Corrosion Resistance of Nickel and High-Chromium Iron Alloys in Turbocharger Application

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Introduction

The goal of this work was to compare the corrosion resistance of nickel alloy NiCr20TiAl to a high-chromium iron alloy in 3M H_2SO_4, individually and in galvanic couple. The study is based on the use of these alloys in the automotive industry, whereas nickel alloys are mainly used in turbochargers and exhaust gases recirculation systems of diesel engines. Nickel alloys are frequently assembled in contact to other metals, producing galvanic couples. In some situations these components fail in field due to corrosion. The studies of the root cause of many failures showed that the sulfur, present in the diesel, react producing sulfuric acid, accelerating the corrosion, whereas it is difficult to understand what subcomponent corroded first and what was the effect of the galvanic couple[1].

This study is based in a galvanic couple that occur in a variable geometry turbocharger. The high-chromium iron alloy is used in a disc that fixes the vanes, produced in the nickel alloy. The vanes move during the running of the engine, guaranteeing that in transient condition the air flow will be adapted to performance and emission level targets of the engine.

The open circuit potential of the materials was measured individually and as galvanic couple, with two different area ratios. Immersion tests were also conducted with the individual materials and with the galvanic couple. The use of immersion tests to evaluate galvanic corrosion was presented by Mansfeld and Kenkel in 1976[2] for aluminum alloys in galvanic couple with several other metals, like silver, copper, zinc, stainless steel and nickel alloys, attempting to show what galvanic pairs were more compatible and what were less. The mass loss results obtained in distilled water, tap water and 3,5% NaCl water solution were compared to galvanic corrosion densities and as a result the authors presented a compatibility list of metals for these specific solutions[2].

Specialists of the automotive industry dedicated in the last years much of their efforts in selecting the most suitable metals to work in the exhaust system of engines, because the applications are getting more and more aggressive and the tests simulating these applications are very complex. There is the possibility of external corrosion due to chloride present in sea atmosphere and present in salts used for deicing streets in countries with rigorous winters. There is the possibility of internal corrosion accelerated by the sulfuric acid formed due to the sulfur present in the diesel. With the increasing use of catalysts there is also the formation of nitric, nitrous, chloride and carbonic acid. Hirasawa et al[3] performed immersion tests in a 80°C condensate with a mixture of acids with different metals. The authors focused in the corrosion depth comparing the results of each metal and suggesting the most suitable for the application[3]. Their work, which is also based in field failure, shows the growing importance of corrosion knowledge and corrosion techniques in the automotive industry.

Experimental

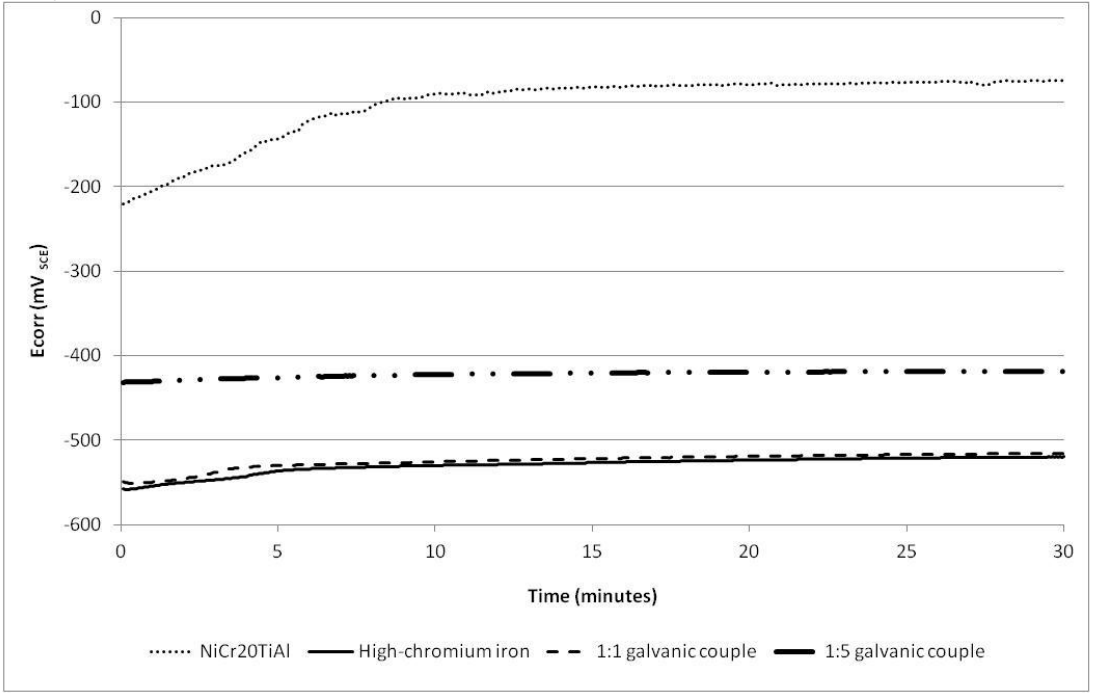
The samples used in the experimental part of this work were removed from turbochargers, more precisely from the disc and the vanes, which are the subcomponents of the variable geometry system. High-chromium iron samples were cut from the disc and NiCr20TiAl samples were cut from the vanes. Table 1 presents the chemical composition of both materials.

Table 1: Chemical composition in % (weight) for the commercial alloys NiCr20TiAl and high-chromium iron.

	C	Si	Mn	Cr	Ti	Al	Fe	Ni	Mo	S
NiCr20TiAl	0,10 max	1,0 max	1,0 max	18,0-21,0	2,0-2,5	1,0-1,5	3,0 max	balance	-	-
High-chromium iron	1,27	2,10	1,11	34,51	-	-	58,6	0,30	2,20	0,28

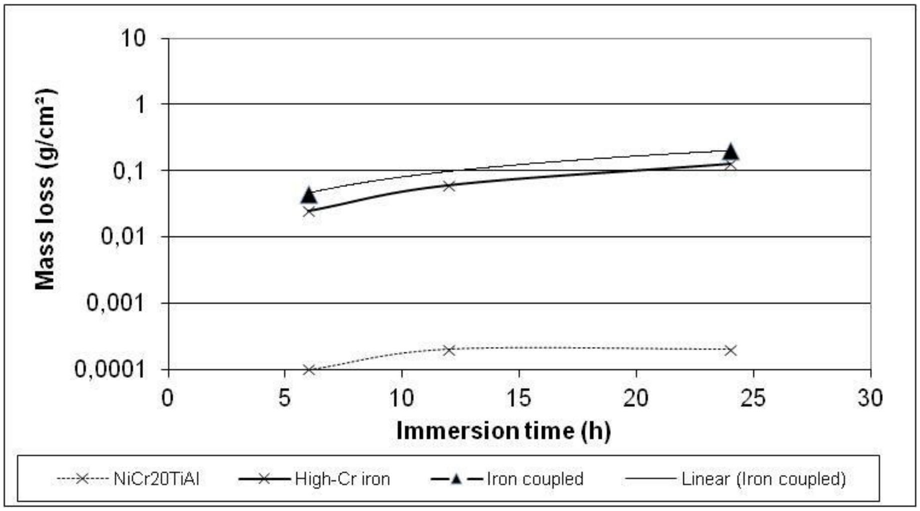
Results and Discussion

Graph 1 presents the open circuit potential for the nickel alloy, the high-chromium alloy and the galvanic couple with 1:1 and 1:5 (NiCr20TiAl) area ratios in measurements done in 3M H_2SO_4 for 30 minutes. After approximately 10 minutes the open circuit potential of the nickel alloy stabilizes in -80mV$_{SCE}$. The high-chromium alloy stabilizes in -520mV$_{SCE}$ after approximately 5 minutes of immersion. The galvanic couple with 1:1 area ratio presents an open circuit potential close to the potential of the high-chromium iron measured individually. A remarkable increase of the open circuit potential to an average values of -420mV$_{SCE}$ can be noticed when the area ratio is modified to 1:5 (NiCr20TiAl), increasing in 5 times the area of the nickel alloy.



Graph 1. Open circuit potential over time for the nickel alloy, the high-chromium alloy and galvanic couples with area ratios of 1:1 and 1:5 (NiCr20TiAl). Measurements were done in 3M H_2SO_4 over 30 minutes.

Graph 2 presents the mass loss after 24h immersion tests in 3M H_2SO_4 for individual and 1:1 area ratio galvanic couple immersion tests. The nickel alloy is passive over time, what is confirmed by the fact that no mass loss could be measured. The results showed that the corrosion of the high-chromium iron alloy increased when in galvanic couple when compared to its individual mass loss result. This result is confirmed by the open circuit potential measurements presented in Graph 1. The rate increased because of the galvanic couple effect, in which the cathodic kinetics of the nickel alloy must be fulfilled[4].



Graph 2. Mass loss measured after individual immersion tests in 1M, 2M and 3M H_2SO_4. The immersion periods were 6h, 12h and 24h.

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References

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