

FINISHING
THERMAL
SPRAYED
COATINGS



ROKIDE

Ceramic Spray System

Invented by the Swiss in the early 1900's, the sprayed metal process was used solely for the maintenance and repair of machine parts. Continuing developments in flame spray equipment and in the materials for application, however, have considerably broadened the range and scope of today's flame applications. Metals of every description, ceramics, and cermets are being flame sprayed to rebuild worn parts, produce wear resistant surfaces, improve resistance to corrosion, reduce weight, and to lower operating costs.

In thermal or flame spray applications, the material to be applied is metered into an applicator gun, where the material is melted and atomized by gasses or an electric arc. The atomized material is then propelled from the gun at relatively high velocities and sprayed onto the workpiece or substrate. As the atomized particles strike the workpiece, they adhere and cool each particle impinging upon and mechanically bonding to its predecessor. As the sprayed-on material builds up, an inherently porous, hard, but somewhat brittle structure is formed.

The grinding and finishing of thermal spray coatings can provide the uninitiated or inexperienced grinder-person with some problems. Many of the materials used for spray application are abrasive resistant and can be difficult to grind. The structure of the sprayed-on mass tends to be porous, hence, highly reflective finishes are somewhat difficult to achieve. Because the bond between the atomized particles is mechanical, individual particles can be pulled out if grinding pressures are allowed to get too high. Also, since thermal sprayed coatings are made up of well defined particles, heat transfer away from the point of grind is slower than heat transfer in similar materials in their solid form. Because of these factors, the commonly accepted methods, practices and techniques used to grind and polish materials in their solid form do not apply to the same materials when flame sprayed.

Finishing Methods

Flame sprayed surfaces can be successfully ground and finished in many ways. The method chosen can range from simple hand polishing operations to off-hand

grinding with coated abrasive belts, to the use of highly sophisticated precision grinders. Factors which influence the finishing method used include the type of material to be ground, the shape of the part, the finish and tolerance required, the type of equipment available, and the economics involved.

Hand Polishing

Hand polishing can be effective on the softer white metals such as aluminum and zinc. These coatings will finish to a bright surface but tend to "load" the face of the abrasive media used. Frequent dressing or cleaning may be needed to restore the cutting ability of the abrasive. When hand finishing, coarse grits are usually used for stock removal, with successively finer grits being used to achieve the desired final finish. While hand finishing is the most elementary method of generating a desired surface condition, care must be used in order to avoid breaking through the relatively thin sprayed-on coatings to insure uniform thickness of the coating. Hand finishing of the harder materials can be very time consuming and is not recommended because of the time-cost factor.

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Tumbling and Burnishing

When smooth finishes are required on a large quantity of very small parts or on parts with unusual contours, tumbling or burnishing can be very effective. When tumbling, the parts are placed into a vibrating or rotating tub containing abrasive media and water. The interaction of the abrasive and part polishes the sprayed-on coating. By selecting the proper abrasive and vibratory time cycle, acceptable finishes can be achieved. Burnishing is accomplished in much the same manner as tumbling, however, instead of abrading the surface to a finish, hard metal balls are used to compress the surface of the sprayed-on coating. The more pressure and the greater the frequency of ball to part contact, the smoother the surface will become. As in the case of all flame spray applications, the finer and more uniform the material is applied, the better the final finish will be.

Abrasive Belt Grinding

Sprayed metal and ceramic coatings can be effectively ground and polished with coated abrasive belts. In some instances, abrasive belts are used to improve the surface produced by prior operation, such as machining. In other instances, coated abrasive belts can be used to perform the entire grinding and finishing function. New developments in

backing materials and in grain design have produced strong waterproof belts which are extremely sharp and durable. Belts made from these new materials produce excellent finishes and good stock removal rates. Abrasive belts provide several advantages over other grinding media. Since they are cool cutting and do not require dressing, they can be changed rapidly when worn, and, in certain applications, abrasive belt costs are very favorable when compared to other machining methods. When grinding and polishing with coated abrasive belts, the part is usually fixtured or positioned in a lathe. The part is then either traversed or rotated under the belt head, while the belt is running at speeds of 6000 to 7000 SFPM. Coarse grit belts are used for rapid stock removal, while finer grit belts are used to improve finishes.

Grinding Wheels

Frequently, because of material type, or because of finish and tolerance requirements, the grinding wheel is the only practical means of processing thermal sprayed parts. The most commonly used machines are O.D. grinders (cylindrical and center-less), surface grinders (horizontal and vertical spindle), and internal grinders. Machines of this type are used to produce uniform parts with good commercial finishes and close tolerances.

When using any abrasive media to grind and polish flame sprayed parts, it is most important to realize that flame sprayed surfaces of a given material are vastly different from the surface of the same material in its solid, wrought, or cast form. The bond between the substrate, the layers of sprayed material, and between the particles themselves is strictly mechanical. If wheels of excessive hardness are used, or if the wheels do not cut freely, individual particles can be pulled from the surface of the workpiece, or, worse, the whole sprayed-on mass can delaminate from the substrate. Furthermore, because the ductility of sprayed materials is very low, too much grinding pressure can cause the surface particles to shift or be displaced. It should also be noted that, because of the mechanical bond, heat conduction away from the point of the grind is not as efficient as it would be when grinding similar materials in their solid form. Therefore, burn and blistering can become a problem if the proper wheel and grinding technique is not used.

Rule I. Always use the sharpest wheel possible. Sharp wheels cut cool and fast

Grinding Wheel Selection

Wheel sharpness is governed by several factors, among which are the type of abrasive grain and the grit size.

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Grain Type

Of the four major grain types used in the manufacture of grinding wheels, the two most commonly used for grinding flame sprayed surfaces are silicon carbide and diamond. Silicon carbide is chosen for its ability to fracture and present sharp new cutting points during the grinding action. Diamonds are used because of their durability and their ability to cleanly cut the harder alloys, ceramics, and cermets. Aluminum oxide and cubic boron nitride (CBN) are used only on occasion to grind some of the steel-based flame spray alloys.

Grit Size

Because of their smaller surface area and sharper points, fine grit abrasives will penetrate hard materials easier than coarse grit abrasives. The grit sizes normally used to grind flame sprayed surfaces will range from 46 through 80 grit, although finer grits may be used to generate finer finishes.

Rule II. Choose wheels with Structures and grades which provide free cutting action.

Wheel Structure

Structure, as it relates to the grinding wheel, is the spacing between the individual abrasive grains within the grinding wheel. Wheels with an open structure tend to grind more freely since the additional spacing between the abrasive grains provides greater

chip clearance. Wheel structures are designated numerically, and, for sprayed materials, structures ranging from 5 to 8 should be employed.

Wheel Grades

Grinding wheels can be manufactured in varying degrees of hardness. While harder wheels will last longer, they also tend to cut more slowly, generate more heat and require more frequent dressing than softer wheels. Grinding wheel grades are designated alphabetically in the grinding wheel marking system. When grinding sprayed materials, grades ranging between F and L are suggested. In general, softer grades are used on large areas of contact or when grinding with wide wheels, when using light grinding pressures, and when attempting to achieve higher stock removal rates. Harder grade wheels are used on small areas of contact or with narrow wheels, when using heavy grinding pressures and when producing finer finishes.

Rule III. Choose the bond type best suited to the operation and equipment.

Vitrified Bond

Vitrified bonds, because of their porosity, rigidity, and strength, can provide high stock removal rates and precision tolerances. They are not affected by water, acids, oils, or ordinary temperature variations.

Most vitrified wheels are, however, limited to a safe operating speed of 6500 SFPM. Although vitrified bonds are the most common type of bond used for grinding flame sprayed materials, they should be used only after it has been established that the operating speed of the machine does not exceed the safe operating speed marked on the wheel.

Resinoid Bond

Designed to operate at speeds of 9500 SFPM resin bond wheels are used for rapid stock removal and to generate fine finishes. The most common application for resin bond in flame spray grinding is in diamond wheels. Although resin bond wheels are generally operated at higher speeds, the machine speed should never exceed the safe operating speed marked on the wheel.

Rule IV. Know the equipment-machines and wheels.

Machines

It is important to know the machine being used for a particular grinding job and to understand its limitations. It is difficult, if not impossible, to generate precision ground surfaces and fine finishes on equipment that is not properly maintained. Chucks must be clean and able to hold the work accurately. Gibs and ways must operate smoothly, and machine spindles must run concentric to

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the wheel face with a minimum of vibration. While these factors may seem obvious, it is sometimes surprising to note just how many grinders are now operating under less than optimum conditions.

Wheels

Careful attention to wheel mounting is important, because any irregularity in grinding pressures can cause poor finishes, poor tolerances, or, even worse, the destruction of the workpiece. When mounting a wheel, make sure it is in balance and that the wheel center-hole fits the arbor properly, and that the wheel runs true. Wheel sleeves, collets, and flanges should be carefully checked to assure they are not worn or distorted. When using cup, diamond, or CBN wheels, always leave them on their own collet after use. This will facilitate remounting and reduce the need for re-truing on subsequent operations.

Grinding Variables

Through a thorough understanding of the various grinding variables open to him/her, the grinder-person can make his/her job easier and more productive.

Wheel Speed

Wheel speed can have an effect on wheel performance and can affect finish and stock removal rates. Lower wheel speeds will cause a given wheel to act softer, while

higher wheel speeds will cause the same wheel to act harder. For example, a K grade wheel normally operated at 5000 SFPM will act like an L grade wheel when operated at 6500 SFPM. Ideally, the speed of the machine should be changed so that the operating SFPM is maintained at a constant rate as the wheel wears. However, the ability to change the cutting action of a given wheel by changing its speed can be of great help where wheel inventories are limited and finishing problems are encountered.

Work Speed

By varying the speed of the work, the cutting action of the wheel can again be altered. By increasing the speed of the work, the wheel will become more aggressive. By traversing the work more slowly, better finishes can be generated.

Area of Contact

The basic principle involved in all types of grinding is unit pressure. The greater the pressure, the greater the depth of abrasive grain penetration. On a given machine of fixed horsepower, a narrow wheel, because of its smaller area of contact, will exert more units of pressure per square inch than will a wider wheel. Because of this fact, narrow wheels are more aggressive than wider wheels. Narrow wheels are very effective where rapid stock removal

is required, when very hard materials are being ground, and when low horsepower machines are used.

Wet Grinding

Sprayed materials can be successfully ground dry, as long as proper precautions are taken. However, the advantages of dry grinding are far outweighed by the advantages of wet grinding. When wet grinding, harder wheels may be used without increasing the incidence of blistering or heat checking, pull-out of surface particles is minimized, and better finishes can be obtained; wheels do not load as fast and less dressing is required. Wet grinding will also help flush out grinding residues that otherwise might become entrapped in the porous structure of the flame sprayed surface.

When grinding wet, effective filtration of the grinding fluids and the maintenance of proper concentration is as important to good finishes as is fluid cleanliness. Normally, water soluble oils with anti-welding agents are used when wet grinding flame sprayed materials. The manufacturer's recommendation for fluid concentration should be followed.

Wheel Dressing

During its use, the condition of the grinding wheel cutting face will change. After a period of time,

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either the abrasive grains on the face of the wheel will wear to the point where the height of the grain will equal the height of the bond, or the wheel face will become loaded with the material being ground. When either of these conditions occur, the cutting ability of the wheel will diminish, and more rubbing than cutting will take place. At this point, the wheel face must be reconditioned or dressed. It is important to note that, when dressing a grinding wheel with a diamond tool, the rate at which the tool is traversed across the face of the wheel governs the final cutting action of the wheel. A fast traverse will open the wheel face, re-sharpen the abrasive grains, and allow the wheel to cut more freely. A slow traverse of the diamond tool will close the wheel face, dull the abrasive grains, and cause the wheel to act harder. While slow dressing rates can be used to produce finer finishes on conventional materials, slow dressing rates are not recommended for use on flame sprayed materials. The use of sharp diamond tools is also important. Be sure to rotate single point diamond tools periodically.

Finishing Techniques

Good, trouble-free finishes can be generated on flame sprayed parts, provided care is exercised during the finishing process. The

following check list of grinding techniques will help make the job easier.

- Use softer, free-cutting wheels. Chances of burn and pullout will be greatly reduced.
- Keep the wheel face in a clean and sharp condition. Observe proper dressing techniques.
- Use coarse grit wheels for stock removal, and fine grit wheels for finishing. Attempting to generate fine finishes with coarse grit wheels that have been dressed closed can lead to pull-out, smearing, and burn.
- Take light cuts. Sprayed coatings are usually very thin. Too much grinding pressure can cause delamination of the sprayed-on surface, or pull-out of surface particles.
- Don't spark out on the final pass. Sparking out tends to glaze or dull the wheel face.
- Grind wet whenever possible. Improved finishes, less chance of burn, and less part contamination will result.
- Use finer grit wheels on hard to penetrate flame-sprayed coatings.
- Use narrower wheels on machines with low horsepower, and for more rapid stock removal on hard materials.
- When grinding, always attempt to keep the coating under compression. By cutting down through the sprayed surface towards the substrate, delamination and pull-out will be minimized. Vibration or chatter may cause cracking of the sprayed coating.
- If encountering problems with a given wheel, experiment with wheel speeds, feed rates, work speeds, and dressing techniques. Changes in these variables can have a great affect on stock removal rates and finishes.

Summary

To a great extent, the effectiveness of flame spray coatings is dependent upon the finishing techniques employed. The fact that the coatings are not a homogenous mass, but are rather many particles mechanically bonded together, dictates that sprayed coatings be finished with wheels and techniques not normally used on similar materials in their solid form. By carefully observing the rules governing wheel selection and by employing proper grinding techniques, the job of grinding flame spray coatings will become relatively trouble-free.

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Grinding Wheel Recommendations Selected Thermal Sprayed Materials

Material	Center-less	Cylindrical	Internal	Surface
Alumina	39C80-GVK	39C80-GVK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Barium Titanate	39C80-G8VK	39C80G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Boron	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Calcium Titanate	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Calcium Zirconate	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Chromium	39C60-J8VK	39C60-J8VK	39C80-L5VK	39C46-H8VK
	32A60-J8VBE	32A60-J8VBE	32A80-L5VBE	32A46H8VBE
Chromium Carbide	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Chrome Disilicide	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Chromium Oxide	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Cobalt	39C60-J8VK	39C60-J8VK	39C80-L5VK	39C46-H8VK
	32A60-J8VBE	32A60-J8VBE	32A80-L5VBE	32A46-H8VBE
Cobalt Zirconia	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Columbium	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Iron	37C46-J8VE	37C46-J8VE	37C60-M5VE	39C46-K8VK
Magnesium Zirconate	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56

Grinding Wheel Recommendations Selected Thermal Sprayed Materials

Material	Center-less	Cylindrical	Internal	Surface
Molydenum	37C60-I8VE	37C60-I8VE	37C80-N5VE	37C80-H8VK
Molydenum Disilicide	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VE SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Mullite	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VE SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Nickel	39C60-J8VK 32A60-J8VBE	39C60-J8VK 32A60-J8VBE	39C80-L5VK 32A80-L5VBE	39C46-H8VK 32A46-H8VBE
Nickel Alumina	39C80-G8VK ASD120-R75N56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Nickel Aluminide	32A60-J8VBE	32A60-J8VBE	32A80-L5VBE	32A46-H8VBE
Nickel Oxide	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V%	39C80-F8VK ASD120-R75B56
Silicon	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Stainless Steel	39C60-J8VK 32A60-J8VBE	39C60-J8VK 32A60-J8VBE	39C80-L5VK 32A80-J8VBE	39C46-H8VK 32A46-H8VBE
Tantalum	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Titania Alumina	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Titanium Oxide	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Tungsten	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56
Tungsten Carbide	39C80-G8VK ASD120-R75B56	39C80-G8VK ASD120-R75B56	39C80-J5VK SD150-R100B56 RMD180-N100V5	39C80-F8VK ASD120-R75B56

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Grinding Wheel Recommendations Selected Thermal Sprayed Materials

Material	Center-less	Cylindrical	Internal	Surface
Zirconia	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Zirconia Oxide	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C80-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56
Zirconia Silicate	39C80-G8VK	39C80-G8VK	39C80-J5VK	39C8-F8VK
	ASD120-R75B56	ASD120-R75B56	SD150-R100B56 RMD180-N100V5	ASD120-R75B56

NOTE #1: The above grinding wheel recommendations are for wet grinding. When grinding dry, it may be necessary to select wheels 1 to 2 grades softer than those indicated.

NOTE #2: The above grinding wheel recommendations are suggested starting points only. Some adjustments in wheel grade and grit size may be required in order to accommodate such factors as machine conditions and operator technique.

NOTE #3: Tests have shown that diamond wheel specification D4/8MIC-R50BXL6145 will produce very fine finishes on thermal sprayed ceramic coatings when used as a finishing wheel in a two-step grinding procedure.