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CO_2 Cooling for Thermal Spray Advances

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Something old is new again (only better)

Conventional carbon dioxide (CO_2) cooling and snow spray or pellet blast cleaning technology has been available to thermal spray coating engineers for many years. Today, newer, much more capable and versatile CO_2 technology is being introduced as new thermal spray process tools. Industries worldwide have investigated and implemented advanced CO_2-based clean manufacturing technology as an alternative to energy-intensive, resource-wasting and polluting industrial processes. Western Digital, Pentel, Gillette-PaperMate, Raytheon, Seagate, Hughes, and TRW are examples of businesses that have implemented advanced CO_2 manufacturing technology in one form or another and have improved the productivity, environmental quality, and profitability of their operations (1-4). Although new to most thermal coating engineers, advanced CO2 technology promises several benefits. Advanced CO_2 composite sprays provide a unique combination of thermal spray process tools including surface preparation (i.e., both etching and precision surface cleaning), temperature control during coating to increase target efficiency (increased percentage of time on the part) and cooling-lubrication during post-finishing (i.e., machining) processes.

Advanced "CO_2 composite spray" technology

CO_2 sprays have been used commercially for cleaning and cooling applications for many years. Properly designed conventional systems can be effective for a limited number of cleaning or cooling applications. However, operating cost is always a prime concern, along with a need for effective process control, both of which have proven to be a challenge for conventional CO_2 processes. This is particularly true in high capacity applications. Moreover, adaptability to process tools has been very difficult.

Advanced CO_2 composite spray technology addresses the drawbacks and limitations of conventional CO_2 spray cleaning and cooling processes. CO_2 composite spray technology provides several process control and performance advantages. These include CO_2 conservation, impact stress control, precise temperature control, additive technology, and easier adaptability to automation and process equipment. Moreover, CO_2 composite spray technology has been adapted to address the needs of modern machining, providing near-dry to dry cooling-lubrication functions during processes such as turning, milling, stamping, and drilling. Figure 1 on page 16 illustrates the patented, Coanda nozzle and composite spray technology used in combining the components of the cooling spray. While Figure 2 presents a graph of the cooling spray temperatures as the system is adjusted.

continued on page 16

INDUSTRY NEWS

continued from page 14

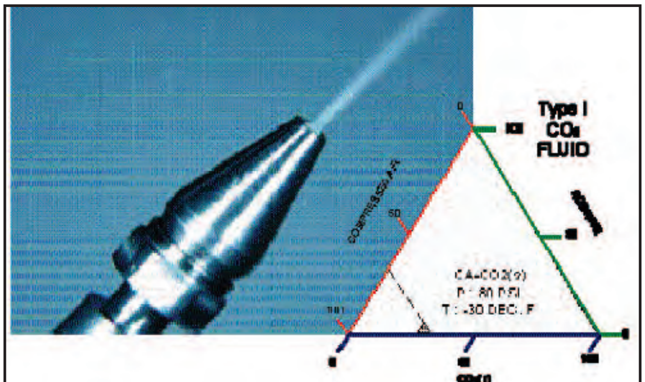

Fig.1 CO_2 composite spray technology for cleaning, cooling and machining.

Referring to Figure 1, a CO_2 composite spray has three ingredients; 1. CO_2 particles having a certain size and concentration, 2. clean compressed air (CA) having an adjustable pressure (P), temperature (T) and flow, and 3. optional additive component comprising an adjustable microscopic flow of liquids (i.e., lubricants) or solids (i.e., micro-abrasives). The patented, Coanda nozzle technology is used to combine the ingredients and deliver the spray composition to a surface. The ternary diagram above suggests a 70% air-30% CO_2 composition.

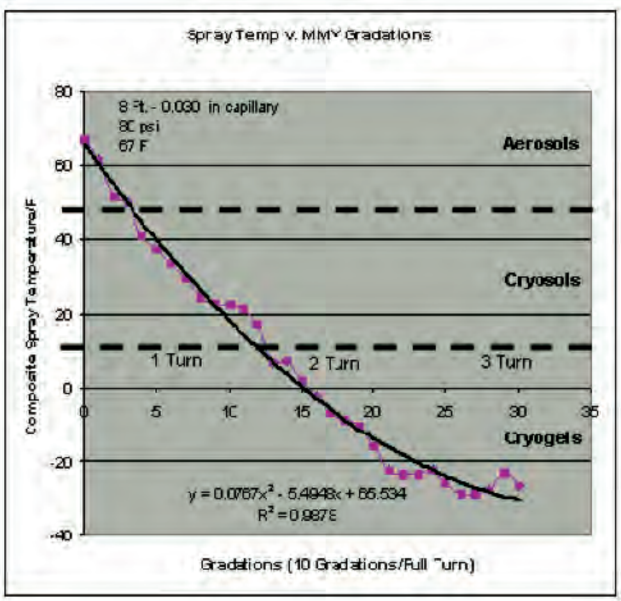

Fig.2 Precise spray temperature control.

Figure 2 shows an exemplary temperature profile for a CO_2 composite spray given the setup indicated in the top left corner (air at 80 psi and 67°F). As the percentage of CO_2 is increased, the temperature of the cooling stream decreases. Spray temperatures as high as +300°F to less than -70°F can be produced depending upon a particular composition employed.

Unlike high pressure liquids and gases, a CO_2 composite spray can generate impact stresses as high as 60 MPa, and much higher if micro-abrasive, solid additives are incorporated within the spray composition. It is this physical property, as well as the unique chemistry of CO_2, that provides the basis for its excellent cleaning, cooling and lubricating performance. For example, Figure 3 is a SEM photomicrograph showing the ability of a CO_2 composite spray to remove sub-micron aluminum oxide particles from a complex surface.

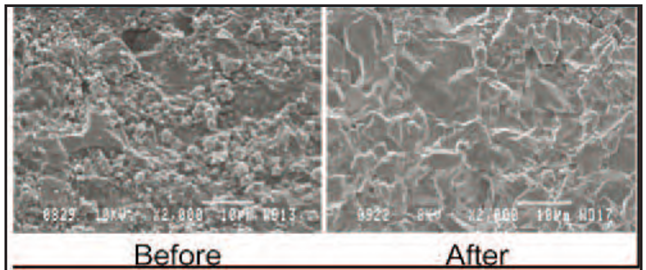

Fig.3 Precision sub-micron particle and film removal.

CO_2 technology is a clean manufacturing solution for thermal spray engineers

Clean manufacturing practices are continuous preventive measures that concentrate on optimizing manufacturing resources and processes to minimize or eliminate wastes of various forms. Advanced CO_2 technology reduces waste generation at the production operation level (source) by modifying the manufacturing processes themselves. For thermal spray processes, advanced CO_2 composite spray technology provides a combination process modification capabilities, as follows:

1. Surface preparation: micro-roughening, etching and precision cleaning,
2. Temperature control: maintenance of substrate surface temperature during coating within an upper and lower control boundary, and
3. Post-operations: precision cleaning and machining operations for following manufacturing procedures or dimensional requirements.

Replacing conventional surface cleaning agents with CO_2's green chemistry eliminates process inputs such as liquid cleaning solvents, aqueous clean agents, detergents, dionized rinse water, and heated air dryers, among other waste-producing inputs. For temperature control, the remarkable cooling efficiency of solid carbon dioxide particles due to three-phase heat extraction involving sublimation, boiling liquid and gas provide superior heat capacity for maintaining surface temperatures during thermal spray coating as compared to cold air or nitrogen.

Another benefit is that the cooling spray is also a very energetic cleaning spray, which simultaneously dislodges loosely adhering coating particles during the coating process. In post-coating operations, CO_2-based advanced minimum quantity cooling lubrication (AMQCL) replaces flooded cutting fluids and associated waste-producing operations such as metalworking fluids management, waste hauling and air pollution control. In particular CO_2 machining fluid technology enables the economic use of advanced cutting tools employing diamond or CBN for machining hard or abrasive substrates, while delivering improved surface finish and cleanliness.

continued on page 18

continued from page 16

Since there are a number of potential applications for the CO_2 beyond just cooling parts during thermal spray and because there are a number cooling processes and associated costs, the next article will discuss the benefits of using CO_2 vs. other gases and cleaning processes from an environmental and cost basis.

Summary

Benefits of Using CO_2 Cooling With the Thermal Spray Process

Thermal Spray Coating Benefits

- Decreased cleaning and handling cost
  - Time, materials and disposal
- Increased target efficiencies
  - Powder savings
  - Energy savings
  - Faster coating times
  - Increased production
  - Greater capital utilization
  - Decreased labor per part
- Improved coating characteristics
  - Cleaner interface
  - Controlled coating stress

Improved Post-Coating Benefits

- Longer machining tool life
- Higher machining speeds/feeds
- Precise thermal control of machining
- Elimination of cooling liquid contamination

Cooling System Features

- Transportable
- Most efficient cooling and cleaning process
- Low capital expenditure
- Low operating costs

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Story on page one.