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CONSIDERATIONS UPON BREAKING STRENGTH OF NODULAR CAST IRON UNDER PLASTIC DEFORMATION

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ABSTRACT

The work aims to demonstrate the existence of a mathematics connection between breaking strength and degree of plastic deformation in case of nodular cast iron.
Research made along time starting 1932-1934 until now, showed that cast iron can be both hot and cold plastically deformed. Deformation degrees reached on various types of cast iron show that plastic deformation is influenced, mainly, by the following factors:

- *Chemical composition;*
- *Cast iron shape;*
- *Basic metallic mass structure;*
- *Plastic deformation temperature;*
- *Tension condition generated by plastic deformation;*
- *Deformation speed.*

As a result of plastic deformation, the cast iron pieces change their shape and size as well as the breaking strength value. The latte increase together with the deformation degree.
Present work analyses the breaking strength depending on the deformation degree for a nodular cast iron (450.5).

1. The experiments on the deformation degree for a nodular cast iron

The experiments have been done on samples from Fgn 450.5 ϕ 60x200 mm, produced in induction furnaces of 250 kg, 2500 Hz. Plastic strain was achieved by forging on pneumatic hammer, between flat tools. Temperature range was 850 – 950 ^{0} C for plastic strain, eliminating this way the possibility for the strain to be influenced by potential phosphorous eutectic with 950 ^{0} C melting point.

Besides, it is known that a content of phosphorous greater than 0,1 % within cast iron decrease the strain temperature.

For determining the correlation between plastic strain degree and shape of graphite segregation, from the hot strained samples with various degree of strain, tensile specimens on main direction of plastic strain have been produced.

The results of tensile test have been compared to the data obtained by calculation, under conditions to be described here below.

For the beginning we'll introduce as notion – the place taken by nodular cast iron. The necessity of this term is the result of the following:

1. Research shows that cast iron plastic deformation possibility is connected to the shape and size of cast iron separations.
2. Cast iron is not plastically deformed and its influence upon cast iron deformation is generated by the shape and size of the place it takes within basic metallic mass.

During plastic deformation process the place taken by cast iron gets deformed, becoming longer, fig.1 (the case of nodular cast iron).

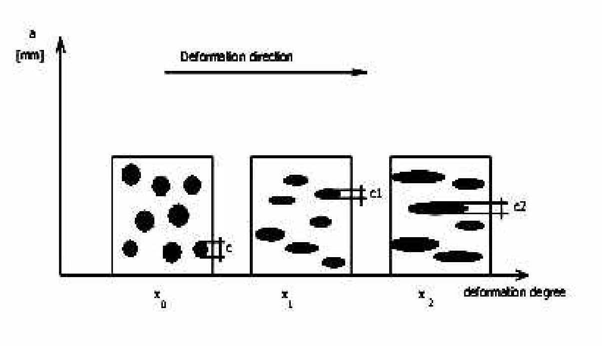

Figure 1 The scheme of place taken by nodular cast iron on initial condition and after various deformation degree

Where:

a – the semi-finished side, perpendicular on deformation direction;

x_0 – initial condition;

x_1, x_2 – deformation degree;

c – dimension of place taken by nodular cast iron in initial condition (x_0);

c_1 - dimension of place taken by nodular cast iron on direction perpendicular on deformation degree, in accordance with deformation degree x_1;

c_2 - dimension of place taken by nodular cast iron on direction perpendicular on deformation degree, in accordance with deformation degree x_2;

It results that, the higher the deformation degree is, the lower the dimension "c" of place taken y nodular cast iron on perpendicular direction is.

Consequently, we can determine the degree of plastic strain of cast iron by following the size of graphite place on main direction of strain.

It is known that, after plastic strain, the cast irons change their mechanical proprieties, i.e. they grow proportional to the strain degree.

Intuiting that one of the influencing factors is the graphite place within cast iron, we'll try to determine a mathematic correlation between variation of graphite place dimensions under various stages of plastic strain and mechanical proprieties, starting from the following reasoning.

We'll consider the place taken by nodular cast iron as a cleft in cast iron basic metallic mass and we'll apply Irwin's theory:

$$\sigma = \left(\frac{E \cdot G}{\pi \cdot C}\right)^{1/2} \quad \text{where :} \qquad (1)$$

G – is the force necessary for cleft extension and depends on the temperature and load application speed;

E – is the material's elastic modulus;

C – is the cleft size;

Iron breaking after tensile test appears like a fragile breaking, consequently we further issue a theory to prove the mathematic correlation assumed between mechanical properties of hot strained irons and variation of graphite place shape by various strain degrees.

Considering we have the same material, same temperature and test speed, we can change the relation (1) into the relation as follows:

$$\sigma = f\left(\sqrt{\frac{1}{c}}\right) \quad \text{where:} \qquad (2)$$

c – is the dimension of place taken by nodular cast iron, on direction perpendicular on deformation direction.

2. Conclusions

Verification of relation was done on nodular cast iron hot plastic deformation ($950\,°C$). After hot plastic deformation with various deformation degrees, samples were taken for traction test on deformation direction.

The results were as below:

1. Initial condition:

- breaking strength on samples: $\sigma_{r_1} = 450\ N/mm^2$;

- average size of place taken by nodular cast iron: $C_{m_1} = 0.0281\ mm;$

2. 18.33% plastic deformation degree:

- breaking strength on samples: $\sigma_{r_2} = 495\ N/mm^2;$

- average size of place taken by nodular cast iron: $C_{m_2} = 0.0236\ mm;$

3. 41.66% plastic deformation degree:

- breaking strength on samples: $\sigma_{r_3} = 683\ N/mm^2;$
- average size of place taken by nodular cast iron: $C_{m_3} = 0.0110\ mm;$

According to relation 2, the influence of place taken by nodular cast iron upon breaking strength is give by "K" value:

$$K = \frac{\frac{1}{\sqrt{C_{m_x}}}}{\frac{1}{\sqrt{C_{m_1}}}} \quad \text{where:} \qquad (3)$$

C_{m_1} - the dimension of place taken by nodular cast iron on initial condition (cast condition);

C_{m_x} - the dimension of place taken by nodular cast iron on a section perpendicular on deformation direction, at "x" plastic deformation degree;

Further to calculation, we get the following breaking strength values related to 18.33% and 41.66% plastic deformation degrees:

1. For 18.33% plastic deformation degree:

$$K_1 = \frac{\frac{1}{\sqrt{C_{m_2}}}}{\frac{1}{\sqrt{C_{m_1}}}}; \qquad K_1 = 1.0918$$

Breaking strength value calculated for samples with 18.33% deformation degree:

$$\sigma_{r_2} = \sigma_{r_1} \cdot K_1$$

$$\sigma_{r_2} = 450 \cdot 1.0918 = 491.31\ N/mm^2;$$

2. For 41.66% plastic deformation degree:

$$K_2 = \frac{\frac{1}{\sqrt{C_{m_3}}}}{\frac{1}{\sqrt{C_{m_1}}}} = 1.518$$

Breaking strength value is:

$$\sigma_{r_3} = \sigma_{r_1} \cdot K_2$$

$$\sigma_{r_3} = 450 \cdot 1.158 = 683.10\ N/mm^2;$$

The results are presented in fig.2.

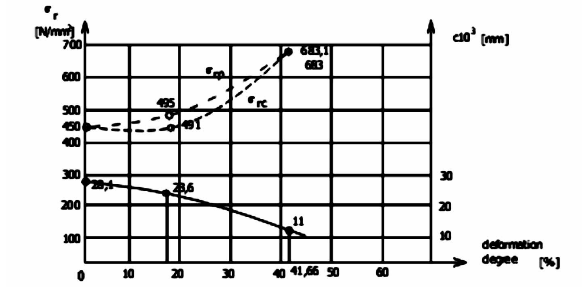

Figure2 The variation of breaking strength and average dimension of place taken by nodular cast iron

Where:

σ_{r_p} – breaking strength values got by traction of some samples of nodular cast iron hot plastic deformation on a direction parallel to plastic deformation direction;

σ_{r_c} - breaking strength values calculated for various plastic deformation degrees;

c – average dimension of place taken by nodular cast iron on a direction perpendicular on plastic deformation direction for various plastic deformation.

Researches and calculations effected showed the following:

- increase of breaking strength values as hot plastic deformation degree increases, can be the results of reduction of dimension of place taken by nodular cast iron on a direction perpendicular on deformation direction and traction direction;
- dimension of place taken by nodular cast iron on a direction perpendicular on plastic deformation direction decreases together with the increase of deformation degree, being also a measure unit of a microscopic analysis;

- differences resulted between breaking strength values and those resulted further to traction are insignificant and can be generated by calculation errors or small differences of traction conditions;

- the place taken by nodular cast iron is like a pre-existed cleft within the cast iron metallic mass;

- the crack’ s radius of curvature (graphite place in our case) stays big enough so that it has no influence upon mechanical proprieties value studied, so the strain does not reach such a level as the graphite place to become flat, the radius to become very small and generate no effect ;

- the mathematic model of correlation between graphite place dimension in various stages of irons plastic strain (on main direction of strain) and mechanical proprieties, can be practically used;

- tensile tests have been carried out on the main direction of plastic strain, samples deformation has been done by forging and straining on pneumatic hammer.

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