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THE INFLUENCE OF Cd-Zn COATING AND DEFORMATION VELOCITY ON MECHANICAL PROPERTIES OF STEEL GRADE 45

WPŁYW PRĘDKOŚCI ODKSZTAŁCENIA NA WŁAŚCIWOŚCI MECHANICZNE STALI 45 Z POWŁOKĄ Cd-Zn

The work presents some researches about immediate strength in tensile test in a increasing temperature. It has been noticed that immediate strength of uncoated steel grade 45 is distinctly decreased after crossing the temperature 400°C. However, in case of steel grade 45 with two-ply Cd+Zn coating, clearly decrease of immediate strength is noticed just crossing the tensile temperature 320°C.

Our investigations shows fundamental influence of latent crack on immediate strength of steel grade 45 in temperature range between 320–525 K.

It was also noticed and ascertained that intensity of latent cracking process is a function of deformation velocity strain rate "$\acute{\varepsilon}$" and this process is more intensified during diminution of deformation velocity (especially when $\acute{\varepsilon} < 2 \cdot 10^{-3}s^{-1}$).

The results of our investigations on polycrystalline material (steel grade 45 with two-ply Cd+Zn coating) are the same as in literature where investigations were conducted on Zinc mono crystals. In both cases it was noticed that together with decrease of deformation velocity material is not plasticized. On the contrary, the fractography of testified steel samples by low deformation velocity, shows the symptoms of brittle scrap-metal. It can be noticed more than in other cases. The results of investigations conducted on polycrystalline samples with two-ply Cd+Zn coating did not confirm the expectations of latent cracking intensification connected with increasing of deformation velocity. This is also not confirmed that plastic properties of samples are decreasing. Whereas, during the investigations we got the coefficients of plasticity on constant level – A_5 = 7–13%, Z = 2–8% in principle, and there are independent from deformation velocity.

W artykule przedstawiono badania wytrzymałości doraźnej, w próbie rozciągania w podwyższonej temperaturze. Stwierdzono, że wytrzymałość doraźna stali 45 bez powłoki ochronnej obniża się wyraźnie po przekroczeniu temperatury rozciągania 400°C. Natomiast w wypadku stali 45 pokrytej dwuwarstwową powłoką Cd+Zn, istotny spadek wytrzymałości doraźnej odnotowuje się już przy temperaturach rozciągania przekraczających 320°C.

W badaniach wykazano istotny wpływ utajonego pękania na wytrzymałość doraźną stali gat. 45 w zakresie temperatur 320–525 K. Stwierdzono również, że intensywność procesu utajonego pękania jest funkcją prędkości odkształcenia "$\acute{\varepsilon}$". Przy czym proces ten jest intensyfikowany w miarę spadku prędkości odkształcenia (szczególnie przy $\acute{\varepsilon} < 2 \cdot 10^{-3}s^{-1}$).

Uzyskano pełną zbieżność wyników badań na polikrystalicznym materiale (stal gat. 45 z dwuwarstwowym pokryciem Cd+Zn) z wynikami badań przedstawianych w literaturze fachowej – prowadzonymi na monokryształach cynku. W obydwu przypadkach stwierdzono, że wraz ze spadkiem prędkości odkształcenia nie następowało uplastycznianie się materiału. Wręcz przeciwnie, fraktografia przełomu próbek stalowych testowanych przy niskich prędkościach odkształcania wykazywała nawet w większym stopniu przejawy złomu kruchego – w porównaniu z innymi. Wyniki badań na polikrystalicznych próbkach z dwuwarstwowym pokryciem Cd+Zn nie potwierdzają również tego, że należałoby oczekiwać nasilania się procesu utajonego pękania wraz ze wzrostem prędkości odkształcenia, a więc przede wszystkim spadku właściwości plastycznych. Natomiast podczas badań uzyskiwano wskaźniki plastyczności w zasadzie na stałym poziomie – A_5 = 7–13%, Z = 2–8% niezależnym od prędkości odkształcenia.

1. Introduction

Models of latent crack showed by Orowan, Rebinder and Murgatroid could be used only in a few cases of cracking [1÷4]. They have been used as the base for the newest more modified models. Generally has been preferred three models of latent cracking under the influence of increasing temperature: the first – model of decrease the surface energy [6], the second- modified by Lynch, adsorb model of decrease the cohesion resistance

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[7] and the third – quench annealing resistance model of cracking [8]. During the analysis of theoretic assumptions of those models we can consider that there is no representative model giving definition of latent cracking under the influence of increasing temperatures. Choosing the right model of cracking in a direct case is so difficult and depends on many factors both environment and cracking material.

In work under a steel grade 45 [9], it can be noticed that the phenomenon of latent cracking could be seen for carbon steel coated with Cd and Zn. It could be observed distinctly decrease of immediate strength for the samples with Cd+Zn coating in comparison with the uncoated samples. The intensity of this process can be noticed in our investigations, during diminution of eutectic temperature of Cd-Zn system, 265°C [10] (262°C [11]). In other works [12] we can consider that usually increasing of deformation velocity guides to intensify of cracking processes. However, the influence of deformation velocity on coefficients of plasticity could be described by different theories. In the earlier works [13], there were noticed, that decreasing of deformation velocity below 1%/min guides to material plasticize (Fig. 1). However, those results could not be confirmed in a later works, where special attention was paid to accuracy of samples preparation [12]. In high value of deformation velocity incidental failure could be caused by non-uniform deforming and creating bands of leaps. This is a place where the initiation of fracture starts from small deformation.

Simultaneously, for small value of deformation velocity there is still enough time to recovery of some defects.

Because of disadvantageous interaction of given above phenomenon on whole construction (they have been a cause of some break – down of aircraft fleet [14, 15]) it have been decided to do deeper analysis of phenomenon and some other tests for giving definition of degree of loss immediate strength and to testify the influence of deformation velocity on latent cracking process.

2. The methodology of the investigations

In investigations have been used a carbon construction steel grade 45. Before preparing samples, the material was normalized temperature 860°C for 4 hours. Investigations were taken for two groups of samples:

I – without coating,

II – with two-ply protective coat (Cd+Zn – thickness of layer coating 10 μm where 8 μm is for Cd and 2 μm is for Zn).

For the first group of samples it have been done the test of static tensile for the range of temperature between 250°C to 525°C and constant tensile velocity – 3 mm/min. For the second group of samples deformation velocity was changing and chosen mechanical properties were registered. The static tensile test for this case was conducted at temperature 375°C, for two groups of samples prepared in the same way previously.

3. The results of the investigations and the analysis

In the tensile test with increasing temperature (Fig. 1), we can observe that immediate strength of uncoated steel grade 45 is distinctly decreased after crossing the tensile temperature 400°C. However in the case of steel grade 45 with two-ply Cd+Zn coating, clearly decrease of immediate strength is noticed just crossing the tensile temperature 320°C. This ascertainment could be confirmed by the graph which shows the relative changing of immediate strength for different tensile temperatures (Fig. 2).

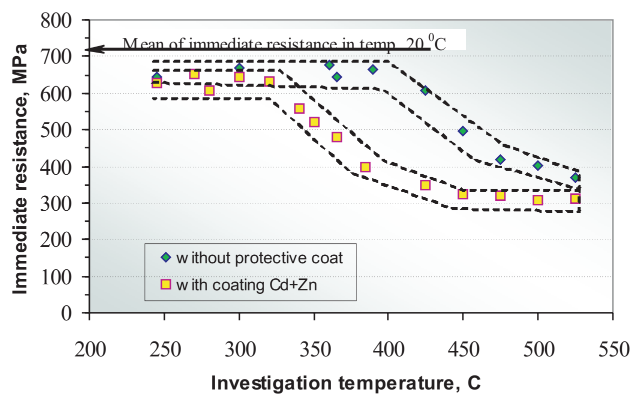

Fig. 1. The influence of tensile temperature on immediate resistance of steel grade 45

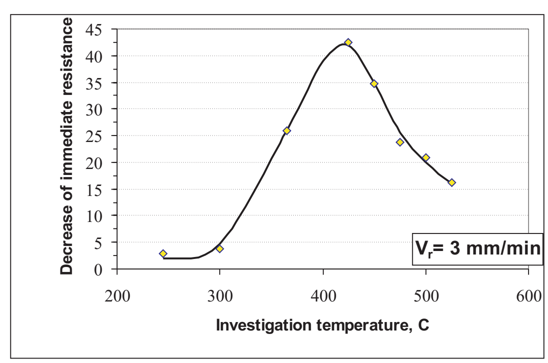

Fig. 2. Relative changing of immediate strength for different tensile temperatures

During the analysis of the curve of immediate strength as a function of temperature (Fig. 1.) and according to relative changing of immediate strength (Fig. 2) we have paid a special attention to the possibility of experiment disturbances. It was the main cause that we decided to conduct the next investigations only at 375°C temperature (Fig. 3). The main aim of those investigations was to define the influence of deformation velocity on degree of loss chosen mechanical properties of steel grade 45 with coating in comparison with uncoated steel.

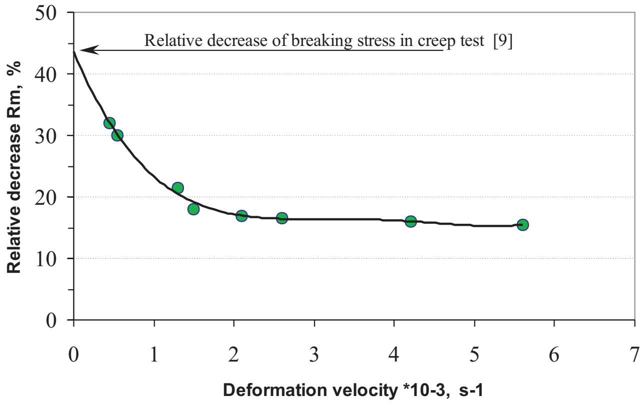

Fig. 3. The influence of deformation velocity on immediate strength of steel grade 45 with two-ply coating type Cd-Zn at temperature 375°C

The static tensile test was conducted for different value of deformation velocity both for samples with and without coating. Relative deformation velocity has been given from dependence as follows (1):

$$\dot{\varepsilon} = dl/(l_0 * dt) = V/l_0, \quad (1)$$

where:
V – linear velocity of working element,
L_0 – initial length of sample.

As we mentioned above, process of latent cracking needed the adequately long time for initiation of brittle fracture. The results of our investigations shows that for the samples of steel grade 45 with protective Cd+Zn coat, such a time is assured by all deformation velocities used in investigations (Fig. 4). Whereas, the value of deformation velocities used in investigations have the influence only on definite mechanical properties of base material. Extrapolating the investigations curve, we have been got a curve describing the influence of deformation velocity on relative immediate strength changing as a function of deformation velocity. Distinctly decrease of relative immediate strength has been seen in case of reducing deformation velocity below $2^* \ 10^{-3} \ s^{-1}$. However, the velocity gradient of decrease relative immediate resistance in function of deformation velocity is inconsiderably lower. Such a course of curve shows the largest sensibility of latent cracking process in steel grade 45 with Cd+Zn coat at temperature 375°C and for deformation velocity above $2^* \ 10^{-3} \ s^{-1}$. The decrease of steel grade 45 with Cd+Zn coating relative immediate strength in comparison with uncoated steel and dependence between cracking intensity and deformation velocity when velocity is comparatively low, considered that we have the confirmation of latent cracking phenomenon. Also the fractography of testified by static immediate test in increasing temperatures samples, confirms this phenomenon (Fig. 5). On Fig. 5 a, as we can see, there are interaction effects of liquid phase during the propagation of fracture (presence of Cd and Zn atoms has been noticed on 30% of surface of fracture).

Our investigations shows the essential influence of latent crack on immediate strength of steel grade 45 in temperature range between 330–525°C. It was also noticed and ascertained that intensity of latent cracking process is a function of deformation velocity "$\acute{\varepsilon}$". This process is more intensified during diminution of deformation velocity (especially when $\acute{\varepsilon} < 2 \cdot 10^{-3} \ s^{-1}$).

a b

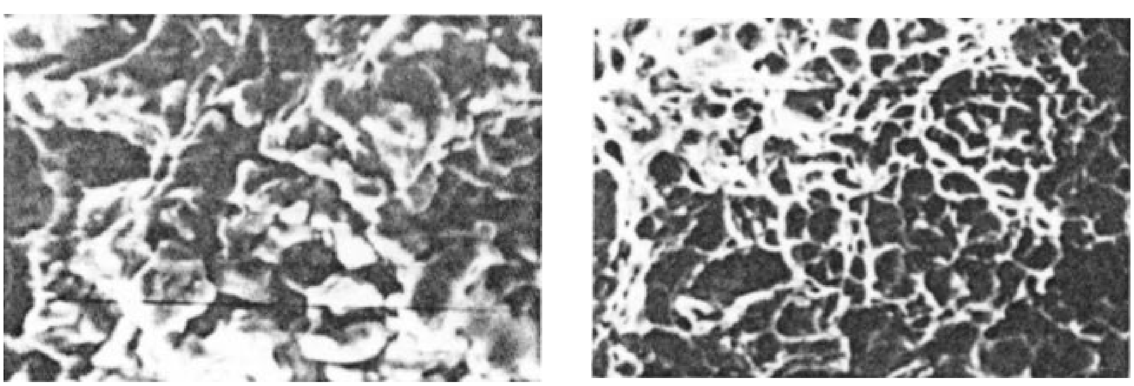

Fig. 4. The fractography of steel grade 45 sample testified in temperature 375°C and velocity $\acute{\varepsilon} = 0.46^* 10^{-3} \ s^{-1}$
a – interaction range of latent crack, magnification 4000x ; b – core, magnification 4000x

The investigation results of polycrystalline material (steel grade 45 with two-ply Cd+Zn coating) are the same as the results on Zinc mono crystals [13]. In both cases it were noticed that together with decrease of deformation velocity material was not plasticized. On the contrary, the fractography of testified by low deformation velocities steel samples shows the symptoms of brittle scrap-metal. This is observed in bigger value than in other cases. The results of investigations conducted on polycrystalline samples with two-ply Cd+Zn coating did not confirm the expectations of latent cracking process intensification connected with deformation velocity increasing. This is also not confirmed that plastic properties of samples are decreasing. Whereas, during the investigations we got the plasticity coefficients on constant level – A_5 = 7–13%, Z = 2–8% in principle, and there are independent from deformation velocity.

4. Conclusions

1. Two-ply protective Cd-Zn coatings with circum eutectic composition could have been a cause of distinctly decrease of immediate resistance of steel grade 45 in range of temperatures above 320°C.
2. The decrease of mechanical properties of two-ply coatings could be connected with passage of protective coating from solid into liquid with special physical chemistry properties.
3. Effect of latent crack is accelerating failure of steel grade 45 with protective Cd-Zn coatings in interaction of tensile and increasing temperatures.
4. Decrease of deformation velocity "$\acute{\varepsilon}$" below $2* 10^{-3}$ s^{-1} testifies about the largest sensibility of working process – latent crack in steel grade of 45 (with two-ply Cd+Zn coating).

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