THERMAL SPRAYED COATING

Process

In thermal spraying, molten and semi molten coating materials are sprayed on to a substrate, where they solidify and adhere to the surface. To do this operation, a gun is used either in a combustion flame, a plasma arc, or an electric arc, melts and propels coating material in finely divided form towards the part to be coated. Heating of the coating material is done through different methods namely: oxyfuel flame, electric arc, and plasma arc. Initial form of the coating material are either wire or rod, or powder. Examples of different coating materials used in this process are, pure metal and metal alloys, ceramics (oxides, carbides and certain glasses), other metallic compounds (sulfides, silicates), cermet composites and certain plastics (epoxy, nylon, teflon and others). Various substrate materials are metal ceramic, glass, some plastics, wood and paper.

Typical characteristics and applications

The thickness of sprayed deposit is usually lies between 0.05 mm and 2.5 mm. Sometimes it may go upto 6 mm and occasionally as high as 25 mm. These coatings are generally porous in nature and the degree of porosity depends on the method of spraying. Porosity is desirable in bearing applications as these pores provide the means of lubricants. Porosity in combustion-flame coatings ranges from 6 to 13 %, in plasma-arc coatings from 1 to 12% and in detonation-gun coatings from 0.25 to 1 %. Thermal-sprayed coatings are significantly harder than the parent coating materials and hence, exhibit superior wear resistance. But these exhibit low ductility and reduced tensile strength. There is no restriction on part size for the applicability of thermal-sprayed coatings. Common purposes for using thermal-sprayed coatings are employed to provide corrosion protection, wear-resistant surfaces, to salvage worn or undersized parts, to provide electrical contact and electrically conductive surfaces, and to provide heat-oxidation protection.
Suitable materials

Coatings:

Any material that can be melted without decomposing can be used for thermal sprayed coating. Different categories of such materials are

1. Pure metals- Aluminum, zinc, nickel, refractory metals, etc.
2. Alloys- Steel, cobalt and nickel-based superalloys, hard-surfacing and self-fluxing alloys, etc.
3. Compounds- Aluminum oxides and other metal oxides, carbides, cermets, and nitrides, etc.
4. Composites and blends - Admixtures and combinations of two or more of the above in a single powder. Cobalt-bonded tungsten carbide and nickel-clad graphite comes under this category.

Substrates:

Commonly used substrate is metal but other materials like ceramic, glass, concrete, plaster, carbon wood, plastic, rubber, or cloth also can be used.

Bonding coatings:

Sprayed coating is applied over the bonding coating. In bonding coating, materials adhere to a clean, smooth surface which will not be subjected to mechanical roughening or grit-blasting. This approach has advantages of reduction in pre-coating surface preparation, which is costly and adversely affect the workpiece. In addition, it provides resistance to bond failure. It is important in many applications. For example, when it is necessary to machine or grind the coating to a featheredge. Molybdenum is the major bond-coating material.

Design recommendations

The following recommendations need to be followed for providing proper coatings.

1. If the primary coat is not self-bonding, the coating is applied through the plasma gun and a thickness less than 0.25 mm is recommended, with the use of a blasted surface.
If the application requires a coating thicker than 0.25mm, a bond coat is recommended and then the topcoat is applied.

2. For machine-design work, when the primary coating is not self-bonding and is applied through a wire or powder combustion gun, then it is always recommended to design for a bond coat. If the required coating thickness is less than 0.25mm, it is advisable to use an undercut greater than 0.25 mm to allow for the thickness of a bond coat.

3. If design requires a thick coating then, it is sometimes advisable to use a low-cost intermediate coat between the bonding coat and the topcoat. Recommended bond coat thickness is 0.075 to 0.12 mm. Coating materials need to be selected to avoid galvanic corrosion between layers.

![Diagram](image)

Figure M5.5.1: Avoid exposed edges of flame-sprayed coatings and also feather edges.

4. Few coatings can serve both the purpose of adhesion of bonding coatings and the functional properties of top coatings. Separate adhesion coating is not required in such cases. It is preferred to avoid exposing of edges of flame sprayed coatings and also
feather edges. Surfaces held by undercuts at the edges are the best. (Refer Figure M5.5.1.)

Depth of internal surfaces that can be used for flame sprayed is to be decided based on recommended values. In case, the opening is large enough for a spray-gun extension, no length restriction is put, otherwise the maximum coating depth is two-thirds of the diameter of the opening, as shown in Figure M5.5.2.

![Figure M5.5.2: Limitations on the depth of internal surfaces for flame spraying](image)

5. It is advisable to design the workpiece to facilitate handling. For example, if a cylindrical part is designed, a means must be provided by which it can be rotated: centers, flanges, etc. A sheet-metal stamping could be partially sheared through to allow handling a continuous strip rather than individual parts at the spraying operation. Irregular parts should include a locating hole or other means for easy orientation.

![Figure M5.5.3: Nested parts during flame spraying to reduce over spray losses.](image)
6. Parts are designed in such a manner that they can be nested together during flame spraying to reduce overspray losses as illustrated in Figure M5.5.3.

To ensure adequate strength, the coated parts to be press-fitted and the coating should be at least 0.13 mm thick. For rotating shafts, recommended minimum coating thicknesses for average conditions of wear and finish machining are provided in Table M5.5.1.

**Table M5.5.1:** Recommended Minimum Thickness of Thermal-Sprayed Coatings on Shafts (Source: Design for Manufacturability Handbook by James G Bralla, 2nd Ed)

<table>
<thead>
<tr>
<th>Shaft diameter, mm</th>
<th>per side, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 or less</td>
<td>0.25</td>
</tr>
<tr>
<td>25–50</td>
<td>0.38</td>
</tr>
<tr>
<td>50–75</td>
<td>0.50</td>
</tr>
<tr>
<td>75–100</td>
<td>0.63</td>
</tr>
<tr>
<td>100–125</td>
<td>0.76</td>
</tr>
<tr>
<td>125–150</td>
<td>0.89</td>
</tr>
<tr>
<td>150 or more</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Figure M5.5.4:** Design for grooving a shaft for flame-sprayed coatings.

Coating thickness on internal surfaces should be kept low. The presence of shrinkage forces in flame spraying has a tendency to separate thick coatings on internal surfaces from the work piece. Further, coatings below 0.08 mm are not recommended because thickness uniformity
cannot be controlled properly. A roughened or grooved surface is advisable to ensure adequate adhesion in flame-sprayed coating. Groove scan be either annular or helical. Knurling at the tops of the ridges produces a dovetail undercut that further ensures a strong bond. Figure M5.5.4 illustrates the recommended groove design for a shaft to be coated.

**DIMENSIONAL FACTORS**

The surface finish of flame-sprayed coatings ranges from 1.0 to 10.0 µm rms. The surface finish and the accuracy of coating thickness depend on a number offactors.

- Uniformity of speed of spray-gun movement.
- Nature of surface preparation
- Shrinkage of coating material

The normal variation of coating thickness under controlled production conditions ranges between 0.05 mm to 0.13 mm.