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SPECIAL FOCUS:

MAKING AUTOMOTIVE PARTS

Split Personality

Machining dissimilar metals in a single workpiece.

► BY KIMBERLY PONTIUS

Bimetal machining, which involves cutting a single workpiece made up of two dissimilar metals, has been performed since the 1950s. However, information on machining bimetals remains scarce.

Bimetals are bonded laminates produced by diffusion bonding, which generates a stable, metallic bond. While these bonded materials are common in heat-sensing applications, emerging technologies are finding additional uses for dissimilar metals. And as weight constraints become more significant for automotive, aerospace and marine equipment, more emphasis will be placed on this technology for machining parts comprised of aluminum and another metal.

Recently, I participated in a bimetal-machining project to produce steelhead pistons. In this application, a composite bushing had to be pressed into a cross-pin bore, so the bushing would serve as a connector for the piston head, skirt and connecting rod.

Initially, bronze bushings were pressed into a 4140 steel forging, which was heat-treated to 32 HRC. The external steel shell resists deformation and holds its position precisely, and the thin, inner bronze stratum provides excellent antifriction characteristics. To ensure proper clearance between the connecting rod and the piston skirt, the assembly had to be machined as a single unit. This proved to be a daunting task, and one for which the tooling-application specialists had little background.

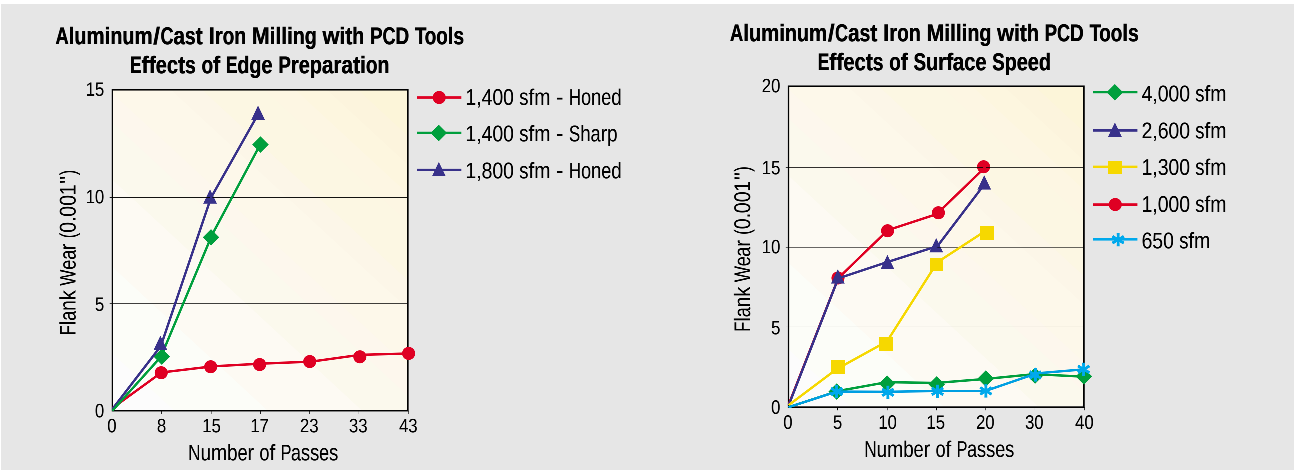
The bronze lamination tearing away from the steel backing was one of several problems that occurred during milling. Also, while climb (down) milling proved superior to conventional (up) milling, the speeds and feeds required for optimum productivity were unattainable because the inserts failed at those rates.

The inserts' edges chipped as the cutters transitioned from steel to bronze and back again. Also, the bushings flexed during material transitions and the inserts tended to break.

The machining approach that proved satisfactory, while somewhat primitive, was to apply a spiral-fluted, TiN-coated, HSS endmill running at 150 sfm and 15 ipm with flood coolant.

Design Requirements

Most applications that require bimetal components have similar characteristics. Bimetal components are pri-



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Results from studies conducted to determine the effectiveness of machining engine blocks with bimetal inclusions.

marily for applications where abrasive metals interface with other components and anti-abrasive or anticorrosive alloys must be present at that interface. Besides meeting wear- and corrosion-resistance requirements, bimetal components are also employed to strengthen a primary structure.

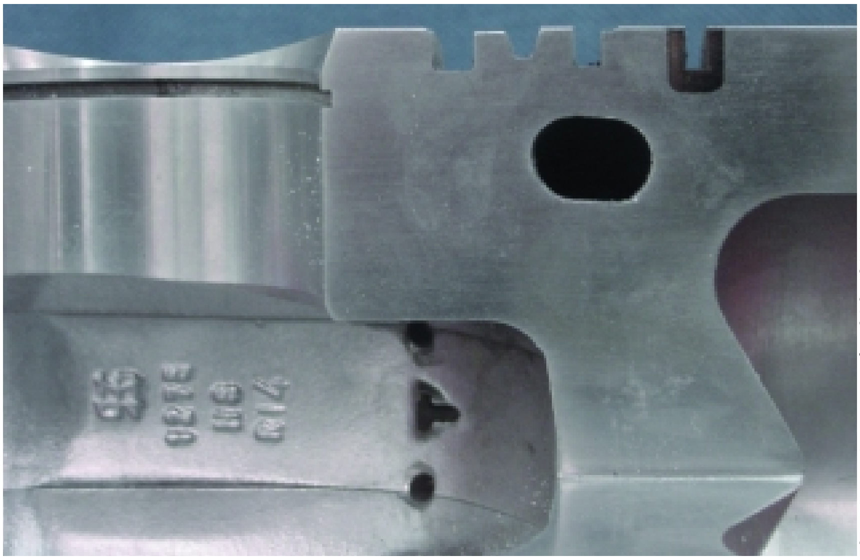
Most bimetallic parts are found in applications where the material properties and thermal and wear characteristics of the different metals fulfill design specifications. However, the physical properties of the two materials demand contradictory machining parameters.

As an example, a Ni-Resist iron ring is often bonded to an aluminum piston for use in high-temperature diesel engines. During casting, the iron ring is molded into the aluminum. Machining simultaneously cuts the iron ring and the aluminum to which it is bonded to generate the piston ring groove.

Until recently, superabrasive cutting tools have been unable to accommodate the differences in the machining parameters of the two different metals. Roughing required uncoated carbide tools to cut the features while enduring the shock. Speeds of 200 to 350 sfm with feeds of 0.010 to 0.015 ipm were common.

While some TiN coatings produced marginal increases in tool life, their cost was difficult to justify. In addition, the required surface finish was often imparted through grinding. On top of this, attempts to cut iron with polycrystalline diamond tools proved futile, whereas cubic boron nitride tools failed when cutting aluminum.

A steelhead piston with a composite bushing pressed into the part's cross-pin bore had to be machined as a single unit to ensure proper clearance between the connecting rod and the piston skirt.



Photos: K. Pontius, courtesy of Karl Schmidt/Unisia

During casting, the dark Ni-Resist iron ring is molded into the aluminum. Machining simultaneously cuts the ring and the aluminum to create the piston-ring groove.

Overcoming Obstacles

Machinists have two primary obstacles to overcome in the absence of a symbiotic relationship between two metals in one workpiece. First, the appropriate machining parameters for cutting one metal tend to tear the other one. A cutting speed that is correct for one material tends to be too low or too high for the other, for instance, or the optimum chip load for the first metal is often too much or too little for the second.

The second obstacle is choosing the proper cutting tool materials so built-up edge is minimized and there isn't excessive heat transfered into the tool, which causes premature tool failure. Yet, the problems do not stop there.

As a tool degrades, cutting forces become excessive. And, as these forces build, they stress the mechanical bond that exists between the dissimilar metals. This stress can compromise the bond in the bimetal matrix and cause the component to fail during machining. Ergo, it is necessary to assume that every machined, bimetal part has a weakened bond.

As such, every part should undergo ultrasonic or flouroscopic testing to verify bond integrity. Magnafluxing may be practical if both metals are magnetic.

Material Changes

The percentage of aluminum in automobiles is increasing in an effort to reduce overall vehicle weight. Studies were conducted by abrasive manufacturer GE Superabrasives, Worthington, Ohio, in conjunction with toolmaker Kennametal Inc., Latrobe, Pa., to determine the effectiveness of machining engine blocks with bimetal—aluminum and another metal—inclusions using PCD tools.

In one study, aluminum cylinder liners for a gray iron combustion chamber were either cast or pressed into place, and the entire assembly had to be machined as a single unit.

The tests on the 4-cylinder aluminum block showed that both metals had to be milled at the same time, and the machining speeds had to remain sufficiently low to avoid a chemical reaction between diamond and iron. This became the determining factor when evaluating PCD tool performance.

The heat generated at the cutter/-workpiece interface caused most of the chemical reactions. In this type of chemical reaction, the cobalt binder leaches out of the tool as the interface temperature rises and tends to combine with one or both metals. As the cobalt dissipates, the tool's diamond grits fall away. Though coolant vaporizes at this point, the coolant subjects the tool material to additional degradation, since the coolant serves as an electrolyte in a chemical displacement cell.

According to test results, PCD tools wear rapidly at speeds greater than 1,000 sfm. A slight edge prep of 0.001" appeared to protect the diamond from premature pullout.

The toolmaker also recommends that the feed rate should be kept low, at 0.005 ipm per insert, to decrease the impact on the cutting edge. And the use of tools with a large nose radius—greater than 0.064"—thins the chip and protects the cutting edge from premature failure.

High-Speed Heat Dissipation

Developments in high-speed machining may also prove helpful when machining dissimilar metals. Some suggest that if speeds are high enough, then the heat will dissipate or may not even be present. If this is the case, then dry machining could negate any bimetallic corrosion.

Accelerated corrosion rates can be very problematic when machining bimetal parts. The differences in electrical potential between dissimilar metals immersed in an electrolyte—the coolant—generates an electromotive force or current flow. During this galvanic activity, one metal constituent becomes a sacrificial anode and corrodes.

Also, the galvanic action contributes to the degradation of the tool material, as well as the machined component in the presence of a conductive coolant.

Regardless of the machining difficulties, bimetal components are highly suitable for thermodynamic applications. The current flow in galvanic cells in bimetallic assemblies is the basis for thermocouples, which sense slight temperature variations. The current flow is measured in microvolts and correlated with temperature degrees.

Also, thermometer elements are made by joining two dissimilar, temperature-sensitive metals. Small changes in temperature cause the machined, bimetal assembly to distort elastically and produce a predictable and measurable deflection. The design takes advantage of the differential in linear coefficients of thermal expansion for the different metals. Thermostatic actuators, temperature sensors and probes for a myriad of industries are typical examples.

Obstacles must be overcome to successfully machine bimetal parts, but as their use grows, a shop may have to add bimetal machining to its capabilities in order to remain competitive.

About the Author

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