STUDY BEHAVIOR AT DYNAMIC AND STATIC STRAIN OF SOME DOUBLE LAYER MATERIAL

L. Brandusan, A. George, G. Batin

Abstract
Sintered parts are subjected to the contact pressure, very often. This leads to surface degradation and removal them from use. Therefore, the material surface properties improving are necessary, especially resistance to wear and corrosion. Elaboration of double- or multi-layer materials is an appropriate method for this purpose. The method consists in making parts of powder layers, with different properties, and sintered them to gather. Double-layer materials were made with the base of iron powder and the coating of other powders or powder mixtures to study the behaviour of materials at dynamic and static strain. The obtained materials were subjected to tensile, shear, hardness, and contact fatigue tests to establish if these layers change the basic material properties. The experimental results show that coating hardness is always higher than of the basic material. In the same time, these layers improve tensile strength also. It was highlighted the coating layer adhesion to base material under static and dynamic strain by shear and contact tests.

Keywords: sintered materials, mechanical properties, contact fatigue

INTRODUCTION
There have been a constant concern to obtaining materials with superior surface properties to those of the starting material, especially with higher resistance to wear and corrosion in the last years. There were identified several techniques to achieve these layers, some of them applying the final phase of processing, such as deposition plating, welding, thermal spraying, PVD and CVD, plastic material deposition, etc. [1].

The making of multilayer structures was intended to confer on the material higher corrosion resistance, physical properties, resistance to wear and/or contact fatigue resistance [2,3]. Thus, it can get an increase of the material performance properties by improving properties and saving some costly elements of the basic material. Certain types of layers can be obtained by specific methods of powder metallurgy. Often, these procedures apply in the process of forming parts, by bilateral pressing of powders or by co-injection of different powder types [2,3,4]. Research has pursued the development of mixture powder or pre-alloyed powder layers on the surface of iron powder materials and characterization of obtained materials.

DOUBLE-LAYER MATERIALS ELABORATION
There were used DWP 200 iron powders as base, the coating mixtures are presented in Table 1 to obtaining the double-layer materials. It was added 0.4% carbon as graphite to some of the coating layers to increase carbon content and mechanical properties. The introduction of nickel in this layer was intended to improve resistance to corrosion, abrasion, and high temperatures [5]. The association of nickel with copper, molybdenum,
and carbon in iron powder leads to materials with superior mechanical properties. This combination is present in high alloyed Distaloy AE (Fe-4Ni-1.5Cu-0.5Mo) iron powder.

Chromium steels is of great importance only when it is combined with carbon, since these steels can be heat treated and chrome contribute to hardening of ferrite. Fine powders of chromium or pre-alloyed ferrochromium are recommended to obtain a homogeneous chemical structure for superior results. Use of chromium powder was made with the intention of achieving layers characterized by hardness and corrosion resistance as high as possible.

Mixture of powders for coating layers was homogenized for 15 minutes in a TURBULA type homogenizer. The iron powder and powder mixtures were bilateral pressed with 600 MPa and sintered at 1120°C for 30 minutes in dissociated ammonia. Obtained sample porosity was between 7-10%. The specimens had a cylindrical shape or tensile test shape. The cylindrical ones were used for contact fatigue resistance and shearing tests at the level of segregation between the two layers. The coating layer thickness was of 2 mm for all specimens.

**EXPERIMENTAL PROCEDURE AND RESULTS**

The specimens were analysed from structural point of view and from mechanical properties point of view. Structural analyses intended to identify the defects at the level of contact surfaces (pore, clusters, and fissures). These defects can have a strong negative effect on mechanical properties and, specially, on contact fatigue resistance. There may appear clusters of aligned pores or fissures at the contact level between layers in the case when forming process was not done in the best conditions. Forming of these pores is a result of the fact it was not a proper interpenetration of covering powder layer on base layer due to the friction between particles, even at the compaction pressure, conducting to the larger pores. The presence of large pores and pore clusters at the interface between neighbouring layers of powder makes contact surface to be reduced and influencing the diffusion processes and mechanical properties of obtained materials. After sintering, due to differential layers contraction, these defects can transform into cracks, which may include the entire area of contact (Fig.1). During of a corresponding forming process a sintered material without identified defects in the two layers is obtained (Fig.2). Section of these materials has a continuity of the iron matrix. Chromium grains contended in the Fe-Ni matrix are observed, particles of chromium form stable oxides on the surface stopping diffusion process and not alloy with iron and nickel in the coating layer of the material presented in this figure as in [5].

![Fig.1. The presence of cracks on the surface of a sintered double-layer material.](image1)

![Fig.2. Contact surface aspect between layers in sintered material section.](image2)
Mechanical properties of obtained materials are presented in Table 1. Analysis of these results shows that the highest hardness presents the layers with nickel. It is noted, increasing nickel content increases the hardness. This fact is confirmed by other researchers, which pointed out the fact the nickel has the greatest influence on ferrite hardening after phosphorus, silicon, and manganese. This is due to the fact during sintering appears a diffusion process, especially of iron into nickel, resulting an austenitic structure at the border of iron particles. Nickel diffusion is faster at the grain surface limit and along grain limits, and slower inside the iron grains [5].

<table>
<thead>
<tr>
<th>Crt. No.</th>
<th>Composition of coating layer</th>
<th>HV10</th>
<th>$\tau_r$ [Mpa]</th>
<th>Rm [Mpa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Distaloy AE</td>
<td>160</td>
<td>140.5</td>
<td>285</td>
</tr>
<tr>
<td>2.</td>
<td>DWP 200+4% C</td>
<td>80</td>
<td>103</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Distaloy AE+4% C</td>
<td>165</td>
<td>145</td>
<td>308</td>
</tr>
<tr>
<td>4.</td>
<td>70Ni+30Cr</td>
<td>91</td>
<td>95</td>
<td>285</td>
</tr>
<tr>
<td>5.</td>
<td>60Ni+30Cr+10Fe</td>
<td>97</td>
<td>97</td>
<td>-</td>
</tr>
<tr>
<td>6.</td>
<td>55Ni+25Cr+20Fe</td>
<td>105</td>
<td>105</td>
<td>264</td>
</tr>
<tr>
<td>7.</td>
<td>50Ni+20Cr+30Fe</td>
<td>119</td>
<td>102</td>
<td>275</td>
</tr>
<tr>
<td>8.</td>
<td>40Ni+20Cr+40Fe</td>
<td>127</td>
<td>98.5</td>
<td>216</td>
</tr>
<tr>
<td>9.</td>
<td>Fe+5Ni</td>
<td>98</td>
<td>112</td>
<td>-</td>
</tr>
<tr>
<td>10.</td>
<td>Fe+10Ni</td>
<td>107</td>
<td>108</td>
<td>-</td>
</tr>
<tr>
<td>11.</td>
<td>Fe+20Ni</td>
<td>116</td>
<td>104</td>
<td>239</td>
</tr>
<tr>
<td>12.</td>
<td>Fe+30Ni</td>
<td>128</td>
<td>114</td>
<td>240</td>
</tr>
<tr>
<td>13.</td>
<td>Fe (DWP 200)</td>
<td>71</td>
<td>-</td>
<td>150</td>
</tr>
</tbody>
</table>

Use of rich alloyed powders as Distaloy AE and Distaloy AE+4% C to realise the coating layer, containing nickel in its composition, conducts to obtaining of the highest hardness. This hardness is determined, on one side, by the material homogeneous structure and, on the other side, by copper in iron content, contributing to the supplementary ferrite hardness. In the case of these steels, copper and molybdenum diffusion is faster and takes place deep inside the iron grains.

For shearing strength test ($\tau_r$) of the coating layer was used a special device adapted on the GALDABINI tensile testing machine. Shearing strength at the level of contact surface of the deposited layer on basic material expresses the measure of strength at which can detach due to the forces appearing during service. Obtained results show the lowest adherence for the layer with chromium powder content. The chromium grains preserve their identity, due to the chromium diffusion less process, reducing connections between layers. The obtained layers of iron and nickel powders present approximatively the same adherence. It is limited by the limited diffusion of the nickel in iron during sintering. The best adherence was obtained for layers formed by Distaloy AE alloyed iron powder; they present a homogeneous structure and, together with nickel, contain other elements (Cu, Mo), diffusing faster in iron, making better connections between layers.
Coating layer made of mixtures of iron powder with nickel powder or alloyed powder have the best tensile strength. This is due to the better mechanical properties of the surface layer and of the superior adherence between them, as a result of nickel diffusion and iron self diffusion.

Contact fatigue test was done on a special testing machine using specimens of the shape and dimensions presented in Fig. 3. This machine allows gripping the specimen between three contact rollers arranged at 120°, assuring on each role a Hertzian pressure of 160 MPa. One of contact roller gives a 1,500 rotation/minute providing a frequency of application of 4,500 cycles / minute. The test lasted for 1 hour. The Hertzian pressure generates in material a variable tangent stress, attaining the maximum under the contact surface level. In this case the calculated maximum tangential tension is 20 µm below the contact surface.

It was found that the same application and numbers of cycles, degraded surface layer is lower in AE Distaloy+4% C than in the case of the case of the 60Ni+30Cr+10Fe layer (Fig.4). This is due to the fact the shearing strength is bigger in the first than in the second case. It is noticed pinches of the surface of material, representing small detachment of material, constituting the start of forming fissures, which will determine detaching
covering layer. The highest pinching concentration is noticed on the surface of the layer formed of 60Ni+30Cr+10Fe, which demonstrates a bigger sensibility of this material to the contact fatigue.

![Image](image.jpg)

Fig.5. Fissure propagation through the material subjected to the contact fatigue (layer of 60Ni+30Cr+10Fe).

Fissure forming, developing, and propagating in subjected to contact fatigue stress layers starts in the zones with imperfections and where the Hertzian pressure generates a shear stress, which exceeds the breaking strength of the material [6,7]. These fissures propagate through the coating and merge with other leading to its detachment from the basic material. Degradation process can occur in layers, successively, as shown in Figure 5.

**CONCLUSIONS**

Materials having a covering layer with high nickel contain or are of high alloyed iron contain have the highest hardness and adherence. Tensile strength is greater for materials presenting a layer of high alloyed iron powder. Contact fatigue resistance is bigger for materials presenting the layer with the highest adherence. Layer detaching is made by primer fissure propagating from a defect or a stress concentrator situated most common on the material surface.

**REFERENCES**

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