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REDUCTION OF METAL CONSUMPTION OF ROLLED PRODUCTS

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ABSTRACT

Weight significantly affects the strength of products and technological parameters of production. Section weight determines temperature mode, power parameters of rolling, conditions of thin-walled section formation. In our solution, the central zone was lightened by transverse stiffeners. This made it possible to reduce the weight of the product while ensuring reliable performance characteristics. Wheels made of sections rolled in Rolling Mill 550 conditions successfully passed road and strain gauge tests.

Keywords: rolled, metal, profile, stress state, metal saving.

INTRODUCTION

Special rolled products for the automotive and aeronautical industry differ from general and industrial products by the fact their design, for one reason or another, takes into account the peculiarities of plastic strain process. If the wheel rim profile comes as a finished product, the section obtained by die rolling is a workpiece for further processing. The trend in solving problems associated with obtaining special rolled products is the use of patterns of plastic forming during the formation of the product and vice versa, taking into account the influence of product design on the parameters of technological process, possibility of obtaining it with minimal costs and high quality.

Weight significantly affects the strength of products and technological parameters of production. Section weight determines temperature mode, power parameters of rolling, conditions of thin-walled section formation. At the same time the reduction of weight significantly worsens the technological capabilities of production.

One of the main directions of global production development is the reduction of metal consumption in the manufacturing process of rolled products, and in their operation [1 - 5]. At the present stage, such trends include:

- use of breakthrough solutions in metallurgy, such as continuous casting of steel, implementation of casting and rolling complexes;
- new materials, abandonment of mass use of carbon steel grades in the future;
- strive to create equal-strength structures, machines and units, allowing in low-loaded areas to reduce their metal intensity in particular, and the entire product in general;
- development of new technological processes that use the effects of plastic forming to change the stress-strain state of the metal, compensating for such negative phenomena as a decrease in the temperature of the end of rolling;
- widespread use of thermo-mechanical processing of rolled products in the manufacturing process, and much more.

In the conditions of market relations, when the useful priorities of past developments disappear, which are not recognized by the new owners of plants, we should pay special attention to the hidden reserves of additional profits which are not understood and not realized by domestic leaders of the new formation. We offer research and development materials related to such a global trend as resource conservation in the new conditions.

A special problem of rolling production is obtaining thin-walled (economical) products. Reducing the metal intensity of thin-walled beams is possible through a more rational distribution of metal across the section, which is an effective measure.

The problem of rational distribution of wheel weight is solved from the standpoint of optimal stress distribution, establishing a correspondence between internal loads and the amount of metal on individual sections of the rim and the wheel as a whole. It is known [6, 7] that the rim section is subjected to the simultaneous action of bending and stretching, the consequence of which is an extremely uneven distribution of transverse and longitudinal stresses across the width (Fig. 1).

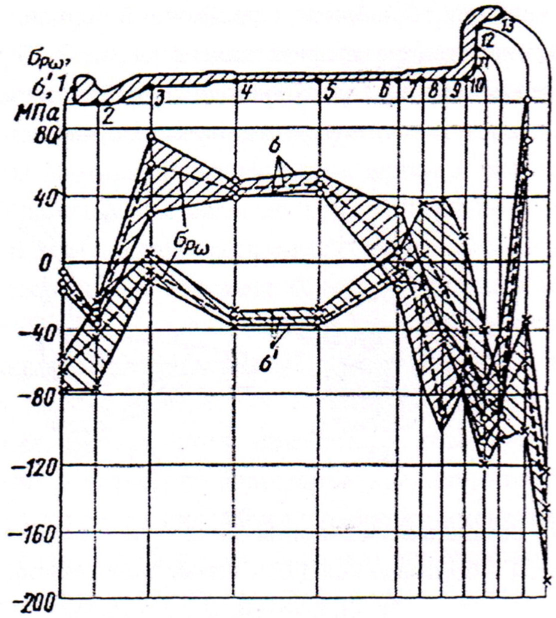

Fig. 1. Distribution of transverse and annular stresses.

A stress averaging in the separately taken along the width zones of the section is achieved by the size of cross-sections. This is not always possible due to the difficulty of accounting for factors that affect the wheel during operation. According to the authors [8], the main task of stress state analysis is to identify the cross sections that determine its strength and durability. In this case, the thickness is assigned to the maximum load which ensures the stable strength characteristics of the wheel. However, there is a sufficient strength margin for the individual elements due to the uneven distribution of stresses over the cross-section.

The experience of implementing rim profiles with reduced weight in production shows that bringing the weight of the product in line with the current load justifies itself [9]. There is excessive strength confirmed by the absence of rim overloads determined by strain gauge, road and operational tests in the central element where longitudinal and transverse stresses are small and have opposite signs [10]. No fractures were observed in this zone during repeated reduction of the thickness during operation. Consequently, the reduction of metal intensity of the profile should be carried out at the expense of the central zone.

Considering the technological factor of production, it was necessary to abandon the traditional method of reducing the metal intensity of the profile by reducing the thickness of individual elements. Weight reduction was achieved by forming indentations (“corrugations”) offset against each other on the sides of the opposite rim surfaces. This shape was dictated by the effect of kinematic action which ensured rolling of thin-walled and especially thin-walled profiles.

A number of works have been carried out to develop new wheel rims with reduced weight in the area of the web [9 - 14]. It should be noted that the vast majority of noted studies have been coordinated through the head institute for section rolling production UkrNIIMet and included in the target complex scientific and technical program “Metal” of Ukraine.

This direction was successfully developed and resulted in the development of new technical solutions related to the reduction of rim weight solely due to the central underloaded section of the profile.

EXPERIMENTAL

In our solution, the central zone was lightened by transverse stiffeners [15]. This made it possible to reduce the weight of the product while ensuring reliable performance characteristics. Wheels made of sections rolled in Mill 550 conditions successfully passed road and strain gauge tests.

It should be noted that such structures are technologically difficult, although the possibility of their production exists. To eliminate vibrations arising from unsteady rolling process of the central part, the edges are not made perpendicular to the rolling direction, but at an acute angle with appropriate overlap [16]. Possibilities of profile production in this case have improved noticeably. The profile was obtained within the specified thickness limits; no increase in rolling force, stand spring, different thickness, no decrease in strip temperature was noted. No temperature drop appears because thinned elements have hotter and thicker areas on both sides. In addition, according to [15, 16], the vibrations in strain zone which are present in the reduction zone, contribute to a decrease in the rolling force. However, the big problem here turned out to be the threading of the rolls.

Proposed technical solution suggests that the rim profile is made with a central wave-shaped part. At the same time, it is allowed to shift the sinusoids relative to each other in the range from -2π/3 to +2π/3, with the formation of some thickening "accumulators" of heat. There is a certain distance between the points that define the lowest notch position at the top and the highest protrusion position at the bottom which creates a layer of metal between the "sinusoids". This is necessary to prevent "unrolling" of the central part of the rim during straightening and curling in the wheel making process and to ensure reliable rim strength characteristics.

The first pilot rolling of the new hot-rolled profile design made it possible to obtain full-scale specimens, produce a batch of pilot wheels and conduct strain gauge tests of the rim under load [17].

RESULTS AND DISCUSSION

Fig. 2 shows the distribution of transverse ring stresses in the central zone, which has a periodic character corresponding to the location of notches and protrusions of the lower surface [18]. When elastic movements of the points of initial surface passing through the centers of protrusions and depressions, caused by curvature of the central part of the rim, convex to the wheel axis, the "wave" is rotated relative to the points of initial surface. In this case, the displacements determined by bending and stretching are algebraically summed up with the displacements caused by the rotation of depressions and notches, on the one hand increasing them, and on the other hand reducing them. Transverse movements are related to strains, and the latter are related to stresses according to Hooke's law. As the wheel rolls, the stresses in the rim change. This change occurs near the stress state defined by the static load. The forces on the wheel rim are maximum in the low position and minimum in the high position. It is important that the minimum stresses caused by the wave shape of the web do not go over zero during operation, i.e. do not change their sign which would lead to fatigue phenomena associated with the Bauschinger effect [19]. Further experience in the operation of wheels showed that there is no fatigue and other types of damage in this area. Technological and operational tests of new profiles allowed starting the development of drawings, coordination of normative and technical documentation, calculation of finishing versions of rolls calibration and real implementation into production.

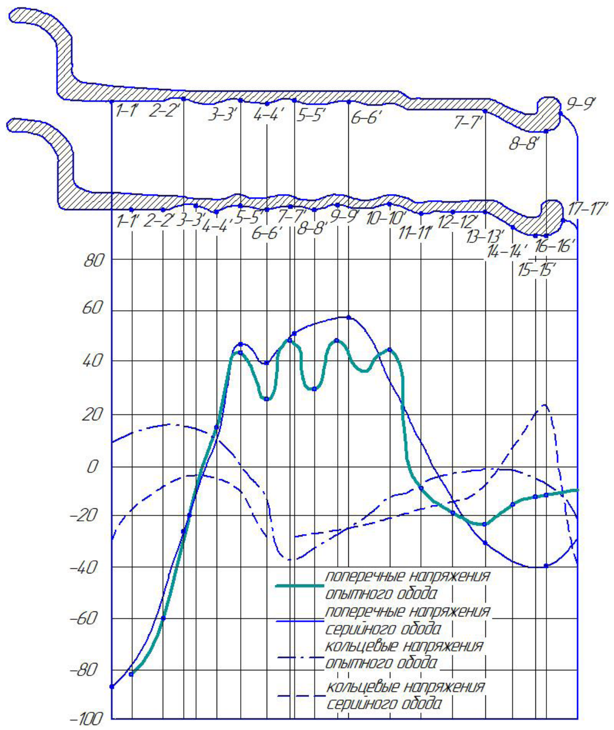

Fig. 2. Distribution of transverse and ring stresses in the central zone of rims of different design.

Special attention should be paid to the strength performance of metal products in the design of rolled sections, i.e. the creation of equal-strength profiles. This is achieved either by increasing the mechanical characteristics of the metal (chemical composition, heat treatment, etc.) or by reducing the magnitude of the working stresses due to the rational distribution of the metal over the profile cross section. In the first case, it is expensive; in the second, it is necessary to know the stress state of the metal during its operation. Fig. 2 shows the distribution of stresses when loading the wheel rim. It can be seen that it has an irregular character. In some areas it reaches the maximum value (corner areas), in others - the minimum (the central part). Experience shows that the weight of the product in accordance with the load justifies itself. In the central zone, longitudinal and transverse stresses are low, there is excessive strength which should be taken into account when reducing profile weight. However, rolling the thin-walled part of the profile causes deterioration of technological parameters, which negates positive effects associated with the reduction of rolled weight. In this regard, there is a need to change the stress state of the strip in the finishing passes during plastic forming. Experimental and theoretical studies conducted in works [20 - 21] have shown that this change is possible with a certain non-uniformity of strain of the thin-walled central part of the profile which causes longitudinal additional tensile stresses. Production process gets stabilized.

Since 1984, using the condition of equal strength and technological effects of production, the production of auto-rim profiles with a wave-shaped central part was started. By 1985, a series of four profiles with a wave-shaped central part was adopted, as shown in Table 1.

There is a result which corresponds to the general trend of production development associated with resource conservation.

It is of interest to know where and how the real technical and economic effect of product implementation with reduced metal intensity is formed. Let us consider this matter in more detail. The customer produces its products regulated by many indicators, including metal consumption. The cost of the finished product unit in mechanical engineering is 70 % - 90 % of the cost of metal. If the customer receives the rolled product with reduced metal intensity and not inferior strength characteristics, therefore, less metal is consumed per product unit. The reduction in the amount of metal represents the technical effect of implementation in the production of lightweight sections. For example, for hot-rolled sections 7.0-20-03, 7.5B-20-03, 8.0B-20-03, 8.5B-20-03 the production volume for the whole period of implementation was (Table 2).

After passing the tests at the customer's plants and a positive final result, a decision is made on the use of this rolled product in its processing. This demonstrates itself, first of all, in the reduction of the metal consumption rate per unit of product which is accepted for execution. The preliminary economic effect at their enterprises will be obtained taking into account the price of the plant product by the value of the reduction of metal consumption.

Table 1. Comparative data by profile.

No.	Profile name	Weight of running meter according to TU 14-2-92-73, kg	Weight of running meter according to TU 14-2-592-84, kg	Weight reduction, kg
1	7.0-20	11.8	11.4	0.4
2	7.5B-20	15.27	13.70	1.57
3	8.0B-20	14.80	14.45	0.35
4	8.5B-20	16.42	16.10	0.32

Table 2. Production volume.

Production volume of lightweight profiles in 1984-1993 tons	7.0-20-03	7.5B-20-03	8.0B-20-03	8.5B-20-03
	374766	18304	20585	206782

Calculation of metal savings per ton of rolled products is determined by the formula:

$$S_{MT} = \left(\frac{1000}{M_n} - \frac{1000}{M_s}\right) M_n,$$

where 1000 - kg in one ton of rolled products; $1000/M_n$ - length in meters of one ton of new profile; $1000/M_s$ - length in meters of one ton of serial profile; M_n - metal consumption per running meter of new profile; M_s - metal consumption of one running meter of serial profile.

Metal savings for the entire production volume [23, 24] is:

$S_M = S_{M\tau} \, . \, V,$

where V - production volume.

Metal savings per ton and total metal savings per profile are shown in Table 3.

Total metal savings or technical effect of lightweight profiles implementation was 19166 tons. It should be added that the technical effect was calculated at the consumer and not at the manufacturer who incurs certain losses due to the complication of production.

Income from the use of implementation object was calculated by the formula, in 1992 prices:

$I = (I_p - C_M) \, . \, F_n - F_n . \, F_q + F_q . V =$ 2 980 298 RUB,

where I_p - product sales income; C_M - product cost; F_n - novelty factor; F_q - quality factor.

The second batch of “rolling wave” type profiles, subsequently completely replaced the profile with a wave-shaped central part. The comparative data are shown in Table 4.

The total economic effect, in 1991 prices, was 1,213,500 RUB.

Compensation to the product manufacturer was made by adjusting the price to account for the loss of production in the manufacture of profiles of reduced metal-intensity.

Implementation of metal-intensive products also has an impact on the environment. Since currently in cities the contribution of transport to the total amount of atmospheric emissions is up to 90 % [24]. A review of foreign research and patent literature has shown that pollutants in the form of suspended matter of varying dispersion have recently become most important. Such suspended matter enters the atmosphere due to the operation of transportation infrastructure. They are formed by operational wear and tear of car tires tread, brake pads of wheel brakes, abrasion of the roadway, etc. Due to their microscopic size, such particles easily penetrate the lungs of a person, accumulate there. Consequently, it leads to the development of various respiratory, oncological and cardiovascular diseases [25]. Also these particles are deposited on the roadside, so according to [26], the roadside soil contains about 2 % of rubber particles.

Table 3. Metal savings.

Metal savings rates	7.0-20-93	7.5B-20-93	8.0B-20-93	8.5B-20-93
Savings per ton, kg	34.2	102.8	23.1	19.3
Total savings, tons	12817	1882	476	3991

Table 4. Comparative data by profile.

No.	Profile name	Weight per running meter before implementation, kg	Weight of running meter according to TU 14-2-592-84, kg	Weight reduction, kg
1	7.0-20	11.4	11.2	0.20
2	7.5B-20	13.70	13.20	0.50
3	8.0B-20	14.45	14.20	0.25
4	8.5B-20	16.10	15.80	0.30

CONCLUSIONS

Weight significantly affects the strength of products and technological parameters of production. Section weight determines temperature mode, power parameters of rolling, conditions of thin-walled section formation. Fuel consumption is also reduced due to lower metal consumption, resulting in lower emissions of harmful exhaust gases into the atmosphere and resulting in lower emissions of harmful rubber dust. The greater the weight of the wheel, the more fuel it takes to spin the wheel during acceleration. After all, more weight requires more moment of inertia because the engine needs more force to produce angular acceleration of the wheel, and that increases fuel consumption. Considering how much fuel is consumed in stop-and-go conditions, we are confident that a large portion of the fuel can be saved by reducing the wheel metal content.

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