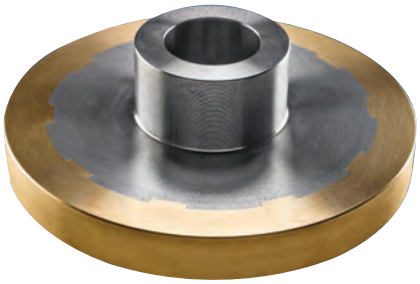
From Many, One

Composite bronze worm gear blank technology is a reliable, off-the-shelf cost savings solution that can be quickly evaluated and adopted.

By Steven Friedrich

Composite gear (lower left) replaces an 8-part worm gear assembly



IN JUNE 2013, A $1B INDUSTRIAL EQUIPMENT MANUFACTURER WAS ON A COST SAVINGS MISSION FOR AN ASSEMBLED WORM GEAR THAT WAS RIPE FOR SIMPLIFICATION. THE ASSEMBLED WORM GEAR DESIGN AND EIGHT DESIGN VARIATIONS THEREOF ARE FOUND IN THE MAJORITY OF THE 10,000–12,000 UNITS OF NEW INDUSTRIAL EQUIPMENT MANUFACTURED EVERY YEAR AT THEIR FACTORY IN THE WESTERN UNITED STATES. THE PRIOR ASSEMBLED WORM GEAR TECHNOLOGY STARTED WITH A HUB TURNED FROM SOLID 12L14 STEEL BAR STOCK AND CONTINUOUSLY CAST BRONZE TUBE STOCK.

Six drilled, countersunk, and tapped holes in each part were needed to secure the rim to the hub. The bronze rim, once cut to size and turned to the precise dimensions needed for mate-up, was sweated onto the hub. This assembly was joined together with six hardened machine screws, manually tightened and torqued. With over 6,000 of these specific gear blank assemblies used per year, there was a significant supply chain, a fair amount of work-in-process (WIP), multiple process steps, thermal energy for the sweating operation, and considerable labor involved. Finished part weight for the 12L14 steel hub was only about 35% of the raw material starting weight—a lot of chips to cut just to get to one of the component pieces.

But fortunately, a much more efficient manufacturing methodology was found at Accurate Specialties, Incorporated (ASI). ASI is a bronze gear blank foundry and machine shop located in Waukesha, Wisconsin specializing in worm gear blanks made from low or non-leaded bronze alloys in size ranges of 60mm to 1275mm outside diameters (OD's). Through collaborative design efforts and some heat treatment experimentation, ASI was able to provide a cast iron hub substitute for the 12L14 steel hub, and pour a C95500 bronze alloy rim around the hub. The iron hub was cast, not turned from bar stock, and this eliminated multiple turning, sweating, and assembly process steps, reduced chip cutting by a factor of three, and dropping finished product costs by over 30%. Perhaps the bigger impact was allowing the equipment manufacturer to focus on machine design and assembly rather than on machining component parts.

Further, the assembly is dramatically more robust. The robustness improvement comes as a result of the cooling bronze. As it sets, the bronze alloy rim shrinks slightly forming a compressive load against the iron hub. The iron hub also has lugs configured into the area over which the bronze rim is poured, assuring a bond much stronger than the machine screws under torque. The combination of design features and compressive load created by shrink reduces worry about screws becoming loose, needing retightening, or backing out.

The process step savings, cost savings, and untethering of internal resources (two machine tools, a sweating oven, and four machine operators) was justification enough to move forward with the technology immediately. The mechanical bond strength advantage left no question of product integrity.

Both ASI and their customer acted very quickly to execute the necessary approvals getting the composite bronze gear blank rolling as replacement for the existing assembled worm gear design, and the two parties went from design concept through prototyping and onto issues of tooling and composite gear blank purchase orders in exactly six weeks. The equipment manufacturer had multiple applications that could be converted into the composite design, saving over $250,000/yr once the composite design was fully implemented across the assembled gear blank family of parts. Upfront investment costs in patterns, gauges, and casting dies were less than $25,000, repaid in cost savings in well under one year on the inaugural part number.

Gear engineers select bronze in worm gear applications for the mechanical and chemical properties bronze delivers. As a non-ferrous material, bronze will not scavenge molecules from the mating pinion or drive worm as can be the case for steel-on-steel applications. Molecule scavenging leads to galling and abnormal or premature gear wear. But in most worm gear applications, the bronze rim portion is all the bronze area needed to achieve the desired wear results. The hub portion, or that portion which fits to a mating shaft, can typically be of another less costly material. Iron is a solid, proven, and low-cost bronze alternative that can be cast to a near net shape as a medium around which molten bronze can be poured successfully. In many gear blank applications, there is an opportunity to use up to 70–75% less bronze by replacing that amount of bronze with a precast iron hub. The cost savings varies, but 10–30% savings is common. In higher volume (EAU) applications, that cost savings can add up very quickly, and justify the casting die and pattern investment in a short amount of time. Further, ASI makes their bronze casting dies in-house, lessening the upfront investment.

ASI is an expert in this bronze composite gear blank methodology. Approximately half of ASI's bronze gear blank sales come from the composite design-type blanks. ASI also manufactures centrifugally cast solid bronze gear blanks. And the composite technology also works very well as a cost-savings alternative to solid bronze gear blanks. Accurate Specialties casts bronze alloy gear blanks in tin bronze, aluminum bronze, manganese bronze and other bronze alloys.

The composite bronze gear blank is not a carte blanche solution for all bronze gear blank applications. "Most of our

iron foundry vendor partners supplying the ductile or grey iron hubs are looking for minimum EAU's of 1500–2000 with minimum releases of 250–500 at a time", says Royce Dahlin, casting engineer at ASI. "And the hub outside diameter over which the bronze ring is poured typically needs to be at least 55–60mm with bronze rim diameters running at 12mm (or more) greater than the hub OD." Accurate Specialties recently experimented with some composite gear blanks in the sub-3.000" range cooperatively with their largest customer. They found that there's a limit to the cost savings benefit of exchanging iron for bronze when the total part weight is under roughly 4#. And at that size, it's a design challenge to get enough bronze for the gear teeth area and still allow space in the iron hub for a key way without creating a stress riser in the hub that could lead to cracking. But the composite gear blank process is cost and time friendly to experiment with because you can machine hubs from bar stock, do a test pour, and be ready to make trial gear designs in a matter of just a few weeks.

Another area the composite bronze gear blank technology might be applied is against solid bronze sector or quarter-turn gear blanks. In fact Accurate Specialties holds a US Patent (#6,058,794 issued May 9, 2000) specifically for such applications. On sector gears the cost savings potential is quite attractive because instead of reducing the bronze content to a rim running 360 degrees around an iron hub, the bronze portion for the gear teeth interface is 100 degrees or less. Therefore, 80% of the gear blank may be converted from bronze to iron; the per-pound cost of a bronze alloy is five to seven times more than the per pound cost of iron.

The C90200-C91700 tin bronze alloys work well in composite gear blank applications. Aluminum and manganese bronze alloys are a tougher challenge. "There's a fine line between the compressive load from the shrink and the iron strength," said Bob Rogers, ASI's Foundry and Machine Shop operations manager. "The iron hub and bronze alloy have to be properly designed such that the compressive load created by the shrinking bronze as it cools doesn't crack the iron hub. There are also some proprietary pre-melting and pour management techniques to get the iron hub ready to accept the molten bronze alloy rim." This kind information is critical in helping the equipment manufacturer arrive at the right gear blank design, material, and heat treatment processes to make the design change into a composite gear blank a success.

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