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Machining and Mechanical Engraving of Copper Thermal-Sprayed Coatings

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Copper rolls and copper thermal spray coated rolls are being used throughout the printing industry. Copper is the material of choice for printing rolls that are subsequently machined, mechanically engraved, and hard chrome plated. However, there are several limitations associated with the application of copper thermal spray coatings, especially onto copper substrates at thicknesses greater than 0.015 in. This article presents thermal spray techniques that will improve the coating quality of copper coatings. These techniques reduce the oxide content, lower the porosity level, and produce a coating with a more desirable hardness range that allows for improved machining and easier mechanical engraving of copper coatings.

Keywords copper thermal spray coatings, engraving, low oxide content

1. Introduction

Copper mechanically engraved rolls are used in the printing of corrugated boxes, paper bags (used in department or grocery stores), and heavy two-ply paper bags used in the packaging of products. Copper is applied onto copper mechanically engraved rolls when either the journals, the roll faces, or the mechanically engraved pattern has worn out and needs to be built back to a specific dimension and brought back to within concentricity. The process begins by preparing the surface for the copper thermal spray coating. This consists of a 0.015 in. deep, 20 threads per inch machine cut. The machine threads are then grit blasted with a coarse medium at a low pressure of 60 to 70 psi. The low grit blasting pressure ensures that grit media do not become embedded in the copper roll.

The thermal spray process begins immediately after grit blasting. For large parts, such as the 24 in. diameter by 46 in. long roll shown in Fig. 1, which requires a large amount of copper material (over 100 lb), arc spraying is the process of choice. Arc spraying is popular because of low operating cost, high throughput capability, and the ability to produce high-quality copper coatings.

After the coating has been sprayed, it is machined to a specific dimensional tolerance and a precise surface finish. Many copper coatings are machined by using carbide inserts and removing 0.005 to 0.010 in. per cut by cutting at a 250 to 500 surface feet per minute (fpm) speed. Removal of 0.010 to 0.015 in. thickness of coating brings the surface finish down to within a 16 to 32 rms.

The coating is then mechanically engraved with a 30° or 45° angle, 0.0005 in. deep cell pattern at 165 to 400 lines/in. After mechanical engraving, the roll is hard chrome plated with a flash coat of hard chrome plate of 0.0002 to 0.0003 in. thickness.

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2. Selection of Copper Coatings

Copper is selected for this application because of its low hardness, which allows it to be machined and mechanically engraved. Copper is a very malleable material, that performs extremely well in the printing press application. Copper is also a conductive material, which is an added benefit during the plating process.

However, there are several limitations associated with the application of copper thermal spray coatings. First and foremost is its adhesion to the part. The bond strength of copper is only 1450 psi, as measured by ASTM-C633. This places the adhesion of copper as only one third of a stainless steel coating and only one sixth of a nickel aluminum bonding material. Therefore, keeping the oxide content and porosity levels to a minimum is not only important for machining and finishing characteristics, but it is also important for adhesion to the part.

Copper oxidizes immediately after and during spraying. Figure 2 depicts a HVOF system applying a copper coating onto a roll. The brownish area on the roll illustrates that a

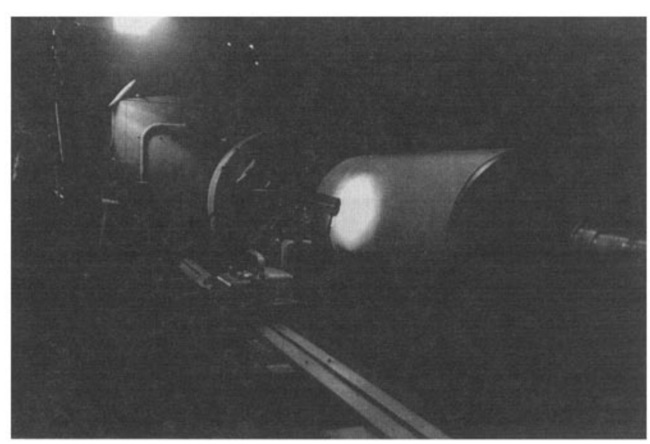

Fig. 1 Copper thermal spray coating of mechanically engraved rolls. Copper arc spray coating is being applied onto a large roll 24 in. diam by 46 in. long. More than 100 lb of copper material is applied to this roll to bring it back into dimension and concentricity.

highly oxidized layer has developed in the coating in just one and a half passes. This highly oxidized layer in copper coatings lowers the bond strength, and the coating will exhibit hardness variations. Coating hardness variations indicate that additional pressure and point contact will be needed to machine the coating. This combination of additional pressure and a low bond strength results in a tendency for coatings to crack and separate from the roll. Figure 3 shows a copper coating failure that occurred during the machining of a highly oxidized copper coating. Several spraying techniques and methods are recommended to minimize copper coating failures.

3. Techniques and Methods to Improve Coating Quality

It is essential to spray at appropriate speeds and feeds. The speed at which the part is rotating in the lathe needs to be coordinated with the amount of material (coating) that is being deposited onto the part. These two factors need to be coordinated with the rate at which the gun is traversing across the part. Copper has a tendency to build up additional residual stresses at temperatures of 300 °F and above. The buildup of heat in the process can be controlled by maintaining the proper spray distance. Figure 4 shows a spraying setup in which a 6 in. standoff from the roll face to the front end of the arc spray gun has been incorporated. Decreasing the spray distance to 4 in., the distance at which most conventional arc spraying occurs, would cause too much heat buildup in the part, thereby reducing bond strength and producing residual stresses in the coating, leading to possible cracking and spalling. Increasing the spray distance from 6 in. to 7 or 8 in. allows the molten copper material to dwell longer in the compressed air stream, thus permitting the development of more oxides in the coating and producing a harder, more difficult to machine coating.

Table 1 Coating quality improvement comparison

	Porosity, %	Oxide, %	Microhardness, HV
Typical arc sprayed Cu coatings	8.35	6.35	153
Special techniques	6.8	6.1	138
Percentage improvements	19	4	10

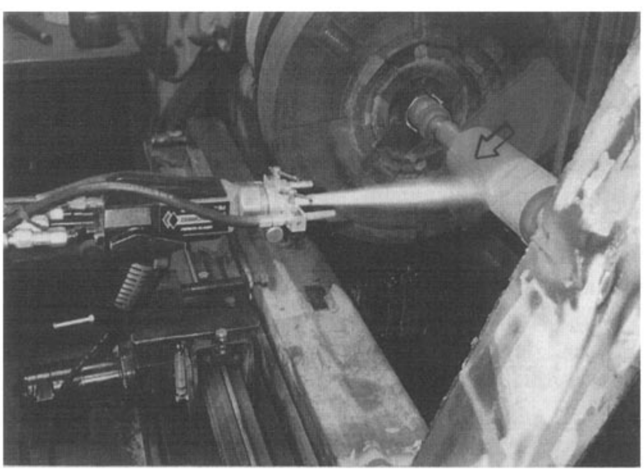

Fig. 2 Copper thermal spray coating oxidation. HVOF system applying a copper coating. Note the darkish area, which depicts how rapidly copper coatings can oxidize. This increased oxidation in the copper coatings will result in a harder, more difficult coating to machine.

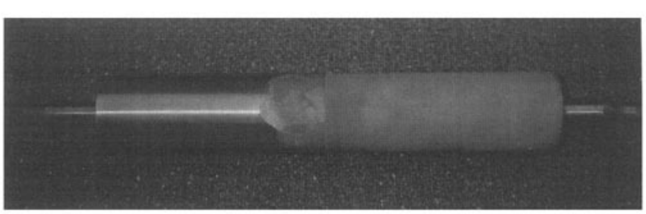

Fig. 3 Typical copper coating failure. A highly oxidized copper coating typically results in coating failures. This photograph illustrates what can happen to a copper coating during machining when additional pressure and point contact are implemented into the coating during the machining stage. The added pressure was necessary because the coating was harder than it should have been.

Another technique designed to help dissipate heat buildup during the process is spraying in one direction. For instance, spraying onto a roll begins while a part is rotating in a lathe at the head stock and continues to the tail stock. Once the gun and manipulator comes off the part at the tail stock, the arc spraying gun is shut off, and the gun and manipulator are brought back to the head stock where spraying begins again. Therefore, spraying directly onto an area that has just been sprayed increases the potential of the part to obtain temperatures of 300 °F and above.

Another method of improving coating quality is the use of an oxidation preventative coating. For example, a coating of either zinc or aluminum can be applied on top of the copper coating to decrease oxidation of the copper coating during the transfer of the roll to the machining facility. Zinc or aluminum are preferred because they are easy to apply, economical, and have excellent corrosion resistance. These materials also can be machined easily.

The optimum spraying procedure would cover 0.0025 in. per pass with a spray traverse rate of 150 sfpm. The per pass deposit and traverse speed should be coordinated with the rotating speed

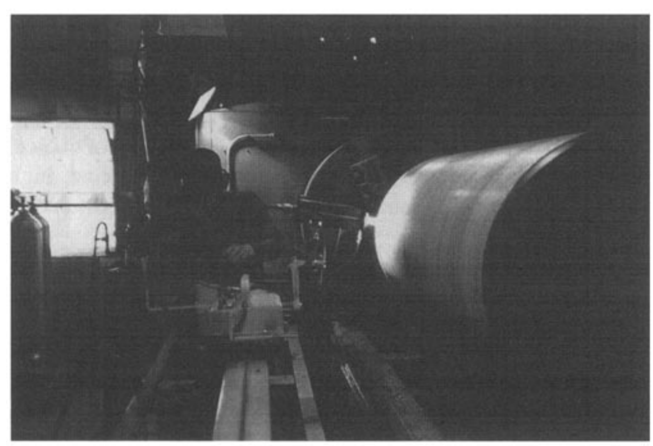

Fig. 4 Copper coating spray distance. Spray distance is critical in producing high-quality copper coatings. This photograph shows a 6 in. standoff from the end of the arc spray gun to the roll face. This distance is farther away than most conventional arc spraying techniques. It also helps dissipate the heat that can build up during spraying, which causes additional residual stresses to develop in the copper coating. Increasing the spray distance from 6 in. to 7 or 8 in. would allow the copper molten material to dwell longer in the compressed air atomizing stream, thus resulting in the formation of more oxides in the coating.

of revolutions per minute (rpm) of the part being sprayed. For example, when spraying copper coatings, the desired traverse speed is 150 sfpm or greater. Using a 24 in. diameter roll, it was found that 3.14 × 24 in. (diam) × 25 (rpm) / 12 = 157 sfpm. Therefore, spraying the 24 in. diameter roll while rotating it at 25 rpm achieves a spray rate of 157 sfpm.

4. Spray Trials

The suitability of the spraying techniques were confirmed by performing a trial on four sets of samples sprayed using four different spraying techniques. Samples were sprayed under the following conditions: (1) using a very slow traversing speed of ~100 sfpm; (2) depositing a very thick deposit per pass of ~0.006 in. per pass; (3) heating the part to near 300 °F; and (4) sprayed using the techniques and methods presented in Section 3. The coatings were analyzed using optical image analysis, which determined the porosity level and oxide content. Additionally, a Vickers hardness test was conducted to determine sample hardnesses.

Table 1 shows that use of the techniques presented in this article can reduce the porosity level by 19% compared to conventional arc spraying. Oxide content can be lowered by 4% and a lower hardness level also can be achieved.

5. Conclusions

In summary, copper coatings were sprayed taking into consideration (1) the correct speeds and feeds, (2) traversing the gun at the proper rate, (3) maintaining the proper spray distance, (4) spraying in one direction only to dissipate heat buildup in the process, and (5) using an oxidation preventative coating. Copper coatings with lower oxide content, reduced porosity levels, and a lower hardness provide improved machining qualities and facilitate mechanical engraving of copper coatings.

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