Brazing of Carbide Mining Tools

BY DR. YEHUDA BASKIN

A miner changes conical bits on a continuous miner. (Photo courtesy of Kennametal)

Mining tools, such as conical bits, roof bits, flats radials, etc., have evolved over the years. Currently, these tools consist of cobalt-bonded, tungsten carbide bits brazed to steel shanks. When properly processed, long-lasting tools are produced which combine great strength, toughness and high hardness.

Early coal mining tools were made of steel, eventually leading to different types of hardened steel. Then came the carbide revolution, which began in the 1920s, but really took off after World War II. The earliest tools with cemented carbide bits increased the lifetime of rock drills by at least a factor of 10 over steel-based drills. With improvements in cemented carbide technology, this advantage has increased.

Cemented carbides, or hard metals as they are also called, are produced by cementing ultra-hard tungsten carbide (WC) grains in a binder matrix of cobalt metal by liquid-phase sintering. The high solubility of WC in cobalt at elevated temperature and the excellent wetting of WC by the liquid cobalt results in superior densification during liquid-phase sintering, and a pore-free structure. As a result, material is produced which combines great strength, toughness, high hardness and wear resistance, and is also readily brazed, which is not the case for pure tungsten carbide. The high hardness is necessary for the tools to function effectively in their working environment. While the various varieties of coal are generally soft, many of the associated minerals are abrasive, causing excessive wear to metal tools.

Carbide mining tools are produced by a joining process called brazing, which is a well-established commercial process capable of producing strong joints. It is widely used in industry because of its ability to join most metallic materials, including dissimilar metals. The American Welding Society (AWS) defines brazing as a group of joining processes that cause the coalescence of materials in the presence of a brazing filler metal that has a liquidus temperature above 840°F/450°C, but below the solidus temperature of the base materials. The filler metal is distributed between the closely fitted faying surfaces of the joint by capillary action. The term brazing temperature refers to the temperature to which a material assemblage is heated to enable the filler metal to spread and adhere to or wet the joining metals.

The mining tool parts to be brazed are the steel shank and the cemented carbide bit. The most common brazing filler alloys used are shown in Table 1. These melt in the temperature range suitable for joining of the tools. All three contain manganese, in addition to nickel, copper and other minor constituents. Manganese is important for bonding to cemented carbides. The most common form for the filler metal is a flat coupon or shim, which is placed between the steel and the cemented carbide at the bottom of the formed pocket. Sometimes, additional alloy wire is added to the upper part of the carbide at peak temperature for additional strength.

Table 1: Filler Alloys Used in Mining Tools

	Composition					
Aloy	%Ni	%Cu	%Mn	%Zn	Solidus	Liquidus
Nicuman 23	9.00	67.50	23.50	—	1,700°F/925°C	1,750°F/955°C
Nicuman 37	9.50	52.50	38.00	—	1,573°F/855°C	1,680°F/915°C
Alloy 548	6.00	55.00	4.00	35.00	1,620°F/880°C	1,691°F/920°C

Prior to final assembly the carbide bits are coated with flux, by putting them in containers filled with water-based flux. The coated bits are then placed on top of the alloy shims within the formed pocket. Recently a new dispensing machine has become available specifically for water-based flux; this allows precise and automated deposits up to 3,600 per hour. The system provides superior resistance to high abrasive constituents, and maintains the flux in optimal condition. Just such a system provides the user with a successful alternative to petroleum-based product.

Cemented carbide bits are brazed to a steel shank. (Photo courtesy of Kennametal)

The fluxes designed for mining tools are water-based, high-temperature brazing paste products, two of which are shown below.

Flux Type	Active Temperature Range
White Paste Flux	*1,400°F/760°C - 2,100°F/1160°C*
Boron-Modified Paste Flux	*1,400°F/760°C - 2,250°F/1230°C*

Both fluxes work exceptionally well in this application, and are perfectly matched with the filler alloys used. The white flux performs best on smaller tools, while the boron-modified flux works well on larger tools, owing to its ability to withstand higher temperatures and longer heating cycles. Fluxes are essential when joining metals in ambient air. Filler metals only wet clean metallic surfaces, and flux facilitates this.

When heated, fluxes perform five critical tasks:

1) Dissolve or react with surface metal oxides;
2) Protect the cleaned surfaces against re-oxidation;
3) Help transfer heat from the heat source to the joint;
4) Lower the surface tension of the filler metals and the joining surfaces; and
5) Remove surface oxides, allowing the filler metal to flow and wet the joining surfaces.

Finally, when all of the parts are properly arranged within the pocket, the tools are set on a conveyor system, which moves them slowly into the heat zone. Induction heating is the preferred method for brazing the mining tools, and is done in ambient air. Brazing temperatures in the range 1,900°F/1,047°C – 2,100°F/1,140°C are used. Various techniques are employed to make sure that optimum bonding occurs between the steel shanks and the carbide bits. Excellent wetting is a necessary pre-requisite for achieving the tool strength needed for prolonged operation. After heating, the brazed tools are generally quenched in water. Flux residues either come off in the quenching process or when the tools receive their final cleaning.

Miners also rely heavily on carbide bits for roof drilling. (Photo courtesy of Kennametal)

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Acknowledgment

The writer gratefully acknowledges the assistance of Dr. Jonathan Baskin.