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Selected properties of new „duplex" cast steel

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Abstract

In this paper selected properties of new „duplex" cast steel are presented. The new cast steel was devised in HYDRO-VACUUM company in Grudziądz, where "duplex" cast steel for pump elements is smelted. The goal was to devise a new grade of "duplex" cast steel of better physicochemical properties and cheaper than now applied. It was demonstrated, that there is the possibility of devising the new grade of "duplex" cast steel. It is characterized by higher mechanical properties, similar wear resistance and greater corrosion resistance in 15% water solution of H_2SO_4 in comparison to now applied "duplex" cast steel. The chemical composition was selected to obtain in microstructure about of 50% ferrite and 50% austenite. It guarantee the highest properties and the lowest costs of its smelting.
In the paper results of: the microstructure, R_m, $R_{p0,2}$, A_5, HB, wear resistance and corrosion resistance in water solution of 15% HCl and H_2SO_4 acids of new cast steel was presented. They were compared with now applied in HYDRO-VACUUM company "duplex" cast steel.

Keywords: „Duplex" cast steel, Microstructure, Mechanical properties, Abrasive wear, Corrosion

1. Introduction

The name of „duplex" cast steel (steel) was taken with regard to the similarity to the chemical composition, treatment and physicochemical properties of ferritic cast steel (steel) and high corrosion resistance of austenitic stainless steels. Its microstructure is consist of ferrite, austenite and carbides. Over 40 grades cast steel (steel) are part of "duplex" group. They are still developed. It was patented in 1936 in France [1; 11÷14; 16], but its evolution was intensified at the turn of seventies and eighties of 20th century with regard to its application to pipelines and undersea gas pipelines. Now applied "duplex" cast steels (steels) can be divided into five groups:

– lean duplex such as 2304, which contains no deliberate Mo addition,
– standard duplex such as 2205, the work-horse grade accounting for more than 80% of duplex use,
– 25 Cr duplex such as Alloy 255 with PREN less than 40 (PREN – Pitting Resistance Equivalent Number; PREN = % Cr + 3,3(% Mo+0,5% W) + 16% N),
– super duplex (PREN 40 ÷ 45), with 25 ÷ 26% Cr and increased Mo and N compared with the 25 Cr grades, such as 2507,
– hyper duplex, defined as a highly alloyed duplex stainless steel with PREN in excess of 45.

The generalized chemical composition of five groups steels is: 0,025÷0,04% C; 18,0÷30,0% Cr; 1,0÷8,5% Ni; 0,05÷4,00% Mo; 0,8÷6,0% Mn; 0,0÷3,0% Cu; 0,0÷2,5% W; 0,05÷0,40% N. Results from it, that "duplex" cast steels are characterized by very low carbon concentration and very high chromium concentration. An amount of austenite is controlled by chromium, nickel, manganese and copper.

"Duplex" cast steel contains significant amount of relatively expensive additions and insignificant carbon concentration. It has a substantial influence on high charge costs and cast steel smelting.

Thereupon the goal of its paper was devising the new grade of “duplex” cast steel, cheaper than now applied in HYDRO-VACUUM company in Grudziądz.

2. Results

The chemical composition of „duplex” cast steel now applied in HYDRO-VACUUM company is presented in Table 1.

In Table 2 the chemical composition of the new „duplex” cast steel devised in HYDRO-VACUUM company is presented.

Table 1.
The chemical composition of „duplex” cast steel now applied in HYDRO-VACUUM company

Chemical composition, %										
C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu
0,209	0,676	0,923	0,0304	0,0073	22,40	2,56	7,87	0,0154	0,0408	0,0601

Chemical composition, %										
Nb	Ti	V	W	Pb	Sn	As	Ca	B	Sb	Fe
<0,004	0,0086	0,0506	<0,010	0,0072	0,0059	<0,0015	0,0012	0,0019	<0,002	65,1

Table 2.
The chemical composition of the new „duplex” cast steel devised in HYDRO-VACUUM company

Chemical composition, %										
C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu
0,038	1,65	2,77	0,0133	0,0036	24,35	2,08	6,85	0,0084	0,0379	2,76

Chemical composition, %										
Nb	Ti	V	W	Pb	Sn	As	Ca	B	Sb	Fe
0,0052	0,0116	0,287	<0,0100	0,0118	0,0153	<0,0015	0,00086	0,0027	0,0063	59,0

From comparison data presented in Table 1 and 2 results, that new “duplex” cast steel has a different C, Si, Mn, Mo, Ni, Cu and V concentration from now applied. The change of these elements aimed at improving properties of new cast steel. The microstructure of as-cast “duplex” cast steel now applied in HYDRO-VACUUM company and new devised is presented in Figure 1 (a÷d).

Comparison the microstructure of two grades of cast steels shows, that now applied “duplex” cast steel contains of about 25÷30% ferrite (Fig. 1 a, b) and new devised (Fig. 1 c, d) about 45÷55% ferrite. It is in step with literature standards.

In both of cast steels there is the microstructure consists of ferrite, austenite and $(Fe, Cr, Mo, Mn)_xCr_4$ and Mo_2C complex carbides. Complex carbides are separated on ferrite grains boundaries. Both of cast steel grades were supersaturated at the temperature of 1070°C/5,5 h and chilled in water. It caused size reduction of ferrite and carbides precipitates and decrease of carbides amount, like it is presented in Figure 2 (a÷d).

In the new cast steel the coagulation of ferrite precipitations takes place (e.g. Fig. 2 c, d).

As a next cast steel ageing at the temperature of 500°C/6 h and cooling in the air was carried out. The microstructure both of cast steel grades is presented in Figure 3 (a÷d).

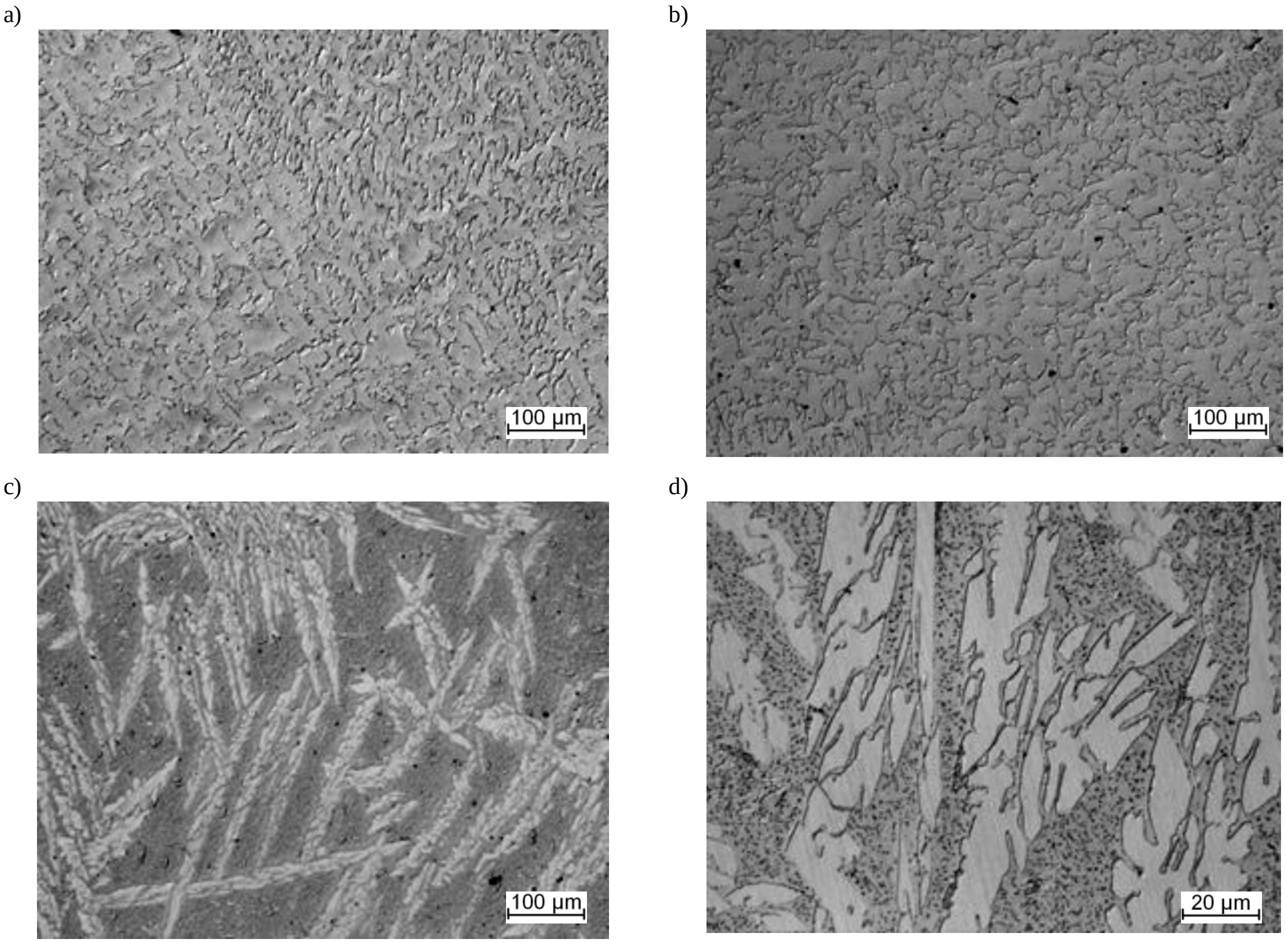

Fig. 1 (a÷d). The microstructure of „duplex" cast steel now applied (a, b) and new (c, d)

a) b) c) d)

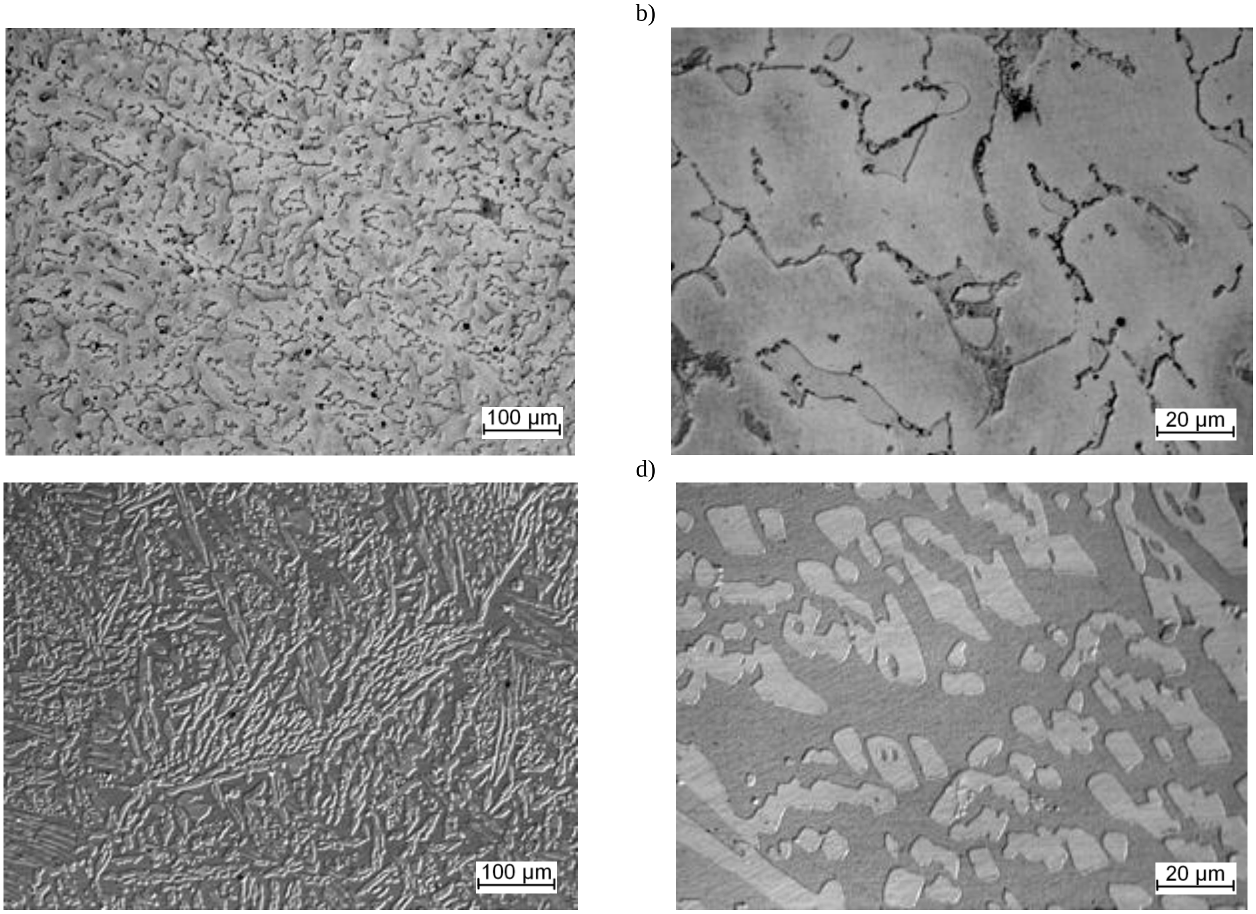

Fig. 2 (a÷d). The microstructure of „duplex" cast steel after solution heat treatment, now applied (a, b) and new devised (c, d)

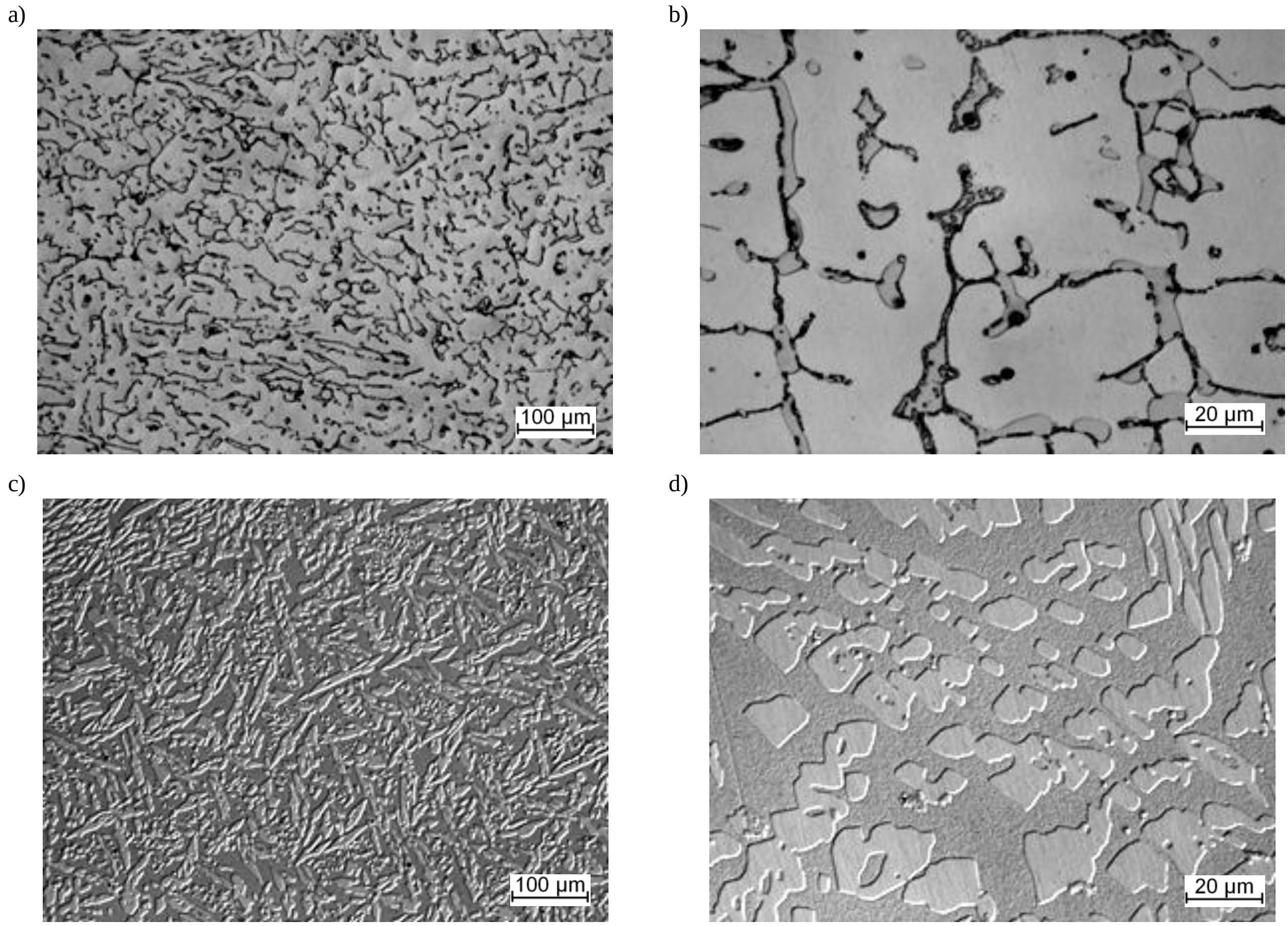

Fig. 3 (a÷d). The microstructure of „duplex" cast steel after ageing, now applied (a, b) and new (c, d)

Comparison both of cast steel grades shows, that in cast steel now applied in HYDRO-VACUUM company reticular precipitation of ferrite and carbides on austenite grains boundaries takes place (Fig. 3a, b) but in new cast steel grainy ferrite and carbides are located uniformly. For the sake of properties it is considerably more advantageous microstructure than previous. Hardness of now applied cast steel is amounted to 185÷210 HB and the new 255÷300 HB. The rest of mechanical properties are as following:

– cast steel now applied in HYDRO-VACUUM company: $R_m \approx 720$ MPa; $R_{p0,2} \approx 510$ MPa; $A_5 \approx 20\%$;
– new cast steel: $R_m \approx 900$ MPa; $R_{p0,2} \approx 620$ MPa; $A_5 \approx 45\%$.

Abrasion resistance of cast steel was tested on special designed and made apparatus. On the rotating at 70 RPM disk P40 abrasive paper was fixed. Specimens were weighted with 10kG. Unit pressure on abrased surface was amounted to 3,6 kG/mm^2. Mass decrease was measured every 30 minutes. In Figure 4 the influence of friction time on mass decrease is presented.

Results from it, that the new "duplex" cast steel has a bit less wear resistance than now applied. It is similar during first ~3 h and after 8 h the wear both of grades approach to oneself. Mass decrease of now applied cast steel after 8 h was amounted to 3946 mg and the new 4068 mg. Thus the difference was amounted to 122 mg, and it practically does not matter for components made of them.

In Figure 5 the mass decrease in water solution of 15% HCl of cast steel now applied in HYDRO-VACUUM company and the new as-cast and after ageing is presented.

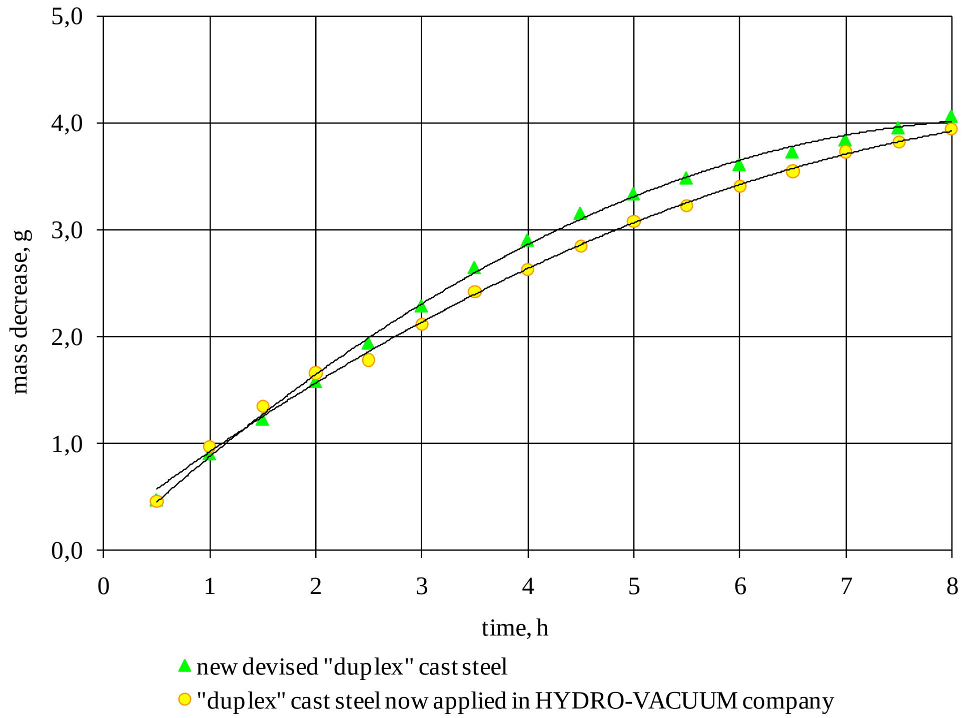

Fig. 4. Abrasive wear of „duplex" cast steel now applied in HYDRO-VACUUM company and the new

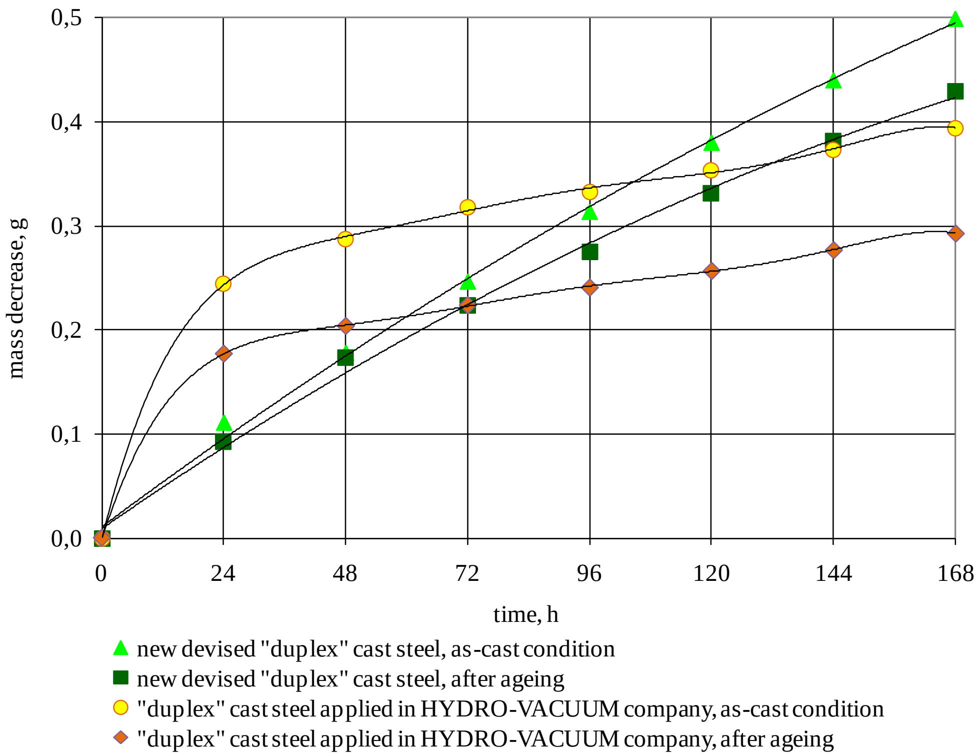

Fig. 5. Mass decrease in water solution of 15% HCl of tested grades of cast steel as-cast and after ageing

Results from it, that better corrosion resistance in water solution of 15% HCl has cast steel now applied in HYDRO-VACUUM company. Probably it is caused by less amount of ferrite in the microstructure, because of its less resistance in dilute hydrochloric acid. Definitely higher corrosion resistance in water solution of 15% H_2SO_4 has the new cast steel. It is presented in Figure 6.

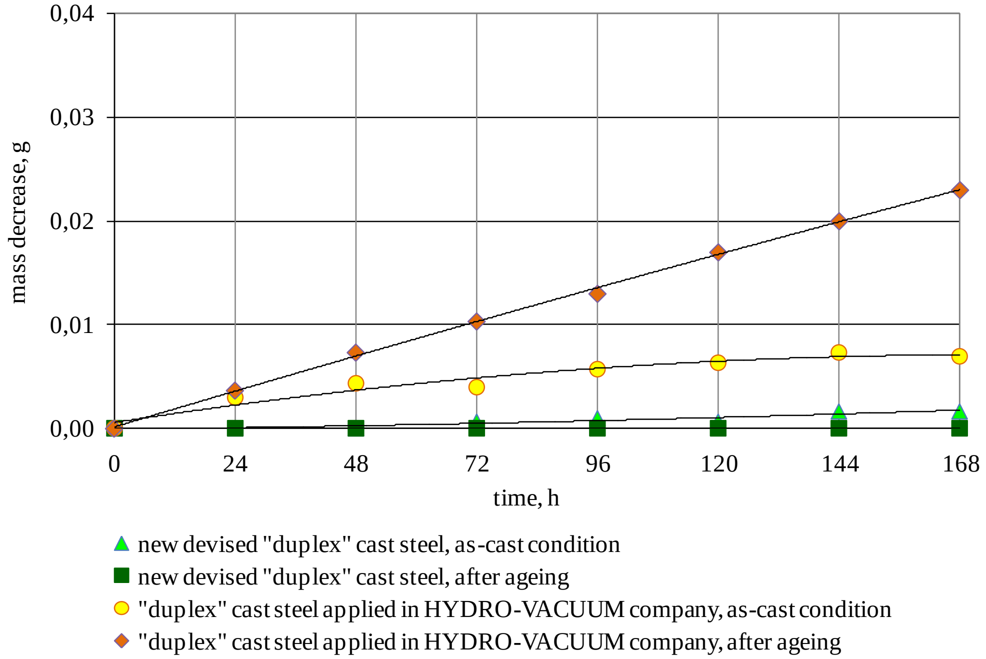

Fig. 6. Mass decrease in water solution of 15% H_2SO_4 of tested grades of cast steel as-cast and after ageing

Results from it, that the new cast steel is more resistant in dilute sulfuric acid than now applied in HYDRO-VACUUM company.

3. Conclusions

Results have indicated the following:

– the chemical composition of new :duplex" cast steel provides lower costs its smelting than new applied in HYDRO-VACUUM company;
– despite a lot of grades of „duplex" cast steel applied all over the world new grades with more advantageous properties than now applied can be devised;
– new devised "duplex" cast steel has a more advantageous microstructure, higher mechanical properties, similar abrasive resistance and corrosion resistance in dilute sulfuric acid than "duplex" cast steel now applied in HYDRO-VACUUM company;
– new "duplex" cast steel has a lesser corrosion resistance in dilute hydrochloric acid than now applied.

Preliminary results of new "duplex" cast steel encourage to its continuation to obtain optimal properties by the lowest costs.

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