QUALIMETRIC PRINCIPLES OF ASSESSMENT OF REINFORCED STEEL

КВАЛИМЕТРИЧЕСКИЕ ПРИНЦИПЫ ОЦЕНКИ АРМАТУРНОГО ПРОКАТА

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Abstract:*The paper considers the issues of qualimetric assessment of quality of reinforced steel. The dependences of the rate group of the mechanical properties from room profile. Built a regression equation characterizing the effects of deformation processing on the quality of rebar.*
KEY WORDS: QUALIMETRIC ESTIMATION, REINFORCED STEEL, QUALITY INDICATORS, REGRESSION EQUATION.

Introduction

The company JSC "ArcelorMittal Temirtau" is constantly working on improvement of the existing technologies, the development and implementation of new technologies aimed at expanding the range of shape rolling mill and improved the quality of steel products. To improve the quality of reinforced steel, analysis of geometry, reducing the number of defects arises the proposed activities of authors [1-4].

Compliance quality calibrated with the requirements of state standards for delivery, and assessment of the stability characteristics of the control material can be confirmed using the principles of quantitative assessment of product quality (principles of qualimetry) [5].

Qualimetry – a scientific field that combines quantitative methods of assessing the quality of various objects [6]. Qualimetric assessment of the quality allows you to comprehensively assess the quality of the product a single numeric indicator at the same time on all its properties.

Thus, the aim of this work is qualitative quality assessment integrated assessment of the quality of long products depending on different modes of deformation processing.

The objective is achieved by solving the following problems:

1) rationale for the range of indicators characterizing the quality of products and services;

2) choice of a technique of definition of indicators of quality of objects;

3) compilation of quality indicators;

2) build of quality equations and its analysis [7].

Methodology of study

Summing up the requirements at the present time the quality of shape metal, on the basis of qualimetry methods to construct a hierarchical set of properties [6], using, for example, tabular form, wood properties (table 1) recommended [7].

Table 1 – *Hierarchical set of properties of reinforcing bars*

i=0	i=1	i=2	i=3	i=4
Quality of the calibrated metal	Quality of metal	Chemical analysis	Content of chemical elements on the ladle analysis	C, %
				Mn, %
				Si, %
		Mechanical properties	Stretching	σ_T, MPa
				σ_B, MPa
				δ, %

The main method of assessing the level of quality used in this work is differential. According to the author [6], the most appropriate differential assessment of the quality of steel products will be the probability of satisfying the requirements of the standard.

According to accepted designations in the work, differential assessment of the quality of the shape rolled metal the equal probability in the interval by the formula for upper bounds:

$$k_{ij} = P\ (r_{ij}^{min} \le r_{ij} \le r_{ij}^{max}) = F(r_{ij}^{max}) - F(r_{ij}^{min}), \quad (1)$$

where $F(r_{ij}^{max})$ and $F(r_{ij}^{min})$ –values of the distribution of cumulative function in the points (r_{ij}^{max}) and (r_{ij}^{min}).

For the case of normal distribution, this dependence takes the form:

$$k = \Phi\left(\frac{r^{max} - \bar{r}}{S}\right) - \Phi\left(\frac{r^{min} - \bar{r}}{S}\right), \quad (2)$$

where Φ – Laplace function.

In accordance with the principles of qualimetry for each level of properties the weighting factors are assigned. First defined group coefficients, then, based on them, the weighting factors for each particular property [7]:

$$\sum \alpha_i' = \alpha_{GR}', \quad (3)$$

where α_i' –weighting factor within the group of properties;
α_{iGR}' – group (tier) weighting factor.

On each tier must comply with the condition:

$$\sum \alpha_i = 1, \quad (4)$$

where α_i – weighting factor $0 \le \alpha_i < 1$.

Then we define a method of consolidating the assessments of individual properties to obtain a comprehensive measure of quality K_0:

$$K_0 = \sum_1^n \alpha_i k_i, \quad (5)$$

where k_i – differential quality index; n - the number of quality indicators ($1 \le j \le n$).

It is theoretically possible that the low differential score on one indicator overlaps high, according to another indicator, i.e., a comprehensive assessment will be quite high, and the measured values r_{ij} will outside of $\left[r_{ij}^{min}; r_{ij}^{max}\right]$. To prevent such situations in qualimetry apply the condition for the vanishing of a comprehensive assessment under certain conditions. This technique is called the "coefficient of veto". The coefficient of veto W is used as a cofactor and has only two values: either 1 or 0.

In case of double-sided border:

$$W_i = \begin{cases} 1, if\ r_{ij}^{min} \le r\ and\ r \le r_{ij}^{max}; \\ 0, if\ r_{ij}^{min} > r\ or\ r > r_{ij}^{max}; \end{cases}$$

$$W_i = \begin{cases} 1, if\ r_{ij}^{min} \le r; \\ 0, if\ r_{ij}^{min} > r. \end{cases}$$

Condition treatment K_0 to zero it is necessary to check for each single quality indicator.

Thus, in the period from January to March 2013 to assess the quality of rebar rebars 10 mm; 12 mm; 14 mm; 16 mm; 18 mm; 20 mm; 22mm; 25mm; 32mm used the technique of the authors [7,8].

As indicators of the quality of rebar, used chemical composition of the steel according to the content of essential elements in % – carbon (C) manganese (Mn), silicon (Si) and mechanical properties of rebar – yield strength (σ_T, MPa), tensile strength (σ_B, MPa), relative elongation (δ, %).

For each quality indicator a complete statistical analysis of sample data [9]. Integrated assessment of the quality of rebars used data from acceptance tests after rolling them on a continuous 16-stand medium section mill in terms of JSC "ArcelorMittal Temirtau" in the study period. The material is all covered in the sample profiles - steel grade 5sp.

In accordance with the adopted methodology, the weighting factors are evenly distributed on the generated table 1 tree of properties in accordance with condition [7].

According to the single properties of the samples calculated differential quality indicators on the example of profile №14: k_C =0,7930; k_{Mn} = 0,9999; k_C = 0,8981; $k_{\sigma T}$ = 0,9019; $k_{\sigma B}$ = 0,7821; k_δ = 0,9188.

Results and discussion

In Fig. 1 shows the calculated integrated values of indicators on the quality of the chemical properties and the quality of mechanical properties of different numbers of profiles. From Fig.1 shows that a more stable quality have average profile numbers № 16÷№ 18. Lowest quality in the profile № 12, equal to 0,81. The other numbers are the profiles show a very good level of quality is approximately 0.90.

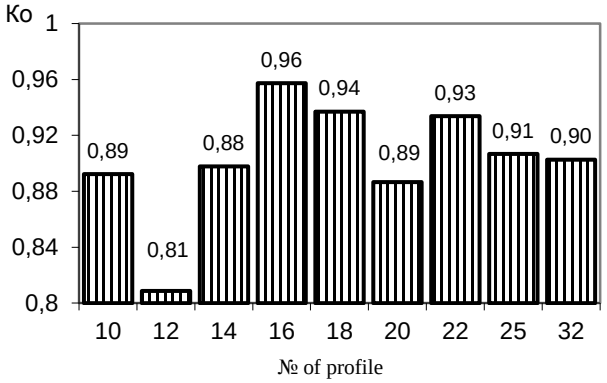

***Fig. 1** – Integrated indicators of quality of different profiles of calibrated rolled metal*

Comprehensive assessment of the quality of rebar № 16 showed a good level – 0,96 that, given the existing lack of influence of the content in the sample of the chemical elements, says about a certain factor, having an influence on the magnitude of the mechanical characteristics of the profile [10]. Likely is a particular mode of deformation processing of this profile that, when well-functioning of the mill provides a stable level of quality, at a somewhat higher ductility and a lower deformation resistance, compared with the adjacent profiles.

To study the effects of deformation processing on the quality profile used data on the quality of mechanical properties, because the quality of the chemical composition is laid in steel melting and deformation modes of processing cannot influence.

Quality indicators of the mechanical properties of various calibrated rolled metal profiles are shown in Fig. 2.

To predict the mechanical properties, in accordance with the recommendations of [10], on the same data the authors calculated the effect on the quality indicator of the mechanical properties of the number of rebar H. Obtained regression equation:

$$K_{мех} = 0{,}7573 + 0{,}0463H - 0{,}0036H^2; \quad R^2 = 0{,}24. \qquad (6)$$

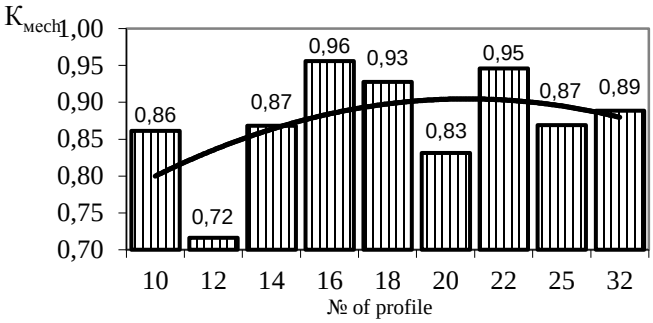

***Fig. 2** – Quality indicators of mechanical properties of different profiles of calibrated rolled metal*

The obtained equation is shown in Fig. 2 as line. From the regression equation follows the weak impact of profile number on the quality of mechanical properties. The histogram shows significant fluctuations in the level of quality of mechanical properties, the value of 0.72 in profile № 12 to the maximum value, equal to 0.96, corresponding to the profile number 16.

Moreover, the fluctuations in the values of quality repeat those have integrated quality indicator *Ko*, indicating the likely influence of deformation processing or other unaccounted factors on the values of the integrated indicator of quality.

To determine the effect of the quality of the chemical properties of the constructed histogram group of quality indicators of the chemical composition of different numbers of profiles (Fig. 3).

The histogram is also showing typical variations in the quality of the chemical properties, but to a much smaller range of 0.90÷0,96, compared with the variation in mechanical properties (0,72÷0,96), which also confirms the relationship of the influence of chemical composition on the mechanical properties.

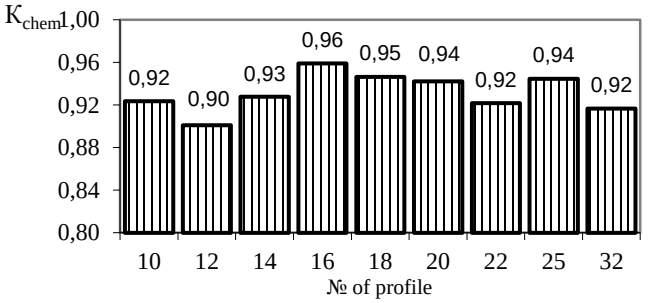

***Fig. 3** – Quality indicators of chemical properties of different numbers of profiles of calibrated rolled metal*

Graphical interpretation of dependence of $K_{мех}$ and K_{chem} is shown at Fig. 4.

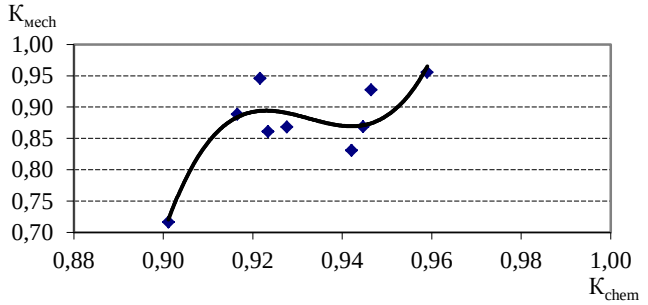

***Fig. 4** –Dependence of the quality indicators of the mechanical properties from the values of chemical properties*

The dependence was approximated by a polynomial of the third degree:

$$K_{мех} = -7251{,}2\ K_{chem}^{\ 3} - 20285K_{chem}^{\ 2} + 18914\ K_{chem} - 5876{,}9. \qquad (7)$$

The equation obtained is shown in Fig. 4 as line. The coefficient

of determination equal to R^2 = 0.79, which indicates a good addiction. It also shows the influence on the mechanical properties, in addition to chemical composition, and also modes of deformation processing, which is in good agreement with the theory and technology of rolling.

Removing from the calculation dramatically highlights the statistical processing of the values along profile № 12, we show the updated dependence in Fig. 5.

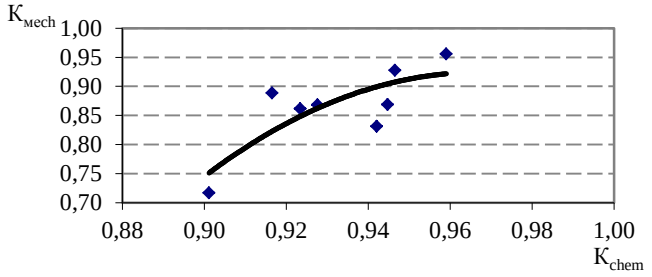

Fig. 5 – Updated dependence of the quality indicators of the mechanical properties from the values of chemical properties

The dependence was approximated by a polynomial of the second degree:

$$K_{мех} = -39{,}891\ K_{chem}^{\ 2} + 77{,}149\ K_{chem} - 36{,}378;\ R^2 = 0{,}64. \quad (8)$$

The equation obtained is shown in Fig. 5 as line. From the regression equation is shown a significant effect of the indicator of the chemical composition on the indicator of mechanical properties. Increasing the level of communication allows us to speak about the influence of deformation processing on the quality of the deleted profile № 12.

Conclusions

1) Defined the purpose and objectives of the qualitative evaluation of the quality of rebar, described the technique of study.
2) As indicators were selected: chemical composition of the steel in % – carbon (C) manganese (Mn), silicon (Si); mechanical properties – yield strength (σ_T, MPa), tensile strength (σ_B, MPa), relative elongation (δ, %).
3) Calculated differential (single), group and integrated indicators of quality. The overall quality appeared to be good within 0,81-0,96. Stable quality have profile numbers № 16 – № 18. Low quality profile № 12 is 0.81. The other profiles show a very good level of quality - 0,9÷0,94.
4) The dependences of the rate group of the mechanical properties from room profile. It is revealed that each profile number corresponds to the mode of deformation processing. The lower the profile, the greater the degree of deformation. The communication layer is insignificant (R^2 = 0,24).
5) In the dependences of $K_{мех}$ from K_{chem}, revealed a high level of quality influence of chemical composition on the mechanical properties for all profiles № 10÷32 (R^2 = 0,79).
6) To study the effects of deformation processing on the quality of the constructed regression equation with the exception of calculation data profile № 12. The level of R^2 = 0,64 describes the influence of deformation processing on the quality of calibrated rolled metal.

References

1) Krivtsova O.N., Panin E.A., Kuz'minova N.Y., Nasonov A.I. Ocenka kachestva armaturnoj stali SPC AO «AMT».// Sovremennaja metallurgija nachala novogo tysjacheletija. K 80-letiju NLMK: sb.nauch.tr.mezhdunar.nauch.-prakt.konf.17-21nojabrja 2014g.Ch.2-Lipeck:Izd-vo Lipeck. gos. tehn. univ., 2014. p.26-33.
2) O. Krivtsova, A.Root, G.Sivyakova, N. Kuzminova, E. Panin. Rational form of pre-calibres at rolling of reinforcing steel / Archives of materials science and engineering.Vols.66. March 2014. pp 39-44.
3) Krivtsova O.N., Panin E.A., Kuz'minova N.Y., Gizer V.A. Prokatka armaturnoj stali perehodnogo profilja v razlichnyh formah predchistovyh kalibrov./ Nauch. zhurn. «Vestnik KGIU», №4, 2014g. p.27-33.
4) Naizabekov A.B., Krivtsova O.N., Panin E.A., Kuz'minova N.Y., Nasonov I.A., Nasonov A.I. Opredelenie racional'noj formy predchistovyh kalibrov pri prokatke armaturnoj stali perehodnogo profilja. M.: «Proizvodstvo prokata», №1, 2015g. p. 18-21.
5) Statisticheskie modeli zavisimostej mehanicheskih harakteristik armaturnogo prokata. O.N. Krivtsova, I.I. Kuz'minov, E. Shirokova, F.A. Jabs / Nauchnyj zhurnal «Vestnik KGIU», – №1. – 2015. – p.14-18.
6) Kirillov V.I. Kvalimetrija i sistemnyj analiz: Ucheb. posobie. – Mn.: Novoe znanie; M.: Infra-M, 2011. – 440 p.
7) Zhadan V.T., Manevich V.A. Sovershenstvovanie tehnologii prokatki na osnove kompleksnyh kriteriev kachestva. – M.: Metallurgija, 1989. – 96 p.
8) Andrianov Ju.M., Subeto A.I. Kvalimetrija v priborostorenii i mashinostroenii. – L. Mashinostroenie. Leningr.otdelenie, 1990. – 216 p.
9) L'vovskij E.N. Statisticheskie metody postroenija jempiricheskih formul. – M.: Vysshaja shkola, 1988. – 239 p.
10) Ponomarev A.A., Shilov V.A. Matematicheskaja model' mehanicheskih svojstv prokata melkosortno-provolochnogo stana 150 / Proizvodstvo prokata. – №11. – 2012. – p.12-22.