The Corundum Conundrum

Setting the record straight on the sapphire versus ruby nozzle debate. What you should know about the make-up of high-pressure needle jet nozzles.

By Steve Corlew

Synthetic industrial jewels in the form of white sapphire and red ruby can increasingly be found on high pressure shower applications on most modern paper machines throughout the world. Longer life of the nozzle orifice and more importantly a longer lasting laminar jet during the life of the nozzle is typically the driving force for choosing a synthetic sapphire or ruby orifice nozzle in lieu of a solid 316 stainless steel body nozzle.

Laminar flow is critical for needle jet nozzle applications due to the fact that a clear laminar jet imparts more of its energy into and often through the target (trim squirt) than a turbulent jet under the same operating parameters. Typical shower applications where synthetic sapphire and ruby equipped nozzles are employed are high pressure oscillating wire/felt cleaning showers and trim squirt nozzles, which precisely trim the sheet to a specified width on the wet end of the paper machine before the sheet leaves the wet end via the couch roll and enters the press section of the machine.

The trim squirt application is one of the most critical single nozzle applications on the paper machine and premature failure will cause sheet breaks and other operational problems down-machine. It is now common on most paper machines to see only sapphire or ruby nozzles on the trim squirt positions.

You may have heard somewhere that a synthetic ruby nozzle orifice has better, more laminar flow characteristics than a synthetic sapphire orifice all other things being equal. Or maybe you have heard the exact opposite. So the question remains; Sapphire or Ruby, which one really has better spray and/or wear characteristics?

SAPPHIRE OR RUBY?

All other things being equal, a white sapphire and a red ruby are identical in composition, i.e. both are exactly Aluminum Oxide a.k.a. Al_2O_3 or Corundum. If you examine the

chemical composition of a sapphire or ruby you will always end up at the same place in the end—looking at the chemical composition: Al_2O_3 Corundum with the same hardness, same wear resistance, same sliding co-efficient of friction, same everything, except for the color.

Industrial sapphire and ruby are gem-quality synthetic forms of Al_2O_3 or Corundum with a hardness of 9 on the Moh's hardness scale, which is second only to diamond which has a 10 rating on the Moh's hardness scale.

While sapphire jewels can be blue, pink and various other colors, a "white sapphire" is the cleanest looking of all variations of corundum because there are no impurities, and therefore the jewel is literally clear.

The red color in the ruby comes from traces of impurity in the Al_2O_3 Corundum. In synthetic ruby, chromium (an 8.5 on the Moh's hardness scale) is typically added to produce shades from a "deep hot pink" to "pigeon blood red".

Deeper examination of the composition of sapphire and ruby is beyond the scope of this article and it is safe to say that for all intents and purposes related to nozzle applications on a paper machine the two jewels are identical. However, for those who are always hungry for more knowledge, there are two excellent starting points on the internet: en.wikipedia.org/wiki/ruby and en.wikipedia.org/wiki/Sapphire.

So the question remains: how and why does a nozzle manufacturer choose to use white sapphire in lieu of ruby orifices? While we cannot speak for other nozzle manufacturers, Auxiliary Process Engineering opts to use white sapphire instead of ruby for reasons related to experiences with white sapphire nozzle orifices in our facilities.

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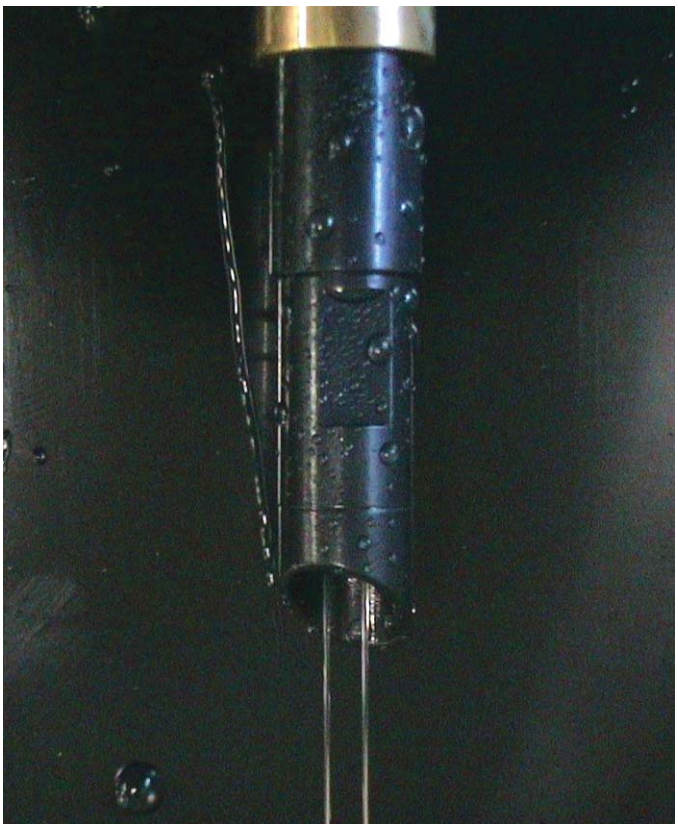
Our plants utilize a 50,000 psig UHP (ultra high pressure) abrasive waterjet cutting machine. This fully automated programmable CNC (computerized numerical control) machine tool was purchased as original equipment with, and continues to use, a white sapphire nozzle orifice as its cutting mechanism. The machine uses Garnet, which is metered into the UHP needle jet stream (after exiting a sapphire orifice) and used as an abrasive agent to pierce and cut through stainless steel, alloy steels, carbon steel, plastic, ceramics, glass, composites and organic materials.



A double sapphire orifice trim squirt with clear laminar needle jets.

The white sapphires performed so well under this extreme application that it made sense to employ the same white sapphire orifice in our high pressure nozzles on paper machine shower applications such as trim squirts or high pressure felt or wire nozzles that operate anywhere from 75 psig to 500 psig. Our experience with the sapphires also shows that we are operating well within, and certainly below, the white sapphire jewels maximum design limits.

In other cases, many UHP abrasive waterjet nozzle manufacturers (for both OEM and spare parts) equip their UHP nozzles with sapphire orifices due to the simple fact that the ruby synthetic jewels are not commonly supplied as original equipment for the UHP waterjet machines.

Additionally, white sapphires are inherently transparent, making visual inspection under a microscope and with the naked eye more efficient—for both the manufacturer and the end user—because the white sapphire is inherently clear.

A high performance anti-stick coated trim squirt nozzle with dual sapphire orifices.

A typical felt/wire high pressure needle jet nozzle with white sapphire orifice.

If you see anything other than the edge of the orifice there has to be either debris present or perhaps a physical problem with the orifice.

The real proof however is in the performance and life of the nozzle. When we test our white sapphires side by side with the same nozzle equipped with a red ruby under a strobe light at all pressures, the white sapphire always has the same laminar and round jet as the ruby equipped nozzles and continues to spray identically at elevated pressures and extended periods of time. It appears that a ground precision hole designed to spray a laminar jet is just that, so the color has no effect.

It is probably fair to conclude that other nozzle manufacturers have researched the same options and for one reason or another ultimately selected to use either a white sapphire or red ruby or possibly some other color of the same base material (Al_2O_3 Corundum).

Other factors such as geographic, economic, and component availability are also variables that must be considered and, without a doubt, carry some influence over which color of Corundum a manufacturer decides to use for their nozzle products.

It is safe to say that some orifice choices have provided superior laminar needle jets over other examples simply because of the physical shape of the orifice and not due to the color of the orifice. Once the correct physical dimensions, finish requirements and acceptable tolerances for the orifice have been proven, both sapphire and ruby will provide the same exact jet pattern. The tolerances typically held by the orifice manufacturer are so remarkably small (.0025 mm or .0001 inches) that any resulting effects on the flow characteristics of the jet stream are insignificant.

Other than the color, a white sapphire and a red ruby are identical in composition.

CONCLUSION

White sapphire and red ruby orifice needle jet nozzles are identical in all but the color of the jewel. Quality is quality, and that is the bottom line.

Manufacturing sapphire/ruby nozzles that spray exceptionally well for long periods of time is not rocket science. It may have been more difficult some 50 to 100 years ago, but this is no longer true due to advances in all areas of technology. By taking advantage of the economy of scale and successful history of the white sapphire industrial jewel—initially created by the abrasive waterjet machine tool industry—a nozzle manufacturer and end user on a paper machine can be confident with their choice of the white sapphire as an equal performing, more available, and more economical alternative to the red ruby. ■

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