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Scientific Statements and Technological Solutions in Effective Metal Goods Production and Application

I. G. Uzlov

Z. I. Nekrasov Iron & Steel Institute of National Academy of Sciences of Ukraine
1 Academician Starodubov Square, Dnipropetrovsk 49050, Ukraine

There are considered the issues of radical enhancement of metal products quality and high competitiveness in the home and foreign markets, which are the major priorities in development of iron & steel industry and metallurgical science.

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Introduction

Development of major branches of national economy (manufacturing engineering, building industry, railway, marine, pipeline transportation, etc.) is directly related to consumption of great volumes of metal products in the nearest future. Over 80 % of this consumption falls at carbonaceous and low-alloy structural steel rolled metal products.

Ukraine as a large metal product manufacturer has a very high index of metal consumption of the national income, which exceeds indexes of industrially developed countries in more than two times. So, specific metal consumption of railway rolling stock in Ukraine is higher by 50 % than the foreign one, agricultural machines – 30%, tractors – 20%, automobile transport - 30 %.

As a result, domestic equipment has fuel and energy rate per unit of useful operation in 1.3-1.7 times higher. In addition, life service of machines fabricated in Ukraine (and other CIS countries) is 4-10 times shorter than their analogues of foreign manufacture.

Considering this problem it is necessary to specify that machine industry and building are not ready for a wide application of high strength sheet products and rolled section. Today, about 80 % of rolled metal products is calculated on limiting stability of elements, which almost does not depend on the level of material properties.

Results and Discussion

The world experience of using metal products is featured by wide application of high-resistant steel in various branches of national economy. Our country (and other CIS countries) has experience of high-strength rolled steel application for hardware manufacture (**Table 1**).

Proceeding from all stated above, the issues of radical improvement of metal products quality and high competitive capacity in the home and foreign markets are the major priorities of development of iron & steel industry and metallurgical science.

Solution of this problem is determined primarily by essential increase of physic-mechanical properties and operational characteristics of steel roll (and first of all its strength properties) at iron & steel plants, and also new engineering solutions and advanced technologies of their application in building, machine industry, coal industry, transport and other branches, which will allow reducing specific amount of metal.

Three primary methods to enhance properties (including strength) of steel products are developed and used in the world practice:

1. Manufacture of metal products from alloyed steels;
2. Application of traditional processes of thermal hardening - quenching after furnace or

electric heating with subsequent tempering;

3. Thermomechanical hardening of steel roll with utilization of rolling heat and subsequent self-tempering after discontinued cooling.

Evaluating the efficiency of mentioned steel hardening methods it is necessary to consider also their specific consumption of materials. As applied to situation in iron & steel industry of Ukraine, these statements are of great importance as we have no sufficient resources of such alloying elements as Cr, Ni, V, Mo, Nb, widely used for high-resistance steelmaking.

In 1960, Z. I. Nekrasov Iron & Steel Institute of National Academy of Sciences of Ukraine started scientific investigations related to creation of nonconventional energy-saving processes of hardening carbonaceous and low-alloy structural steel rolled metal products with the use of rolling heat. It was determined that there was a uniform distribution of elements across the austenite grain, decrease of detrimental impurities amount in border zones, favorable sub- and dislocation structure was formed as a result of deformation processing during thermal-mechanical treatment of steel. Austenite grain was refined as a result of dynamic and partially static recrystallization. The subsequent steel cooling at high rates led to formation of fine grains and high-dispersed products of austenite decomposition. Such structural condition ensures increase of strength values, fatigue characteristics, viscous properties (including at low temperatures) and crack resistance of carbonaceous and low-alloy steels in 1.5-2.0 times.

Creation of thermal-mechanical treatment of shape steel-rolled stock under discontinued quenching technology with subsequent self-tempering, which allowed providing a high complex of rolled metal products properties, was basically new and highly effective solution (**Table 2**).

It is especially necessary to notice high impact strength even at negative temperatures. Impact strength values of steel Ст3 and 09Г2 at minus 70 °C and after hardness aging correspond to impact strength of steel in the improved condition and considerably exceed requirements of State Sdandard 19881-73 on low-alloy steels.

Table 1. Examples of effective application of heat-treated rolled products instead of hot-rolled

Item name	Properties of heat-treated rolled products, σ_{YS}, N/mm^2	Application efficiency
Arm of crane with load-carrying capacity 6.3 t fabricated by Balashikhinsk Plant	600	Metal economy 30 % (340 instead of 480 kg)
Side members and car frame of MAZ	650	Cyclical strength increase in 3-4 times, mass reduction by 12 %
Excavator bucket	600	Metal economy 40 %
Supporting piers	390	Metal economy 18-20 %
Roof of one-story industrial building	390	Load-carrying capability increase by15 %. Operation at -65 °C

Table 2. Mechanical properties of steel Ст3 (analogue A 105 Gr1, ASTM) and 09Г2 (analogue 7Mn6, DIN) after thermal-mechanical hardening

Steel grade	Rupture strength, N/mm^2	Yield stress, N/mm^2	Elongation, δ_5, %	Impact strength KCU^{-70}, J/cm^2
Ст3	500-640	400-570	25-20	80-225
09Г2	560-810	450-690	28-16	115-240

System study of thermomechanically hardened rolled metal of strength index 46/33 reveals its high reliability and cold resistance. So, critical temperature of brittle fracture is minus 50 °C, which is 30-45 °C lower as compared to hot-rolled steel. Proceeding from high cost and deficiency of alloying elements (especially for Ukraine) it is necessary to reconsider the use of hot-rolled alloyed steel grades in such branches as machine industry, building, transport, ore mining industry. As experience shows, application of alloying elements for rolled products manufacture is technically and economically justified only in case of using this material in thermally hardened condition. Only in this case potential possibilities of alloying elements are used in full extent-strength properties raise by 30-40 %, the brittle fracture temperature is essentially reduced. Data presented in **Table 3** confirm this (State Standard 19281-89).

Table 3. Properties of steel rolled products in hot-rolled (HR) and thermostrengthened (TS) conditions

Steel grade	Condition	Additional treatment	Strength index	Mechanical properties			
				σ_{YS}, N/mm^2	σ_{TS}, N/mm^2	δ_5, %	KCU, J/cm^2 (-40 °C)
10Г2С1 (analogue 10MnSi74KE, EN)	HR		295	295	430	21	29
14Г2 (analogue A 515 Gr70, ASTM)	HR	—	325	325	450	21	39
17Г1С1 (analogue 1.0570, St52-3, DIN)	HR	—	325	325	450	21	39
10Г2С1 (analogue 10MnSi74KE, EN)	HR	TS	390	390	510	19	44
14Г2 (analogue A 515 Gr70, ASTM)	HR	TS	390	390	510	19	44
17Г1С1 (analogue 1.0570, DIN)	HR	TS	375	375	510	20	39

It is necessary to correct temperature-deformation conditions of rolling when working out metal roll thermal strengthening. Equipping of iron & steel plants with modern rolling mills leads to decrease of steel properties due to significant temperature increase in the end of rolling. Comparison of properties of steel Ст3 I-beams and channel beams No. 16-18 rolled on low-speed mill 650 of integrated works "Azovstal" and continuous (high-speed) mill 450 of Western-Siberian Iron & Steel Works reveals decrease of yield stress from 350 to 270 N/mm^2 and time rupture strength from 450 to 400 N/mm^2 at simultaneous decrease of viscous characteristics of rolled metal fabricated at high-speed rolling. This was a consequence of rise in temperature in the end of rolling by 280 °C on a continuous mill (1080 °C against 800 °C on a linear mill). Deformation processing of reinforcing steel at low temperatures was tested at integrated works "Krivorizhstal". It was shown that decrease of finishing temperature from 1100 to 850 °C ensured strength improvement by 100-150 N/mm^2, growth of ductility indexes on average by 20 %, fatigue life increased in1.5 times.

Results of investigations carried out by Iron & Steel Institute and Institute of Electric Welding named after E. O. Paton of National Academy of Sciences of Ukraine showed that thermomechanical hardening of ordinary carbonaceous and low-alloy steel grades satisfied specification of International standards on impact strength level at positive and negative temperatures on samples with sharp notch. It was determined that there was no significant steel softening during welding. Thus, thermomechanically hardened carbonaceous and low-alloyed steels are competitive regarding both strength and viscous properties (including cold resistance) of base

metal and welded joints. It allows certifying a considerable part of metal rolled products in full accordance with specifications of International and National foreign standards.

Advanced processes of railway wheels thermal hardening and their deformation processing developed by Iron & Steel Institute allowed building new wheel rolling shops at Nizhnedneprovsk Tube Rolling Plant and Vyksa Steel Works. Now these plants supply products to railways of CIS and Baltic countries, and also export to many countries of the world.

Iron & Steel Institute cooperates with Ukrzaliznitsya and Nizhnedneprovsk Tube Rolling Plant in the area of creation of new wheels as applied to new conditions of their operation (increase of axle loading to 25-30 tons and rain running speed freight train to 120 km/h). The new microalloyed wheel steel and effective processes of thermal hardening ensured hardness level above 320 HB and wear resistance growth over 40 %.

Cast irons with globular graphite hardened by isothermal hardening method (austempering) compete with traditional alloyed steels due to their lower cost, satisfactory conformity of their mechanical characteristics at obvious advantage of wear resistance. Economic advantages of such solution were confirmed by the world practice.

According to “General Motors” data, manufacture of traditional articles from cast irons with bainite matrix shows power economy by 50 %. According to corporation "Fiat", durability of processing tool raises by 100-900 %.

Iron & Steel Institute is creating high-strength sheet, rolled section and shape steel-rolled stock using steels microalloyed by nonconventional ferroalloys and rich alloys (for example, nitrogenous addition alloy developed by Prof. A.V. Rabinovich in National Metallurgical Academy of Ukraine). As a result, high complex of strength and viscous characteristics was obtained in heat hardened condition (**Table 4**).

Table 4. Properties of car-building steels

Steel grades	σ_{YS}, N/mm^2	δ_5, %	KCU, J/cm^2			
			+20 °C	-20 °C	-40 °C	-70 °C
09Г2Д (analogue 7Mn6, DIN)	295	21.0	98.0	-	29.0	-
10ХСНД (analogue 10ChSND, BDS 9801)	390	18.0	-	-	34.0	29.0
New steel	550-600	21.0	-	-	-	75.0-85.0

Conclusions

So, as experience of Iron & Steel Institute has shown, the only real way of further productive operation is creation of interbranch target scientific and technical programs with participation of specific plants except for scientific institutions interested in more effective products.

It is necessary to raise the role of Ministry of Industrial Policy of Ukraine as a representative of state interests, organizer and coordinator of major developments related to creation of new competitive metal products in Ukraine taking into account the features of our production capacities and raw materials.

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Научные положения и технологические решения производства и использования эффективной металлопродукции

Узлов И.Г.

Рассмотрены вопросы коренного повышения качества металлопродукции и обеспечения ей высокой конкурентной способности на внутреннем и внешнем рынке, которые являются важнейшими приоритетными направлениями развития черной металлургии и металлургической науки.