MICROWAVE BRAZING, A NOVEL METHOD FOR JOINING CERAMICS TO METALS

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ABSTRACT

Microwave brazing of ceramics is both quick and efficient, and industry is becoming increasingly aware of its potential. Microwaves have long been considered as an energy source for diffusion bonding ceramics such as alumina, zirconia, mullite, silicon nitride and silicon carbide. However, microwave brazing methods for joining ceramics to metals is relatively new. Technology International, Inc., with the cooperation of NASA JPL and the Colorado School of Mines, has developed a unique brazing method. The inventors were awarded the 2002 Space Act Award for Innovation. Successful application of microwave brazing for drill bit cutters required high attachment strength with a dissimilar material pair – thermally stable polycrystalline diamond and tungsten carbide. The tungsten carbide has a thermal expansion coefficient 2x greater than a thermally stable polycrystalline diamond. When 9 to 22 mm diameter thermally stable diamond discs are brazed to tungsten carbide using conventional brazing methods, high residual thermal stress causes delamination (debonding) and diamond fracture. Preferential microwave heating of the diamond layer and braze filler metal creates the ability to control residual brazing stresses and prevent the diamond layer from cracking. Preferential heating of the braze filler metal results in a reduction in porosity and other defects. Thermally stable diamond cutters with attachment shear strength of over 50,000 psi have been achieved with the development of custom microwave reactors and brazing processes. Petroleum drill bits employing the new microwave brazed cutters can result in higher rates of penetration, a 15% reduction in drilling costs, and a 7.5% savings in overall project cost.

Successful microwave brazing of thermally stable diamond and tungsten carbide was first observed using an existing NASA JPL variable frequency TWT powered single-mode microwave reactor. It was discovered that thermally stable polycrystalline diamond and braze filler metals absorb microwave energy more efficiently than tungsten carbide. In fact, the diamond was observed to be at white heat while the tungsten carbide was black. The microwave susceptibility of these and other ceramic-to-metal material pairs will be reported. The microwave brazing process results in preferential heating of the lower expanding ceramic, thus providing the ability to match the thermal contraction of the dissimilar material pair on cool-down. Peak electrical and magnetic locations within the reactor were determined empirically and verified with models to aid in the accurate control of diamond and braze filler metal temperatures throughout the brazing cycle. For production brazing, a custom built 2.45 GHz magnetron powered reactors was acquired and operated at the Colorado School of Mines. Process development resulted in improved process control and a viable commercial microwave brazing process.

Microwave brazing has numerous potential applications including cutting tools, abrasives, ceramic substrates for electronic devices, turbocharger rotors, turbine blades, automotive engine components, nuclear fuel rods, heating elements, heat exchangers, and fuel cells. The results of microwave susceptibility tests on a variety of ceramic and metal material pairs will be reported.
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