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NATURE OF THE BRITTLENESS OF METALS

The brittleness of material is considered as a specific manifestation of mechanical behaviour under load, which appears in the instability of the strength characteristic value under conditions of non-uniformity of the stress–strain state (SSS). For the naturally ductile metals, such a mechanical behaviour is possible under conditions of non-uniform SSS under the action of stress raisers (SR), cracks, *etc*. The existent ductility of material counteracts the strength instability ($\sigma_{0.2}$ is yield strength), but as a specific indicator, namely, the deformation resistance (break resistance) B_r, which comprehensively reflects the degree of ductility and strain hardening of the metal within the SR zone. The critical value B_{rc} corresponds to the strength $\sigma_{0.2C}$, at which the strength stability switches over a state of instability at temperature T_C, where the fracture of specimen with SR occurs at a nominal stress σ_{NF}, is less than $\sigma_{0.2C}$: $\sigma_{NF} \leq \sigma_{0.2C}$. We analyse the experimental findings of different authors for samples with SR (cracks), which enable to estimate the critical values of $\sigma_{0.2C}$ and B_{rc} depending on the existent level of B_r in steels. A regular permanent dependence of B_{rc} on B_r for different types of SR is revealed, that allows predetermining the predisposition of the investigated steel to the strength instability under the action of SR according to the known values of standard mechanical characteristics of stretched samples $\sigma_{0.2}$ and S_K (true failure stress in the specimen neck). The concept of the metals' brittleness, as a manifestation of the strength instability under the conditions of SR, may become a foundation for the development of innovative methodology for engineering calculation of force reliability of products containing SR or known cracks. This is possible through determining the maximum allowable critical characteristic of the strength in alloy, $\sigma_{0.2C}$, that guarantees a non-occurrence of brittle fracture for a product with this type of SR, if $\sigma_{NF} \leq \sigma_{0.2}$.

Keywords: strength, strength instability, brittleness, embrittlement of steel, stress raiser, break resistance, ductility.

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1. Introduction: Problem Statement

Metal and metal alloys as structural materials are characterised by their natural ability to plastic deformation when stressed above the yield point $\sigma_{0.2}$. However, it is known that this ability depends significantly on the strength level. High ductility is inherent to pure low-strength metals (gold, silver, copper, *etc.*); however, it is lower for their stronger alloys. Then, it gradually decreases when moving to strong (iron, nickel, molybdenum) and refractory (chromium, tungsten) metals and, especially, for alloys based on these metals, which are stronger than pure metals. Therefore, the reduction of ductility or embrittlement of metals is unambiguously related to their strength. In particular, this is the cause of embrittlement of high-strength tempered steels, cold brittleness of steel products at low temperatures, and the embrittlement effect of cracks and other stress raisers (SRs), which are the reason for increase in the yield strength $\sigma_{0.2}$ due to the hydrostatic component of tension in the regions of triaxial stress–strain state (SSS) [1–5].

It is obvious that there is a fundamental relationship between the properties of strength, $\sigma_{0.2}$, and plasticity, ψ_K (ψ_K is reduction in area when breaking), of metals, the nature of which needs to be clarified in terms of certain quantitative ratios (initially, empirical, but unambiguous) within the possibilities of modern materials science. According to the authors, the fact that this has not happened yet indicates that the characteristic of plasticity ψ_K (or the uniform elongation of specimen, δ_p) is unsuitable for such an analysis. It does not fully characterise the deformation process in metal within the range of stresses above $\sigma_{0.2}$ before the neck breaking, S_K, because it does not take into account the effect of strain hardening of metal. Let us denote KCV is work of fracture at impact of specimen with a notch; K_{Ic} is fracture toughness of specimen with a crack [6, 7]. Attempts to replace ψ_K or δ_p with fracture toughness characteristics KCV or K_{Ic} can give even less reason for success, because they do not characterize the property of metal itself, but mean *certain* parameters of metals' behaviour in specimens of *certain* type under *certain* conditions of fracture.

For research within the framework of the task, it is necessary to use a characteristic of metal itself that is different from the existing ones: ψ_K or δ_p. It must characterize adequately the deformation process in metal within the stress values of $\sigma_{0.2}$ and S_K. Authors believe that the break resistance (or deformation resistance) index B_r, earlier proposed in Refs. [8, 9] and successfully used in Refs. [10–12] to study the effect of embrittlement of steels by SR, can serve as such characteristic:

$$B_r = \frac{S_K}{\sigma_{0.2}}. \quad (1)$$

The break resistance index B_r is more informative than ψ_K, as it accounts for not only the value of ductility, but also the effect of strain hardening of metal. Moreover, characteristic B_r represents ductility in a form comparable to strength $\sigma_{0.2}$, albeit in dimensionless form. This enables to consider the strength itself in a more general way than is accepted in the conventional approach, namely, the full strength of metal, S_K, is the sum of two components, namely, the basic strength, $\sigma_{0.2}$ (purely elastic part), and the plastic margin of strength, $\Delta\sigma$:

$$\Delta\sigma = S_K - \sigma_{0.2} = \sigma_{0.2}(B_r - 1), \tag{2}$$

i.e.,

$$S_K = \sigma_{0.2} + \Delta\sigma = \sigma_{0.2} B_r . \tag{3}$$

Application of the concept of ‘strength margin’ and its characteristic, namely, the break resistance index B_r, opens up the possibility to analyse in details physical nature of metal brittleness, which is the aim of this work.

2. Instability of Strength as the Main Sign of Material Brittleness

From a physical point of view, embrittlement of a metal means a decrease in strength margin ($\Delta\sigma$, B_r); therefore, complete brittleness occurs in the complete absence of this important component of metal strength, *i.e.*, $\Delta\sigma = 0$ or $B_r = 1$. Then, according to Eq. (3), $S_K = \sigma_{0.2}$; therefore, brittleness means that the full strength of material consists entirely of only the basic, *i.e.*, elastic part of the strength. This is correct for naturally brittle materials such as glass, granite, minerals, *etc.* As for metals, formally, brittleness means a condition where $B_r = 1$, and, according to (3):

$$S_K = \sigma_{0.2} . \tag{4}$$

However, this is conditional brittleness, since the value of $\sigma_{0.2}$ itself, which is measured at the residual strain of specimen, $e = 0.002$ (0.2%), is conditional one. Therefore, from a physical point of view, brittleness of metals is quite appropriately interpreted as ‘quasi-brittleness’ [13] because of the term, which does not have a specific quantitative measure.

However, technical manifestation of the state of metal brittleness ($\Delta\sigma = 0$, $B_r = 1$) fully corresponds to the mechanical behaviour of naturally brittle materials, in which lack of a plastic margin of strength is manifested itself in such mechanical phenomenon as a high sensitivity of their strength to the smallest non-uniformity of SSS (bending, skewing, presence of SR, *etc.*). This makes unstable the behaviour itself of the strength characteristic of a brittle material. It can be called *strength instability* of a brittle material, in contrast to the characteristic $\sigma_{0.2}$ for a metal, which has a certain strength margin ($\Delta\sigma$, B_r) and, therefore, exhibits ductility (ψ_K). However, the strength margin of metal may not be large enough to compensate fully for the non-uniformity of SSS due to the action of a certain SR, and in this case, manifestations of strength instability are possible even for an insufficiently ductile metal.

Thus, although brittleness, as a physical state, is fundamentally impossible for metals, but the main mechanical feature of brittleness, namely, instability of strength is quite possible for insufficiently ductile metals. The main problem in this case is to determine the level of sufficient plasticity. As shown above, traditional characteristics of plasticity (ψ_K, δ_p) are unsuitable for solving this problem. The possibilities of using a more general characteristic, namely, the break resistance index B_r, will be demonstrated below.

3. Instability of Strength in Metals

Currently, there is a considerable progress on the use of the break resistance index B_r in studies of the conditions of steel embrittlement under the influence of SR [8–12, 14].

The trend of decreasing ductility with increasing strength of steels is well known, but the embrittlement rate significantly depends on the way of $\sigma_{0.2}$ increasing. In work [8], two methods of hardening steels were compared: (i) low-temperature cooling; (ii) changing the structure and composition of alloys. As found, in each method of strengthening, there is a threshold of the rational strength level, $\sigma_{0.2}$, which corresponds to the largest bearing capacity of specimen, σ_{NF}, after which the further increase in $\sigma_{0.2}$ of specimens with this type of SR does not make sense, since the fracture stress of specimen with a notch, σ_{NF}, steeply decreases (Fig. 1). With the 'temperature' method of strengthening steel (i), this threshold of $\sigma_{0.2}$, which corresponds to σ_{NF}, occurs much earlier than with the 'structural' method (ii), that is, with significantly lower values of σ_{NF}, that is due to a higher rate of exhaustion of strength margin B_r in the first case. As to the reasons for more moderate exhaustion of index B_r in the case of the 'structural' type of strengthening, they are explained as follows. *With a decrease in temperature*, only the basic strength of steel, $\sigma_{0.2}$ increases rapidly (type of structure is invariable, and S_K is little dependent on temperature), *i.e.*, B_r, according to Eq. (1), rapidly decreases. However, *when the steel structure changes*, both components ($\sigma_{0.2}$ and S_K), grow, although the growth of $\sigma_{0.2}$ slightly predominates the growth of S_K, and therefore, B_r decreases more slowly (Fig. 1). From this comparison follows quite appropriately the fact that, in all studies on the brittleness of steels, it is the low-temperature method of embrittlement of specimens with SR that is widely used.

Figure 2 presents the results of the study of mechanical properties on specimens made of armco-iron (α-Fe) in the temperature range from

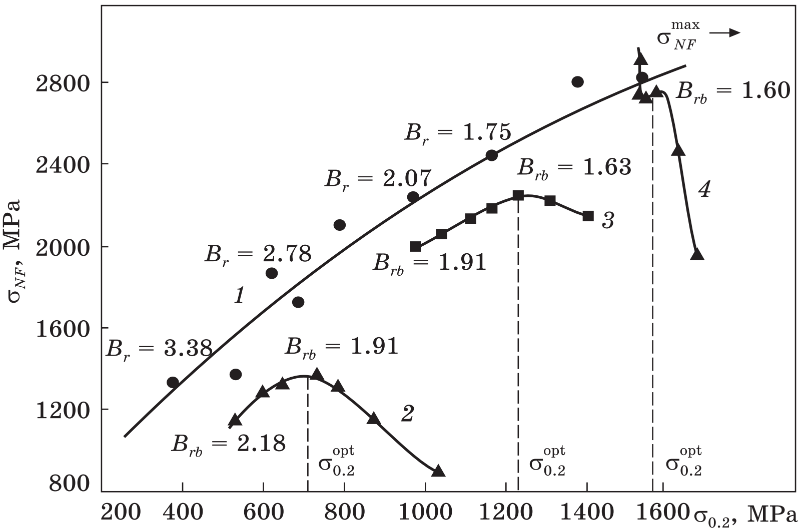


Fig. 1. The effect of basic strength value, $\sigma_{0.2}$, on the structural strength of steels in notched specimens, σ_{NF}, due to various strengthening factors: when lowering the temperature for steels with different basic strength (temperature factor) — curves *2* (steel 40, norm.); curves *3* (30ChGSA, quenching + tempering at 520 °C), curves *4* (30ChGSA, quenching + tempering at 300 °C); when changing the composition and structure of steels (structural factor) — curve *1*. B_r is the break resistance index; B_{rb} is index B_r at $\sigma_{0.2}^{\text{opt}}$ [8]

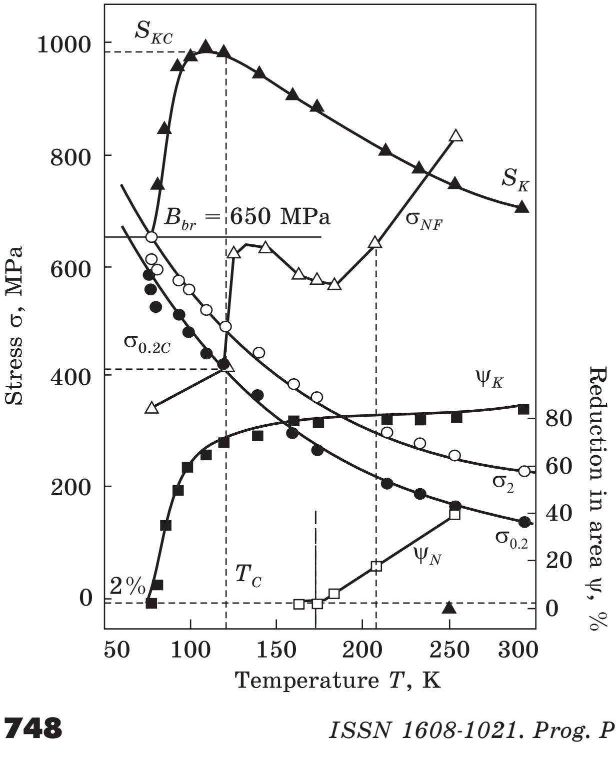


Fig. 2. Dependence of the fracture stress of notched specimens made of α-Fe in tension, σ_{NF}, on the test temperature. Here, T_C is the critical temperature of basic strength instability ($\sigma_{NF} \le \sigma_{0.2C}$); R_{br} is the brittle strength (according to Ref. [15])

300 K to 77 K, obtained in Ref. [15]. The fracture stress of specimen with an annular notch, σ_{NF} (bearing capacity of specimen with SR), significantly exceeds the strength of metal, $\sigma_{0.2}$ for $T > T_C$ (Fig. 2), where a certain ductility of specimen with SR is observed, $\psi_N > 0$. However, a critical temperature T_C exists, at which the bearing capacity of sample with SR drops sharply below the level $\sigma_{0.2C}$. This indicates an excessive sensitivity of the metal strength to SSS non-uniformity due to the notch. Therefore, if, at $T > T_C$, bearing capacity σ_{NF} stably exceeds the strength of metal itself $\sigma_{0.2}$ ($\sigma_{NF} > \sigma_{0.2}$), then, at $T < T_C$, such stability of supercritically high metal strength $\sigma_{0.2} > \sigma_{0.2C}$ is lost. Like any brittle material, completely ductile armco-iron ($\psi_K \approx 70\%$) in these supercritical conditions loses the stability of its strength $\sigma_{0.2}$, *i.e.*, it demonstrates the brittle behaviour of metal due to the effect of strong SSS non-uniformity.

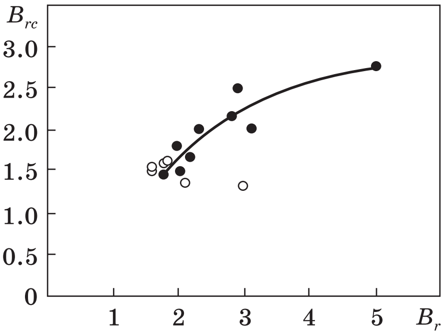
From a technical, engineering point of view, this type of mechanical state of the ‘specimen–SR’ system may be quite reasonably called metal brittleness, although from the physical point of view it is only ‘quasi-brittleness’ [13], or incomplete brittleness. Therefore, for metals, which are ductile by their nature, it is advisable to interpret the state of *acquired brittleness* as a state of *unstable strength*, since this is the main feature of mechanical behaviour of brittle materials under their force loading. It is from this point of view that we will consider the problem of embrittlement of metals and alloys.

4. Materials Science Means of Preventing the Strength Instability of Metal Alloys

For naturally brittle materials (glass, concrete, *etc.*), brittleness is due to the complete absence of a plastic margin of strength ($\Delta\sigma = 0$ in Eq. (3)). However, for metals, in which the very physical nature of their fracture is caused by the cracks nuclei (CN) in dislocation pile-ups [16, 17], at least, the initial signs of microplasticity in the grains of structure are fundamentally necessary for fracture [16]. Therefore, for strength instability in metals, the condition $\Delta\sigma = 0$ is not applicable, and it should be interpreted as $\Delta\sigma \to 0$. Qualitatively, this looks like an insufficiency of the strength margin ($B_r \to 1$) for certain SSS non-uniformity. Therefore, to prevent instability of strength, it is necessary to provide the metal with only sufficient value of break resistance B_r for this SSS, which will exceed the critical value of B_{rc} at $T = T_C$ (Fig. 2):

$$B_r \geq B_{rc}. \tag{5}$$

The next task is to determine the critical value of B_{rc} for any alloy with SR of type, which can be used in the laboratory practice of testing mechanical properties. In Ref. [18], dependence of the critical value B_{rc}



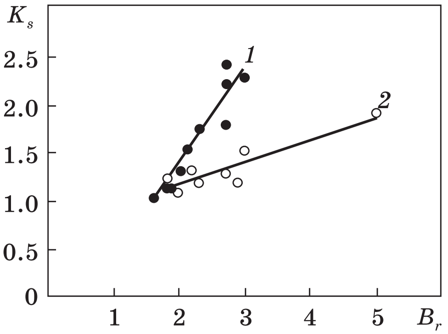


Fig. 3. The effect of break resistance index, B_r, on the critical value of break resistance index B_{rc} [15]: ○ — lines *1–7*; ● — lines *8–16* (data from Table)

Fig. 4. The ductility effect (*via* the break resistance index B_r) on the coefficient of break resistance margin K_s: *1* — tension of specimen with circular notch [2]; *2* — three-point bending specimens with a crack [15] (according to Ref. [12])

on the initial value of B_r for steels of different strengths ($\sigma_{0.2}$ = 140–1100 MPa) was ascertained for the condition ($\sigma_{NF} = \sigma_{0.2}$)

$$B_{rc} = \frac{S_{KC}}{\sigma_{0.2C}}. \qquad (6)$$

This enables to conclude that it is the property of *ductility*, which is 'contained' in the *break resistance* index B_r that pre-determines the resistance to the strength instability of the metal. However, the ability of plasticity to keep stability depends on the strain hardening index n, according to Hollomon [19]:

$$\sigma_e = \sigma_{0.2}\left(\frac{e}{e_{0.2}}\right)^n, \qquad (7)$$

where σ_e is the yield stress of the metal at the value of strain e, $e_{0.2} = 0.002$ is the strain value at the conditional yield point, n is the strain hardening index. The larger the index n, the smaller the value of ψ_K is when the ultimate strength of S_K is reached at the moment of specimen breaking, which reduces the strength margin $\Delta\sigma$ according to Eq. (2), or B_r in Eq. (3).

Nevertheless, for the value of S_K, and, therefore, for B_r, the basic strength of the alloy $\sigma_{0.2}$ plays a much greater role, as can be seen from Fig. 2, where, in the temperature range from T_K to T_C, $\sigma_{0.2C}$ exceeds the initial level of $\sigma_{0.2}$ approximately by three times. At the same time, the ratio $S_{Kc}/S_K \approx 1.3$; therefore, the strength margin $\Delta\sigma$ sharply decreased to the critical level $B_{rc} \approx 2.5$.

In more detail, the critical break resistance indexes B_{rc} were analysed in Ref. [20] according to the data of Refs. [2, 15], which present the temperature dependences of mechanical properties of structural steels on smooth specimens ($\sigma_{0.2}$, S_K, ψ_K) and on specimens with an annular notch (σ_{NF}, ψ_N) or on prismatic specimens with a fatigue crack (σ_{C0}). The data given in the works were sufficient to calculate the indexes B_r and B_{rc}, which were not found in Ref. [2, 15].

The analysis of the data from Table enables to conclude that when bending a specimen with SR (crack), there is a dependence of B_{rc} on B_r, but not on the strength $\sigma_{0.2}$ (Fig. 3).

5. Discussion on Results

As seen from Table, different types of SSS (tension with an annular notch (lines *1–7*) and bending of specimen with a crack (lines *8–16*)) with the same B_r give significant spread of critical values of B_{rc}. There-

Table. **Strength $\sigma_{0.2}$ and $\sigma_{0.2C}$ and break resistance indexes, B_r and B_{rc}, for structural steels in comparison with the 'ductile-to-brittle transition' temperature, T_C (according to Refs. [2, 15])**

No.	Steel, treatment	SR type	$\sigma_{0.2}$, MPa	$\sigma_{0.2C}$, MPa	B_r	B_{rc}	K_s	T_C, K	ΔT_C, °
1	Steel 30	Group 1. SR1 [9] annular notch, tension	350	800	2.97	1.31	2.28	77	216
2	30ChGSA (quenching + + tempering at 200 °C)		1400	1600	1.58	1.5	1.05	150	143
3	30ChGSA (isothermal quenching at 300 °C)		1500	1600	1.8	1.45	1.24	130	163
4	30ChGSNA (isothermal quenching at 200 °C)		1450	1700	1.77	1.57	1.13	83	210
5	30ChGSNA (isothermal quenching at 300 °C)		1170	1400	2.1	1.36	1.54	77	216
6	10Ch2SVA		1600	1700	1.83	1.59	1.15	160	133
7	Steel U8 (quenching + tempering at 400 °C)		1180	1300	1.58	1.54	1.03	200	93
8	α-Fe	Group 2. SR [10] bending with cracks	140	350	5.0	2.77	1.81	140	153
9	Steel U8 (annealing)		340	450	2.8	2.15	1.3	220	73
10	Steel 3		160	400	3.1	2.0	1.55	147	146
11	10ChSND		310	420	2.9	2.5	1.16	180	113
12	AK35		1027	1100	2.3	2.0	1.15	180	113
13	Weld 12ChN2MDF (boron doping $c_B = 0$)		640	700	1.97	1.81	1.09	173	120
14	Weld 12ChN2MDF (boron content $c_B = 0.001$)		640	820	1.8	1.46	1.23	175	118
15	Weld 12ChN2MDF (boron content $c_B = 0.0022$)		640	977	2.0	1.5	1.33	65	228
16	Weld 12ChN2MDF (boron content $c_B = 0.004$)		650	968	2.17	1.67	1.3	81	212

fore, their certification according to the tendency to the strength instability requires the selection of a certain standard methodology, as, for example, when determining the impact toughness index [6] or fracture toughness index [7]. Nevertheless, this scatter reduces essentially for the ratios of indexes B_r/B_{rc} or B_{rc}/B_r, which also have their own physical meaning:

$$K_s = \frac{B_r}{B_{rc}} \geq 1, \tag{8}$$

where K_s is the coefficient of break resistance margin, safe margin of strength, quantitative measure of protection against strength instability.

$$K_{br} = \frac{B_{rc}}{B_r} \leq 1 \tag{9}$$

is the coefficient of metals' predisposition to embrittlement due to SR, a measure of strength instability.

The specific feature of coefficients K_s and K_{br} is that, for the first time, in metals science, they act as a quantitative measure of approaching a state of brittleness (strength instability) due to the SR. This opens up the fundamentally new possibilities for certifying the mechanical properties of metal alloys, more adequately evaluating their structural suitability and strength reliability in the products of technology.

Moreover, in the future, there is an opportunity to develop a fundamentally new approach to calculating the strength of product at the design stage. Instead of providing the *maximum permissible stress* of structural element (SE) $[\sigma] = \sigma_{0.2}/\mathrm{K}_{SM}$ for the selected metal with strength $\sigma_{0.2}$ and with a certain safety margin $K_{SM} > 1$, the task may be formulated in another way. This way consists in calculation of the *maximum permissible strength* of the same metal, $\sigma_{0.2C}$, below which this SE does not require a margin of safety ($K_{SM} \approx 1$), since its fracture at $\sigma_N < \sigma_{0.2}$ is impossible in these conditions due to ensuring the stability of its strength $\sigma_{0.2}$. That is, in addition to calculation of the permissible load on SE by tools of mechanics, materials science is able to add to the means of engineering calculation of force reliability of SE also the methodology of determining the structural reliability index for the same material and for this SE with its specific SSS. The break resistance margin K_s (according to (7)) is determined to do this, that is provided by a sufficient ductility margin of metal, which is 'contained' in the characteristics of B_r if $K_s \geq 1$.

The reverse value, K_{br} (according to Eq. (8)), is, on the contrary, a measure of embrittlement, *i.e.*, a measure of strength instability. At $K_{br} > 1$, such a degree of strength instability of metal due to SR is possible, and the state of biaxial deformation manifests itself, for example, in specimen as a thick bar with pre-crack to determine the fracture toughness K_{Ic} [7]. Therefore, indexes K_{Ic} and K_s may correlate with each other, but it requires individual research.

On the practical side, to determine the magnitude of B_{rc}, knowing B_r, it is more convenient to use the dependences of K_s on B_r (Fig. 4), (instead of Fig. 3), which were presented in Ref. [12] in the form of such correlation ratios:

$$B_r/B_{rc} = 0.436 + 0.915B_r \tag{10}$$

for specimen with annular notch (lines *1–7*, Table (correlation coefficient is $R = 0.99$), curve *1*, Fig. 4), and

$$B_r/B_{rc} = 0.806+0.194B_r \tag{11}$$

for three-point bending specimen (lines *8–16*, Table (correlation coefficient is $R = 0.71$), curve *2*, Fig. 4)

6. Conclusions

The brittleness of naturally brittle materials (glass, granite) is caused by the very structure of the metal itself, which is why ductility is absent even with a completely uniform SSS. The nature of the ‘brittleness’ of metallic materials is completely different, and consists in the exhaustion of the existing ductility due to the effect of SSS non-uniformity.

By nature, metals are purely plastic materials. Metallic materials can only be in a state close to brittleness (‘quasi-brittleness’), which manifests itself in the form of strength instability of metal products due to the extremely high sensitivity of metal to SSS non-uniformities. The strength instability is caused by the lack of margin of ductile properties for this type of SSS. However, not the characteristic of plasticity ψ_K (or any other) is the quantitative measure of this absence, but the break resistance index $B_r = S_K/\sigma_{0.2}$, which comprehensively characterises the margin of plasticity ψ_K and the strain hardening factor of metal.

For each type of SSS non-uniformity (for example, near the SR or during bending), there is a critical level of B_{rc}, at which the strength instability occurs. The value of B_{rc} for each type of SSS of given alloy is a qualifying characteristic of its structural suitability for a certain product. The measure of structural suitability of a metal alloy for a product with a given type of SSS (*i.e.*, with SR or a crack) is the coefficient of break resistance margin $K_s = B_r/B_{rc}$. The normative value of K_s for each product should depend on the degree of responsibility (importance) of the force reliability of product, general, normal or high ones, when choosing the most ‘rigid’ system of certification of metal for structural suitability. Such a testing method may be fracture of specimens with cracks according to the standard for determining the fracture toughness index K_{IC}. However, without the mandatory condition of realizing the state of biaxial deformation (BD), since precisely in BD absence, the coefficient of the margin of break resistance, K_s, may exceed unity, *i.e.*, ensure stability of strength by of existing SSS conditions or no danger of brittleness for this product.

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ПРИРОДА КРИХКОСТИ МЕТАЛІВ

Розглядається стан крихкости матеріалу як специфічний прояв механічної поведінки під навантаженням, що проявляється у нестабільності значення характеристики міцности в умовах неоднорідностей напружено-деформаційного стану (НДС). Для природньо пластичних металів така механічна поведінка можлива в умовах неоднорідного НДС під дією концентраторів напружень (КН), тріщин тощо. Протидію втраті стабільности міцности ($\sigma_{0,2}$ — умовна межа плинности) чинить наявна пластичність матеріалу, але у вимірі особливого показника — деформаційної стійкости (зламостійкости) B_r, який комплексно відображає міру пластичности та деформаційного зміцнення металу в зоні дії КН. Критична величина B_{rc} відповідає міцності $\sigma_{0,2C}$, за якої стабільність міцности переходить у стан нестабільности за температури T_C, де розрив зразка з КН відбувається за номінального напруження σ_{NF}, нижчого за $\sigma_{0,2C}$: $\sigma_{NF} \leq \sigma_{0,2C}$. Аналізуються експериментальні результати різних авторів на зразках з КН (тріщинами), для яких можливо визначити критичні величини $\sigma_{0,2C}$ та B_{rc} залежно від наявного рівня B_r у сталях. Виявлено сталу закономірність залежности B_{rc} від B_r для різних видів КН, що уможливлює попередньо визначати схильність досліджуваної сталі до втрати стабільности міцности під дією КН за відомими показниками стандартних механічних характеристик під час розтягнення зразків $\sigma_{0,2}$ і S_K — істинного напруження руйнування у шийці зразка. Розглянута концепція крихкости металів як прояву нестабільности міцности в умовах дії КН може стати основою для розроблення інноваційної методології інженерного розрахунку силової надійности виробів техніки, що містять конструктивні види КН або відомі тріщини. Це можливо шляхом визначення гранично допустимої критичної характеристики міцности стопу $\sigma_{0,2C}$, що ґарантує відсутність крихкого руйнування для виробу з даним видом КН за умови $\sigma_{NF} \leq \sigma_{0,2}$.

Ключові слова: міцність, нестабільність міцности, крихкість, окрихчення сталей, концентратор напружень, зламостійкість, пластичність.