international standards.
- A comprehensive estimation of how such rearrangement can influence the properties of primary billets and finished items at existing iron & steel enterprises.

More than 400 tons of trial ship steel (grade A32 – D32, State Standard 5521 – 93, chemical composition meets Germanischer Lloyd and Russian Maritime Register requirements) were melted in a 250-ton converter according to the current instructions on steel melting and continuous casting. Rolled section steel macrostructure depends upon the macrostructure of primary billets and rolling pattern. The quality of the obtained items was estimated proceeding from Branch Standard 14-1-235-91 [4]. The most common macrostructure defects are axial physical and chemical inhomogeneity, liquation bands and cracks, dot inhomogeneity. None of them can be eliminated in the process of hot deformation; they remain in the rolled steel at any reduction rate.The macrostructure of primary casted billets must correspond to the State Standard requirements. Otherwise it will be impossible to obtain rolled section steel with satisfactory macrostructure.

We have studied the structure of experimental square billets with section 170x170 mm produced using the first technique. The analysis has shown that their surface is very good, without any visual defects typical of rerolled billets. These billets are characterized by homogeneous

chemical composition, smaller (against casted ingots) number of shrinkage and liquation defects, homogeneous and dense macrostructure (Figure 2a). The only exception is a narrow core zone. Here we can see the remains of the initial dendrite structure of a continuously casted bloom, as well as center segregation/axial chemical inhomogeneity (0-1 points). Dendrite and granular structure dispersity is three times higher than that in the bloom. Nonmetallic impurities were reduced by four times as compared to the metals produced using common techniques (melting in an oxygen converter – casting – rolling).

a)

b)

Figure 2. The structure of square steel billets
a – section 170x170 mm; b –section 160x160 mm

The macrostructure of such billets has one more peculiarity. It is a dense white-etched edging 5-8 mm thick along the section contour (inherited from the rim zone of a bloom) and a poorly pronounced heat center.

Unlike the structure of 170x170 billets, the macrostructure of continuously casted billets produced using the second method (figure 2b) is of lower quality, i.e. dendrite and granular structure dispersity is lower, center segregation reaches 0-1 points, the heat center is clearly pronounced. At the same time, the content of nonmetallics is the same as in the billets obtained according to the first method.

As far as metal resistance to multicyclic and thermal loads is concerned, the most dangerous defects are the following: segregation bands and cracks located in the interaxial spaces of dendrite structures and stress cracks, which cross dendrite axes and spread about the template section in the form of broken lines.

Marginal dotted impurities (nonmetallic inclusions of endo- and exogenous origin) have similar influence. They are arranged separately, in clusters or in lines along the cross-section of a template. We have estimated the quality of the produced items and come to the conclusion that the metal under consideration has no segregation bands; and marginal dotted impurities are present only in 160x160 billets and do not exceed 1 point.

Low quality of central zones in continuously casted ingots leads us to the necessity of estimating the quality of finished flat-bulb profiles. Their macrostructure was studied using the quality control method provided in Branch Standard 14-1-235-91. However, taking into account the fact that Ukraine and CIS countries were the first to produce flat-bulb profiles from continuously casted metal and that there is no information about analogous experiments in industrially developed countries we estimated the quality using the approach proposed in [5]. The adequacy of this approach is confirmed by similar conditions in which the profiles are used (cyclic and thermal loads) on the one hand and by high toughness requirements (the metal must be resistant to exposures) on the other.

We estimated the quality of experimental asymmetric flat-bulb profiles №24A, 22A, 20A, 20B, State Standard 21973-76 (primary billet section 170x170 mm) and experimental items №22A, 20A, 18A, State Standard 21973-76, 18A, B, C, E, DIN EN 10067 (primary billet section 160x160 mm) proceeding from the current requirements.

The surface of both primary billets and finished bulb-flats profiles was analyzed in the process of 100% visual examination. The share of surface defects (which appear as a result of rolling) did not exceed the average value typical of the given technology and equipment.

The analysis of test results has shown that the quality of the produced metal items satisfies completely the requirements of State Standard 21937-76 (Table 1). We analyzed mechanical properties distribution in flat-bulb profiles and found out that these properties are distributed uniformly in the profiles of different sizes within one melting. In some cases strength characteristics decreased by 20-30 H/mm^2 due to carbon and sulfur zonal segregation (the samples were taken from the area of thermal centre).On the average the mechanical properties of flat-bulb profiles meet the Standard requirements, and we came to the conclusion that the metal in flat-bulb profiles made of continuously casted ingots is more homogeneous.

Flat-bulb profiles produced from continuously casted ingots (obtained using two different methods described above) have a dense white-etched edging 1 – 1,5 mm thick (Figure 3). around the section contour. It is more pronounced in the items made of 160x160 billets.

Macrostructure defects of rolled products made of continuously casted steel [5] can be classified into three basic types:

1 – axial chemical inhomogeneity;
2 – marginal dotted impurities;
3 – segregation bands.

Table 1. Mechanical properties of symmetrical flat-bulbs made of continuously casted billets

Number of profile	Type of billet, mm	Mechanical properties **					
		R_m	R_e	A_5, %	Bend in cold condition	Impact work KV, Joule*	
		N/mm^2				0°C	- 20°C
Experimental-industrial batch							
20 A, B State Standard 21937-76	170×170	481 – 525 / 504	334 – 363 / 344	29,0 – 33,0 / 31,5	satisfactory	37,3 – 63,8 / 46,1	33,5 – 49,0 / 41,2
22 A, B State Standard 21937-76	170×170	490 – 540 / 509	324 – 363 / 341	26,0 – 32,0 / 29,3	satisfactory	39,2 – 110,0 / 67,1	35,5 – 70,6 / 53,5
24 A, B	170×170	491	334	32,3	satisfactory	40,2 – 59,0 / 44,1	35,5 – 41,4 / 38,5
Experimental batch							
22A, 20A, 18A State Standard 21937-76 18 A, B, C, D EN 10067:1996	160×160	475 – 520 / 499	325 – 370 / 349	28,0 – 34,5 / 31,1	satisfactory	39,2 – 98,1 / 61,2	31,4 – 63,8 / 47,6
The requirements of the technical specifications							
		≥ 440 – 590	≥ 315	≥ 22,0		≥ 31,0	≥ 31,0

* - longitudinal specimens;
** - in numerator – minimum and maximum values, in denominator – average values;

Figure 3. The macrostructure of flat-bulb profiles № 22A made of continuously casted metal

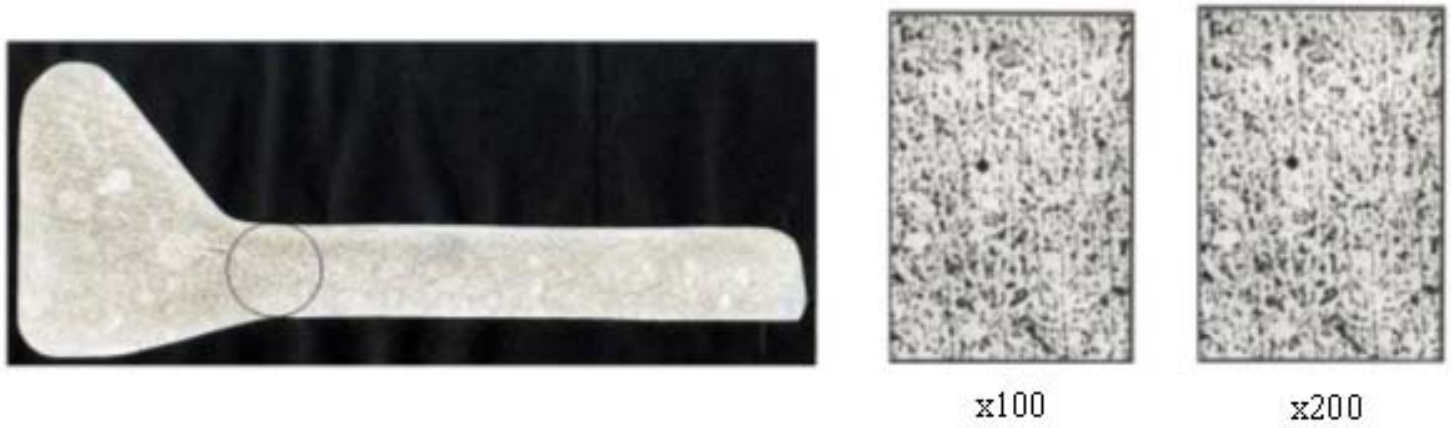


Figure 4. The streakiness of macro- and microstructure of flat-bulb profiles № 22A

The research results show that the degree of axial chemical inhomogeneity can serve as one of the basic criteria in quality estimation of flat-bulb profiles rolled from continuously casted billets. This particular defect reveals itself as micro- and macrostructure streakiness (Figure 4), and it is connected with sulfur, carbon and phosphorus segregation typical of the central zone of a continuously casted billet. Quality control of finished products of different sizes (12 sulfuric prints) has shown that in flat-bulb profiles this defect is present only on a definite area (see Figure 4). Its occurrence on the surface, on the head (and in adjacent area) was not observed. The zone of its concentration is the area located (0,65-0,70)b away from the shelf edge (b – is the width of a profile).

The research has shown that melting, heat finishing and continuous casting techniques applied by leading Ukrainian iron & steel companies can guarantee the production of steel billets with 0,08 – 0,16% carbon content (in particular, ship steel A32, State Standard 5521-93). In this case the practice of steel casting into large blooms (with section 335x400 mm) and their further rerolling can become the basic one.

Thus, a comprehensive quality and performance estimation of flat-bulb profiles shows that the obtained rolled steel products meet the highest requirements of leading classification societies. It is proved by the fact that the practice of steel melting and producing the billets for further rerolling (Dneprovskiy Iron & Steel Works) and the methods of flat-bulb profiles production (Kramatorsk Iron & Steel Works) were certified by classification societies GERMANISCHER LLOYD and DET NORSKE VERITAS A.S. (Norway) as classes A32 and D32.

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