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Letter to Editor

# THE INFLUENCE OF THE RESIDUAL COPPER ON THE PIPES STEEL HOT PLASTICITY ACCORDING TO ENVIRONMENTAL REQUIREMENTS

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***Abstract***

*Considering the importance of gaseous and/or liquid fuels impact on the environment, the resistance of pipelines at hot plastic deformation is important. Therefore, in order to avoid or reduce any adverse impact on the environment, the influence of residual copper on hot deformability of steel pipes was investigated in this paper. The negative copper influence was experimentally proved using torsion deformation at temperatures above 1000$^o$, under the air and argon atmosphere. The samples were heated and then deformed at different temperatures with constant deformation rate. Also, structural analysis of investigated materials was done, using metallographic and SEM analysis.*

*Keywords pipelines, torsion deformation, fracture deformation, structural analysis, environment*

## 1. Introduction

The free market economy considers manufacturing of the high quality level products with minimum losses as a must. A way to gain the profit is the proper use of technological, chemical composition, together with the reduction of the imposed range of chemical elements, including residuals (which determine the technological characteristics of materials during the processing). In that way the proportion of Mn/S for modification of sulphures nature (avoiding the FeS which decreases steel hot plasticity) can be controlled technologically, by avoiding the $Al_2O_3$ forming which reduces wire forming ability, or the proportion of $Al/N_2$ which leads to steel ageing.

The study the cooper content influence as residual element in steel pipes is given in this paper, considering the fact that copper presence in steel leads to surface defects during the hot deformation in the steel pipes - the copper as residual element is limited to max 0,3 % in the product specifications.

## 2. Experimental

*a) Materials*

The samples - 7 ingots - were produced in the induction heater, with chemical composition shown in the table 1.

The ingots have been forged in bars of ϕ 18 mm and then air cooled. For obtaining of structural homogeneity, each bar has been normalized at 880 $^0$C for 30 minutes and after that torsion test was done.

b) *Techniques*

Steels plasticity was determined by torsion test using machine of Setaram type. The samples was heated and then deformed at different temperatures with constant deformation rate, $\varepsilon$ = 0.1 s $^{-1}$. For each test, the momentum and number of torsions to fracture were noted. Test was carried out under argon and air

***Table 1.*** *Chemical composition of experimental ingots.*

| Number ingot | Sample numbering | % C | % Mn | % Si | % S | % P | % Cu | % Ni | % Sn |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1286 | 0.19 | 0.30 | 0.24 | 0.015 | 0.010 | 0.24 | 0.33 | 0.012 |
| 2 | 1287 | 0.22 | 0.36 | 0.26 | 0.017 | 0.011 | 0.52 | 0.49 | 0.011 |
| 3 | 1290 | 0.22 | 0.36 | 0.27 | 0.017 | 0.016 | 0.26 | 0.49 | 0.011 |
| 4 | 1292 | 0.18 | 0.31 | 0.24 | 0.013 | 0.024 | 0.002 | 0.041 | 0.010 |
| 5 | 1293 | 0.19 | 0.34 | 0.27 | 0.015 | 0.027 | 0.006 | 0.53 | 0.010 |
| 6 | 1294 | 0.18 | 0.32 | 0.25 | 0.013 | 0.024 | 0.38 | 0.042 | 0.009 |
| 7 | 1295 | 0.19 | 0.32 | 0.29 | 0.015 | 0.025 | 0.26 | 0.038 | 0.009 |

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***Table 2.*** *Deformation fracture at different deformation temperature*

| Number ingot | 800 | | 900 | | 1 000 | | 1 100 | | 1 200 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | air | argon | air | argon | air | argon | air | argon | air | argon |
| 1 | 3.54 | 4.01 | 7.87 | 9.75 | 24.55 | 27.3 | 27.62 | 30.15 | 28.19 | 32.96 |
| 2 | 2.01 | 2.85 | 7.35 | 6.89 | 24.32 | 25.01 | 26.15 | 26.23 | 27.33 | 28.93 |
| 3 | 2.46 | 3.15 | 7.68 | 9.62 | 25.23 | 27.4 | 25.33 | 28.14 | 28.07 | 31.15 |
| 4 | 5.23 | 5.9 | 11.64 | 13.12 | 29.52 | 31.7 | 30.42 | 32.14 | 33.15 | 33.8 |
| 5 | 3.09 | 3.52 | 8.66 | 9.45 | 26.15 | 29.23 | 29.02 | 30.47 | 31.71 | 33.12 |
| 6 | 3.55 | 5.01 | 6.93 | 7.2 | 20.12 | 21.91 | 21.09 | 22.32 | 18.17 | 23.91 |
| 7 | 3.12 | 4.62 | 9.94 | 10.02 | 22.13 | 24.19 | 23.52 | 24.72 | 21.56 | 26.15 |

atmosphere. Structural analysis of the samples was done using optical microscopy at apparatus of JX - 3 A type.

## 3. Results and discussion

The values of deformation at rupture, $\varepsilon_{r,}$ as a measure of material's plasticity, for every sample in different testing conditions (argon or free air) at temperature range (800 - 1200) $^0$C for every 100 $^0$C increase are presented in table 2. Note that if up to 1000 $^0$C the plasticity of steels increases sharply with increasing T deformation, up to 1100 $^0$C remains approximately constant and then increases slowly or even decreases to the deformation in air, for content over 0.2% copper (Figure 1). At high temperature (deformation at 1100 $^0$C and 1200 $^0$C), the plasticity of steel is decreasing with the increase of the copper and Cu / Ni proportion, the nickel being the element that reduces the negative effect of copper expressed above a certain limit (Figure 2).

Given the results of the experiments performed, which confirmed the negative influence of this residual cooper on the hot plasticity steels for pipes, they conducted a series of structural determination. It is known that iron oxidation at the surface of the products heated over 1100 $^0$C, leads to a copper enrichment by diffusion of surface layer [1, 2, 3].

Because the copper is an element nobler than iron, does not oxidize with it and migrate short distances, enriching the surrounding areas of iron oxide.

a)

b)

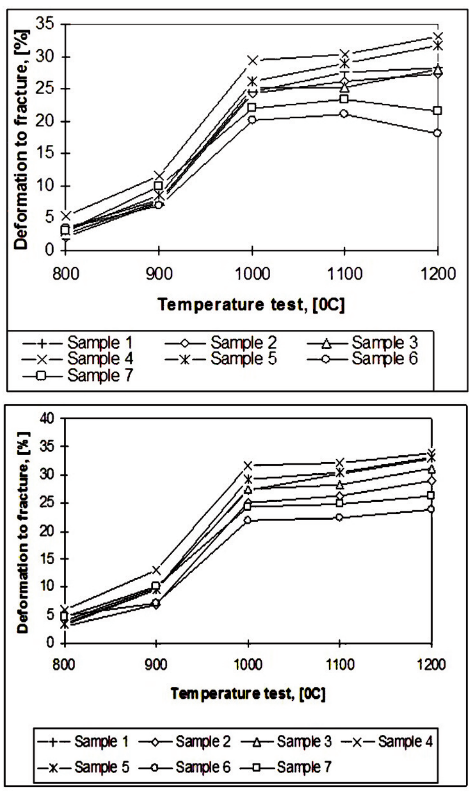


***Figure 1.*** *Plasticity steels with deformation temperature a) deformation under air; b) deformation under argon*

a)

b)

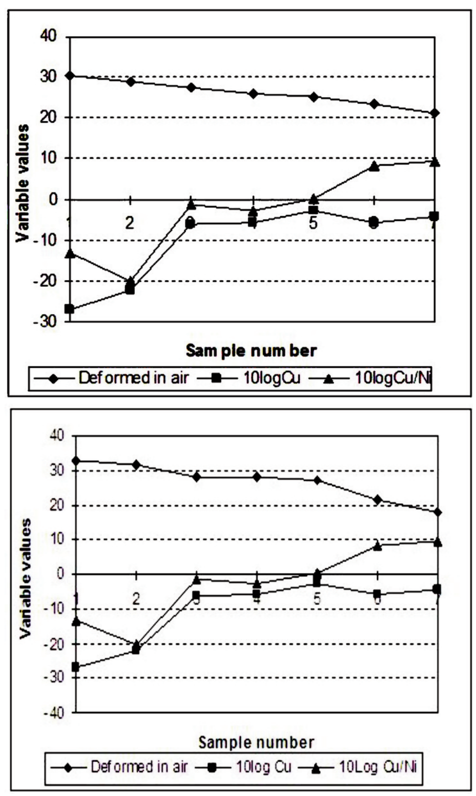


***Figure 2.*** *Values of plasticity steel (e$_{rupture}$ %) deformed in air at 1100 $^0$C and 1200 $^0$C compared with variable values of Cu % and Cu/Ni for the samples, a) $T_{def.}$ = 1100$^0$C ; b) $T_{def.}$ = 1200$^0$C*

Highlighting copper, as residual element (Cu < 0.3%) on the state of the surface pipes during heating, was carried out on samples (Cu=0.38 % and Ni = 0.042 %). The samples were oxidized by heating in air for one hour at 1200 $^0$C and analyzed the microscopic appearance of surfaces polished metallographic samples section.

The analysis highlighted the following aspects:

- transversal surface of samples is uniformly oxidized in thin film (less than 0.1 mm);

- the oxidation was produced locally, radial on the bars section, in areas with an depth between 0.2 - 0.5 mm (Figure 3);

- in the radial oxidized areas, was observed local the presence of some compounds (stressed in the figure with c) with metallographic aspect different by iron oxides (Figure 3). Oxidized area, (Figure 3) was analyzed by SEM the investigations carried out followed identifications of phases in oxidized area (optically selected) and its repartition. Results showed a concentration of copper in oxidized area, as we can see in the Figure 4.

a)

b)

c)

*Figure 3.* *Optical image of the cross section of the sample oxidized excessive (sample numbering 6 Cu = 0.38 %, Ni = 0.042 %) after forced oxidizing ($T_{heating}$ = 1200 $^0$C; time 1 hour), x 250*

It was remarked the lack of copper in the oxidized areas and a slight difference in the concentration of iron oxide (Figure 4).

Copper particles are sub microscopic, but in excessive oxidation conditions, at limit were observed even microscopic precipitates (C particles). These microscopic phase particles, containing copper have the form of intercristaline precipitates (Figure 3) and were formed after heating, at the austenite grains limit. The temperature of melting phases that contains copper being less than the required heating for hot deformation in shallow areas of the product intercrystalline discontinuities occur, which lead to surface cracks during deformation. Such way of research, using the structural analysis of materials, present a standard way of research study [3-8] in these cases.

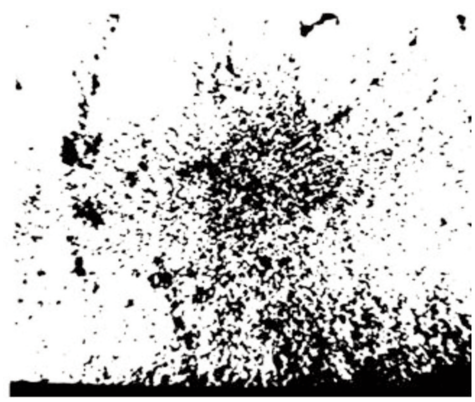

*Figure 4.* *Electrono - optical aspects and elements repartition (x 600): a) Image of absorbed electrons; b) Cu repartition $K_\alpha$ line; c) Fe repartition $K_\alpha$*

## 5. Conclusions

The following remarks can be drawn:

a) Hot plasticity is strongly influenced by the copper as residual element, even if its variation limits are specified by the product specification (max. 0.030 %). Its influence is strong at the temperatures over 1000$^0$C, having as effecting a decrease in deformability and start of surface cracking. The tests done under protective atmosphere showed better deformability of material, comparing to the tests done under air, under similar conditions - in the last case the oxidizing process took place;

b) The presence of nickel, with at least same percentage as copper, reduces negative copper influence, and plasticity increases that way;

c) Structural analysis showed surface enrichment in copper content and decrease of iron content by oxidation during heating previously to deformation at temperature of 1200$^0$C.

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