Corr-I-dur® - Gas nitrocarburizing with post-oxidation for industry applications

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1. Introduction

The requirements for corrosion resistance combined with resistance to mechanical wear lead to continuous process improvement. Current processes based on either stainless steels or coatings based on Cr, Ni, Zn, or a combination thereof, do not give acceptable results where processing a large number of parts at a reasonable price is required.

One of the processes that solves this problem to an acceptable extent is nitrocarburizing of steel with subsequent oxidation.

2. Nitrocarburizing and corrosion protection

It is known that surface layers increase the corrosion resistance after nitriding or nitrocarburizing. However, it does not in itself meet the criteria of standard requirements for industrial applications. E.g. salt nitrocarburizing processes meet the current requirement of up to 96 hours in corrosion salt fog test, but this technology is not able to meet the new requirements of the automotive industry for 240 hours and more.

The corrosion resistance of the material is evaluated by the Pilling-Bedworth index (PB). Materials with a PB value < 1 do not form oxide layers with adequate protection, for materials with PB > 2 the layer is already peeling off and does not have a suitable protective effect. This category includes, for example, corrosion on steel, eg **α-Fe**.

Materials with PB from the interval **> 1 to <2** behave optimally in terms of forming a passivation layer on the surface. In this interval, there are also layers formed by iron oxides in combination with nitrides **γ´** or **ε**, or nitrocarbides ensuring the improvement of the corrosion resistance parameter (Table 1). An important finding is that with increasing amount of nitrogen in the **Fe_3O_4 / ε-Fe_2N_{1-x}** layer, PB decreases and corrosion resistance increases

Vrstva	**Pilling-Bedworth Ratio**
Fe_3O_4 / α - Fe	**2,09**
Fe_3O_4 / γ´-Fe_4N	**1,8**
Fe_3O_4 / ε-Fe_2N_{1-x} (7,3 hm.-% N)	**1,79**
Fe_3O_4 / ε-Fe_2N_{1-x} (11,0 hm.-% N)	**1,69**

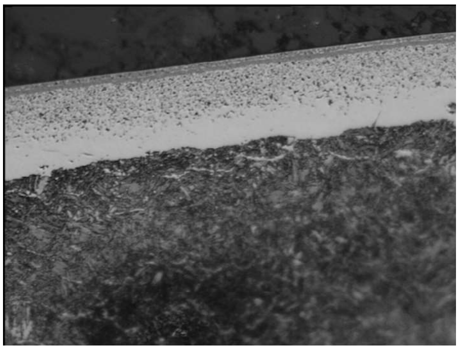
Table 1 *– PB ratio for different combination oxide and nitrides of Fe*

3. Layer characteristics

Fig. 1 shows a typical structure of the Corr-I-dur® layer composed of individual intermediate layers of carbonitrides and **Fe_3O_4** oxide. The optimal layer is a layer that consists mainly of the **ε-Fe_2N_{1-x}** phase, has a thickness of at least 15 µm and a high nitrogen content. The layer should be sufficiently porous in the surface part so as to promote better nucleation of iron oxides during oxidation and to ensure better adhesion of these oxides to the surface.

A layer of **Fe_3O_4** oxides up to **3 µm** thick is formed on this base layer [1], but at least **1 µm**. The oxide layer must be compact with a high density and must not be damaged. There is also a close link to the surface roughness that should be

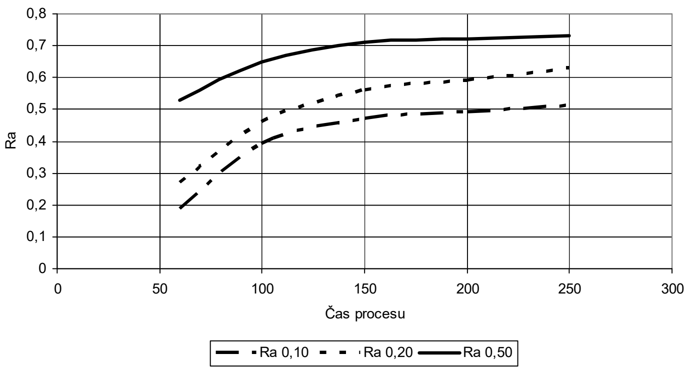
Hardness of the layer, resp. its resistance to wear is given on the one hand by the precipitation of iron nitrides, nitrocarbides and carbides and the alloys present, and on the other hand by the interstitial solid solution of nitrogen in iron **α**.



<u>Fig. 1</u> *– Metallographic picture of Corr-I-dur® layer*

The surface roughness also significantly determines the resulting corrosion properties. Fig. 2 shows a typical application for Corr-I-dur® technology with a highly polished surface in the area of the ball joint and the condition of the polished surface after the corrosion test.

<u>Fig. 2</u> *– The example of Corr-I-dur® application on ball pins before and after corrosion test.*



<u>Fig. 3</u> *- The change of surface roughness during the time of cycle [2]*

It can be seen from Fig. 3 that the surface roughness deteriorates significantly during the nitrocarburizing process. It stabilizes after about 2 hours of the process and does not change significantly. However, this overall change has a negative effect on corrosion resistance. For this reason, an integral part of Corr-I-dur® technology is to restore the surface roughness to its original level, preferably by re-polishing the surface after surface treatment.

4. Equipment

Since the required layer properties (corrosion resistance) can only be achieved under certain defined conditions, in practice this means setting certain technical criteria for the equipment and technology that will ensure the desired result. Fig. 4 shows an example of a set of chamber devices for Corr-I-dur® technology [1], but similar results can be achieved on conventional pit furnaces under the conditions of compliance with the necessary technological parameters (Fig. 5).

<u>Obr. č. 4 a 5</u> *– The set of chamber and pot furnaces for Corr-I-dur®*

5. Conclusion

Corr-I-dur® technology meets the demanding requirements of the automotive industry, both in terms of wear resistance and corrosion resistance. This technology is becoming an excellent tool for increasing the life of car parts. Bodycote managed to solve not only the technological side of the process and its reproducibility, but also the implementation of the entire process in production lines so that the possibility of automation of the entire process increased significantly.

[1] G. Walkowiak, Dieter Muller, Uwe Zeibig – Integration of Corr-I-dur® Gasnitrocarburizing and Oxidizing in Masse Production line for Brake pistons, IFHTSE 2004

[2] Mikael Fällström - Internal presentation Bodycote Plc.