

**TECH SPOTLIGHT**

Furnace fusing of nickel-base hardface coatings

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Fusing is a remelting step during which the as-sprayed coating becomes more dense. It eliminates virtually all the pores that were present during the initial spraying step, and enhances the ability of the coating to resist corrosive attack from aggressive fluids. Furnace fusing offers several advantages over other fusing options, including reduced labor time, minimized distortion, and consistency on parts having complex geometry.

Furnace fused coatings of self-fluxing alloys have been successful in many applications, such as petrochemical gate and ball valves, plastics extrusion screw segments, agricultural blades and disks, and mine teeth and sizer screens. This article describes the furnace fusing process and compares it with other fusing methods.

**Furnace fusing alloys**

Wear resistant, self-fluxing alloys are metallurgically defined as the NiCrBSiC type, and each alloying element has a very specific function during the fusing process. Chromium enhances corrosion resistance and helps the formation of chromium borides. Boron and silicon depress the melting point to enable fusing at a reasonable temperature without melting the substrate; they help in the formation of hard borides/silicides for abrasion resistance; and they also help in the self-fluxing action during fusing. The table shows several common alloys suitable for furnace fusing.

The NiCrBSiC alloys can be applied alone, or they can be blended with tungsten carbide-cobalt (WC-Co) powders for enhanced abrasion resistance. During fusing, the carbides become embedded in the NiCrBSiC matrix to provide additional wear resistance.

**Fusing steps**

Fused nickel-base hardface coatings are usually applied in a two-step process: thermal spray and then post-spray fuse. The fusing step is critical to developing the best features of nickel-base coatings.

The sprayed coating is fused by reheating it to a temperature between the solidus and liquidus. At this temperature, the coating reaches a semi-solid state at which the material becomes densified and oxides are fluxed, a metallurgical bond is developed, and hard phase precipitates.

Oxides, which are generally formed during the initial spraying step, are reduced during the fusing step. Reducing or eliminating oxides from the coating is beneficial because oxides are paths for corrosive attack. The fusing step allows the oxides to be "fluxed," meaning that it allows the formation of borosilicate compounds, which rise to the surface and are removed from the coatings.

Prior to the fusing step, the as-sprayed coating has the limited strength of a mechanical bond with the substrate. The fusing step enhances some diffusion between the coating and the substrate, and creates a much stronger metallurgical bond if done properly.

Metallurgical reactions are beneficial because the fusing step is completed at temperatures between the solidus and liquidus. These metallurgical reactions cause a significant amount of hard phase (carbides/borides and combinations) to be precipitated in the matrix of the coating. Upon cooling after the fusing step, these hard phases remain in the coating and provide excellent abrasion/wear resistance. In general, nickel-base coatings can be tailored to have hardness anywhere in the range between HRC 35 and 65, depending on application requirements.

**Types of fusing methods**

The three common fusing options are an oxy-fuel flame, induction heating, and hydrogen or vacuum furnaces.

Fusing by means of a handheld oxy-
fuel flame torch is cost-effective only if parts are small and quantities are limited, because the handheld torch method is labor intensive. It is also virtually impossible to provide uniform heating to a manually fused part.

Induction fusing is well-suited for multiple parts having simple geometries. However, it is difficult to uniformly induction-fuse the coatings on parts having complex geometries.

On the other hand, furnace fusing has none of these drawbacks. Some of the advantages of furnace fusing are:
* Double sided parts, such as oil-field well-head-valve gates, may be successfully fused without problems.
* Multiple parts can be processed in one batch. This is especially advantageous for small parts in batches of several hundred, for which manual fusing would be time- and labor-intensive.
* Consistent fusing is possible, especially for complex geometric parts, because of precise temperature control between the solidus and liquidus.
* A thicker coating may be developed, which leads to longer service life. For example, with torch fusing, the maximum coating thickness is approximately 0.070 inch, compared with 0.200 inch for furnace fusing.
* Uniform cooling minimizes distortion and other harmful thermal stresses to the part. It also allows special treatments for alloy steels such as AISI 4130.
* Slow, uniform heating in a non-oxidizing environment, under instrument control, leads to excellent bonding. It also permits:
  * Easy handling of safety-critical high-integrity parts such as railway couplings and suspension components, as well as oil-field well-head gates and seats.
  * Easily fused coatings on difficult base metals such as 500 series stainless steel, Nimonic 75, 17-4 PH, and cast iron.
  * Improved handling of batches of large parts, which are extremely difficult to heat uniformly by manual fusing methods.

**Other fusing alloys**

Nickel-base alloys are the most prevalent of the self-fluxing alloys in terms of wide applications and cost. Some cobalt-base alloys are also self-fluxing, but due to the higher cost of cobalt and limited advantages over nickel, these alloys are used only in limited applications.

On the other hand, iron-base alloys of this type may be more economical, but have not been developed well enough to function at the level of nickel-base alloys.

### Furnace fusing alloys

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Nominal composition</th>
<th>Fused hardness, HRC</th>
<th>Fusing temperature, °F (°C)</th>
<th>Resistance to the following, where 1 provides the highest resistance and 4 provides the lowest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colmonoy 4</td>
<td>C 0.40, Cr 10.00, B 2.20, Si 2.30, Fe 2.50 Ni Balance</td>
<td>35-40</td>
<td>1925 (1050)</td>
<td>4 2 2 3</td>
</tr>
<tr>
<td>Colmonoy 5</td>
<td>C 0.50, Cr 13.80, B 2.30, Si 3.40, Fe 4.80, Ni Balance</td>
<td>45-50</td>
<td>1880 (1025)</td>
<td>3 2 3 3</td>
</tr>
<tr>
<td>Colmonoy 6</td>
<td>C 0.70, Cr 14.30, B 3.00, Si 4.20, Fe 4.00, Ni Balance</td>
<td>56-61</td>
<td>1890 (1030)</td>
<td>1 1 4 1</td>
</tr>
<tr>
<td>Colmonoy 62</td>
<td>C 0.60, Cr 15.00, B 2.80, Si 4.50, Fe 4.00, Ni Balance</td>
<td>56-61</td>
<td>1875 (1025)</td>
<td>1 1 4 1</td>
</tr>
<tr>
<td>Colmonoy 69</td>
<td>C 0.55, Cr 16.50, B 3.60, Si 4.80, Fe 3.00, Cu 2.10, Mo 3.50, Ni Balance</td>
<td>58-63</td>
<td>1890 (1030)</td>
<td>1 1 4 1</td>
</tr>
<tr>
<td>Colmonoy 88 **</td>
<td>C 0.80, Cr 15.00, B 3.00, Si 4.00, Fe 3.50, W 16.50 Ni Balance</td>
<td>59-64</td>
<td>2020 (1100)</td>
<td>1 1 3 1</td>
</tr>
<tr>
<td>Colmonoy 98 **</td>
<td>C 0.60, Cr 8.00, B 3.20, Si 4.20, Cu 2.50, Mo 2.00, Nb 2.00, Ni Balance</td>
<td>65-60</td>
<td>1860 (1015)</td>
<td>2 1 3 1</td>
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<tr>
<td>Colmonoy 64</td>
<td>C 2.50, Cr 9.00, B 1.70, W 33.00, Si 2.90, Fe 2.30, Co 4.80, Ni Balance. (40% tungsten carbide particles)</td>
<td>58-63</td>
<td>1950 (1065)</td>
<td>1 2 4 1</td>
</tr>
<tr>
<td>Colmonoy 75</td>
<td>C 2.90, Cr 7.50, B 1.40, W 41.40, Si 2.40, Fe 2.50, Co 6.20, Ni Balance. (50% Tungsten Carbide Particles)</td>
<td>58-63</td>
<td>1950 (1065)</td>
<td>1 2 4 1</td>
</tr>
<tr>
<td>Colmonoy 750</td>
<td>C 3.00, Cr 6.80, B 1.40, Si 8.00, Fe 2.40, Co 6.10, W 56.80, Ni Balance. (50% tungsten carbide particles)</td>
<td>58-63</td>
<td>1960 (1070)</td>
<td>1 2 4 1</td>
</tr>
</tbody>
</table>

* U.S. Patent No. 5,141,571 **U.S. Patent No. 5,183,636 Source: Colmonoy Alloy Selector Chart, Technical Data Sheet Tech-1

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**References/acknowledgements/bibliography:**

Colmonoy® technical data book.

Verbal communications with Dr. S. Rangaswamy, Director of Technical Services and Quality, Wall Colmonoy Corporation.

Verbal communications with David Bielec, Manager of Technical Services, Wall Colmonoy Corporation.

Written communications with Peter Walter, Technical Consultant, Wall Colmonoy Limited.