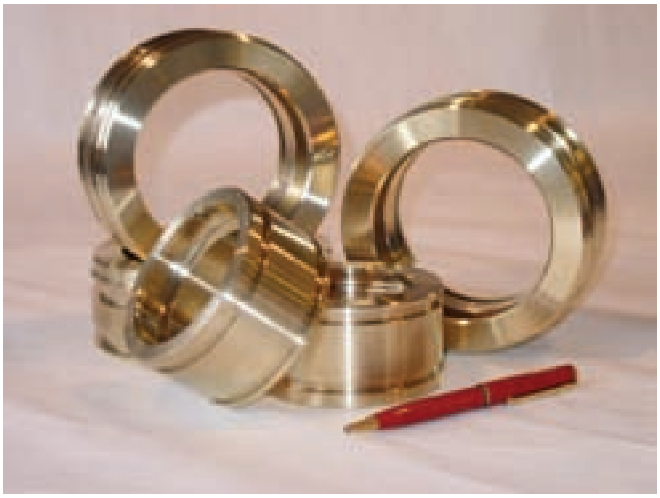
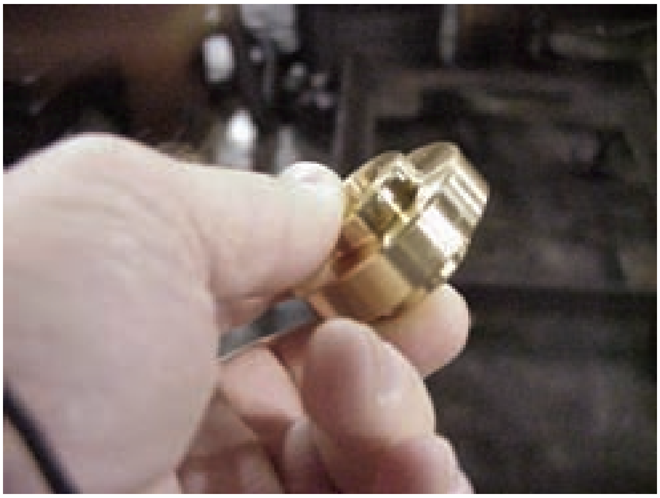
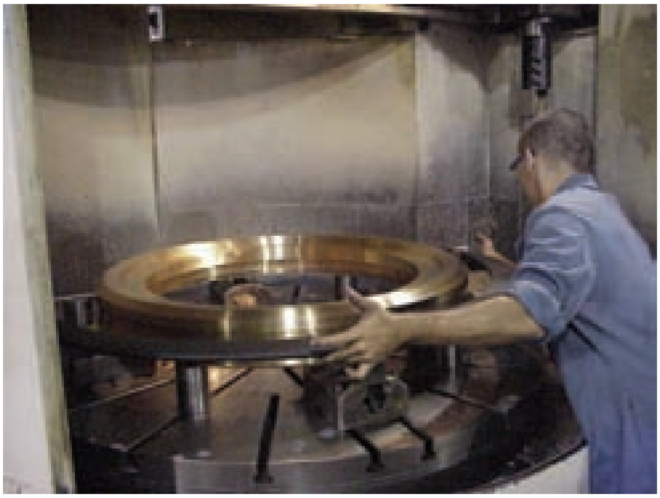
CAST GEAR BLANKS

What to Consider when

Joseph L. Hazelton, Associate Editor







Above photos courtesy of Accurate Specialties Inc.

The gear job is being defined; a number of questions have already been answered. The gear manufacturer knows various parameters: how many gears will be needed, what their life expectancy will be, what conditions they'll operate in, and so on.

But other questions remain, and many of them involve the gear blanks and center on two main questions: Should I obtain the blanks as castings, and if so, what type of casting should be used to make them? Before getting the answers, though, gear manufacturers have to consider many factors.

One is material. What material has the properties needed for the gear application?

For example, there are four bronze types commonly used for casting worm wheel blanks. The types are tin bronzes, nickel-tin bronzes, aluminum bronzes and manganese bronzes. Each type has different properties, making it suitable for certain gear applications.

Selecting the best type depends on a number of factors, such as whether the application will be continuous duty, whether it'll be subjected to shock or impact loads, what its operating temperature will be, and what its input speed will be.

Tin bronzes have good wear properties—nickel-tin bronzes even better—so they're good for continuous-duty applications. Aluminum and manganese bronzes are stronger materials, though, so they'd be best if an application involves high shock or impact loads.

Gregory Estell of gear blank manufacturer Accurate Specialties Inc. mentions bucket trucks, "cherry pickers," as appropriate for aluminum bronze worm wheels. Aluminum bronzes can be as much as 50 percent stronger than tin and nickel-tin bronzes. Also, in cherry pickers, the aluminum bronze worm wheels are intermittent duty, which is good. "Their wear properties are inferior," says Estell, who leads ASI's sales and marketing efforts.

ASI casts gear blanks with diameters ranging from 1.5"–48+". It casts most of its gear blanks for industrial worm gear speed reducers for applications such as food processing, conveyors, construction equipment, utility trucks and hydroelectric dams.

Even stronger than aluminum bronzes are manganese bronzes, which can be as much as 50 percent stronger. Their strength comes with a price, though. "Their wear properties are even more of a challenge," Estell says.

Deciding Whether to Use Them

However, gear properties can be influenced by more than material alone. The different types of casting can lead to different results. So, each gear application involves the question of: Which casting process will provide the desired properties?

In the worm wheel example, blanks of a certain bronze type can be stronger if they're made via centrifugal casting than via spin casting, chill casting or sand casting.

"Centrifugal casting will give you best properties in tin or nickel-tin bronzes in terms of overall strength and grain size, which affects wear," Estell says. More specifically, he says a centrifugally cast tin bronze can have an ultimate tensile strength as much as 50 percent greater than a sand-cast tin bronze.

Ian Sadler, president of Miller Centrifugal Casting Co., adds that centrifugal casting can be performed at gravitational forces 40–60 times greater than the force of normal gravity, so resulting gear blanks can be quite dense along the rim, where gear teeth will be cut. Like ASI, MCC casts worm wheel blanks. Its diameters, however, are 12"–99".

However, the casting process may have no effect on gear blanks' properties. For example, aluminum and manganese bronzes solidify so quickly, they're not sensitive to process from a metallurgical standpoint, Estell says.

Casting may be the best way to make gear blanks depending on their designed shape. Casting can provide design flexibility—"Particularly if there's shape," Estell says, referring to the shape's complexity. Blanks can be cast to near-net shape, with features such as hubs or inner flanges. In many instances, less material is required for casting a gear blank, thereby lowering the overall cost of the blanks.

Estell adds that composite casting probably offers the most opportunity to combine components into a single mold and therefore can be a cost-effective manufacturing method. However, the types of casting need to be considered in terms of their tooling costs.

"Centrifugal casting lends itself very well to rims or shaped gears that are produced in low to moderate volumes," Estell says. "The tooling is relatively inexpensive."

In spin casting of composite worm wheel blanks, the tooling can be more expensive because it has to be manufactured to cast a blank's bronze outer portion and its iron or steel inner portion.

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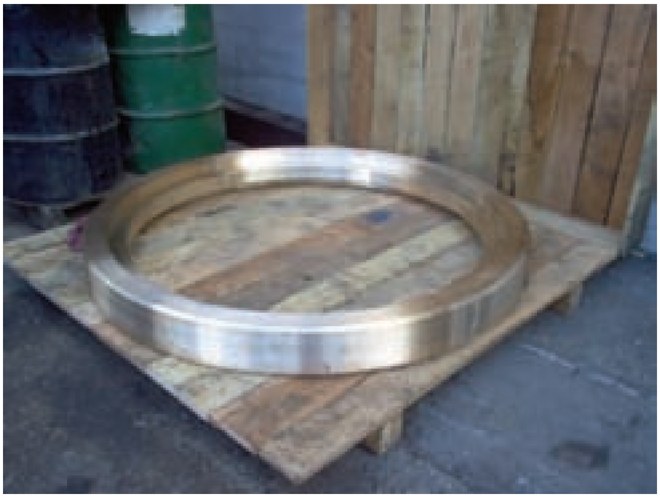

Above photos courtesy of Miller Centrifugal Casting Co.

"Composite tooling can be two to five times that of centrifugal tooling," Estell says.

However, he adds the higher cost can be offset if spin casting allows for the removal of large amounts of bronze from the worm wheel blanks. In that case, the decreased amount of bronze could quickly pay for the increased cost of the tooling. "The rocket science in this is: bronze expensive, cast iron cheap," Estell says.

Also, a blank's design could preclude it from being spun cast as a composite. For example, a worm wheel blank may have a hole so large that its bronze outer part will be too thin after creating its iron inner part. Or the blank may be so small that spin casting won't save enough money by replacing bronze with iron. In that case, it might be cheaper to cast the blanks from bronze alone.

If chill casting is an option, it can offer a fair degree of design flexibility with modest tooling cost, Estell says.

Also of importance is a supplier's ability to cast gear blanks in the needed Brinell hardness range. John McGoldrick, quality assurance manager and technical director for Hodge Foundry Inc., cites the range of larger ductile iron gears. Those gears usually have Brinell hardness numbers (Bhn) of 200–300. A particular gear blank will have a minimum specified Brinell hardness for its rim, with a target hardness range of 40 Bhn.

Hodge Foundry casts gray iron gears and ductile iron gears for the mining and cement industries. It has cast gray iron gears with diameters up to 20' and ductile iron ones up to 26.5'.

As for its importance: "You use hardness to rate the gear set," Craig D. Danecki says.

Danecki is vice president of engineering for Rexnord Geared Products Group, formerly the gear division of The Falk Corp. A manufacturer of open gears and gear reducers, Rexnord casts steel gear blanks, which have ranged from 1.5'–43' in diameter. The company makes most of its cast gears for the mining, cement, paper, power generation, marine and grain industries.

The relationship between Brinell hardness and a gear's rating can be found in AGMA standards. They provide rating factors and calculation methods for involute spur and helical gear teeth.

Also, Danecki says it's critical to use a material that will guarantee hardness at the root of the gear tooth, at the gear's midface and after a "significant" amount of machining has occurred.

Manufacturers may inspect their gear blanks in a number of ways. MCC visually inspects its bronze worm wheel blanks. Giri Rajendran, MCC's vice president–technology, says this surface inspection is sufficient 99 percent of the time because bronze is so reflective that a shadow, indicating a hole, will be easily visible: "It's going to jump out at you."

Rexnord checks its steel gear blanks using ultrasonic inspection, which finds defects such as holes, large cracks and inclusions—for example, sand from the mold's surface. Different types of gear blanks, though, require different methods of ultrasonic inspection. Danecki discusses the method Rexnord uses for ring gears.

After being cast and rough turned, the blanks are ultrasonically inspected from the outside diameter and from the rim face. To do that, they must have surface finishes of not more than 250 RMS (root-mean-square). A ring gear, though, has various areas with different stress levels, so the ultrasonic tolerance band will be tighter for higher stressed areas and wider for lower. Although band widths differ, the industrial blanks are still high quality.

"Ring gears are designed with an expected life of 20 years," Danecki says. "You can't have a low quality casting, or it just won't survive." Given the life expectancy, he recommends every gear be ultrasonically inspected. "It's something you really want to do, if you want to be safe," Danecki says.

Gear blanks may also be examined via magnetic particle inspection, dry or wet. Dry MPI checks for cracks in the blank's surface. Danecki says manufacturers focus dry MPI on areas that their experience tells them are the most likely to have problems.

Wet MPI is performed after blanks receive their final heat treatments. This method is commonly used to check whole blanks for detecting surface and near subsurface discontinuities. Wet MPI

Photo courtesy of Rexnord Geared Products Group.


Photos courtesy of Hodge Foundry Inc.

uses a solution that includes suspended iron particles, often water with a rust inhibitor. Cables are wrapped around certain sections of the blank. Powered by electricity, the cables generate magnetic fields, and the blank is exposed to a black light.

"If there's a crack or defect, you'll see it under the black light," Danecki says. He adds that wet MPI is typically used on through-hardened steel gears.

Magnetic particle inspection is detailed in standards created by the American Society of Testing Materials (ASTM).

Hodge Foundry also uses ultrasonic inspection and magnetic particle inspection to ensure the soundness of its gear blanks. "These inspection methods are a carryover from cast steel production," McGoldrick says.

Danecki suggests companies also obtain the results from a manufacturer's solidification software. He describes the software as being like a finite element program. It shows how a gear blank will solidify and helps to identify defects, such as shrink, and other solidification issues that can arise.

Danecki says the software should be used before the manufacturer makes the mold, so the buyer can see the design of the structure that will support the gear teeth.

Without proper solidification, gear blanks can have major defects, such as feeding porosity. That defect can arise as a casting solidifies, while it's contracting. If there's insufficient molten metal available to compensate for the shrinkage, then voids result. These voids are known as feeding porosity.

Also, when choosing a type of casting, customers need to consider the number of gear blanks to be produced. For example, if the production volume is low and other factors allow, sand casting may be the best, most economical option.

In contrast, centrifugal casting usually requires more than low volumes. When centrifugally casting worm wheel blanks, the production volume should be sufficient to pay for the mold, Sadler says. Centrifugal casting uses permanent molds, which are made of metal (iron or steel) and generally cost more to produce than temporary molds, which are usually made of sand.

A gear manufacturer has to keep all these factors in mind as he looks for the answers to his main questions: Should I get my gear blanks as castings.

Even with the answers, though, the gear manufacturer has other main questions: about the best method for cutting the gear teeth, about the most appropriate type of heat treating, about whether finishing operations will be needed. But learning whether cast gear blanks can be used helps define the gear job until all questions are answered and physical work can start. ■

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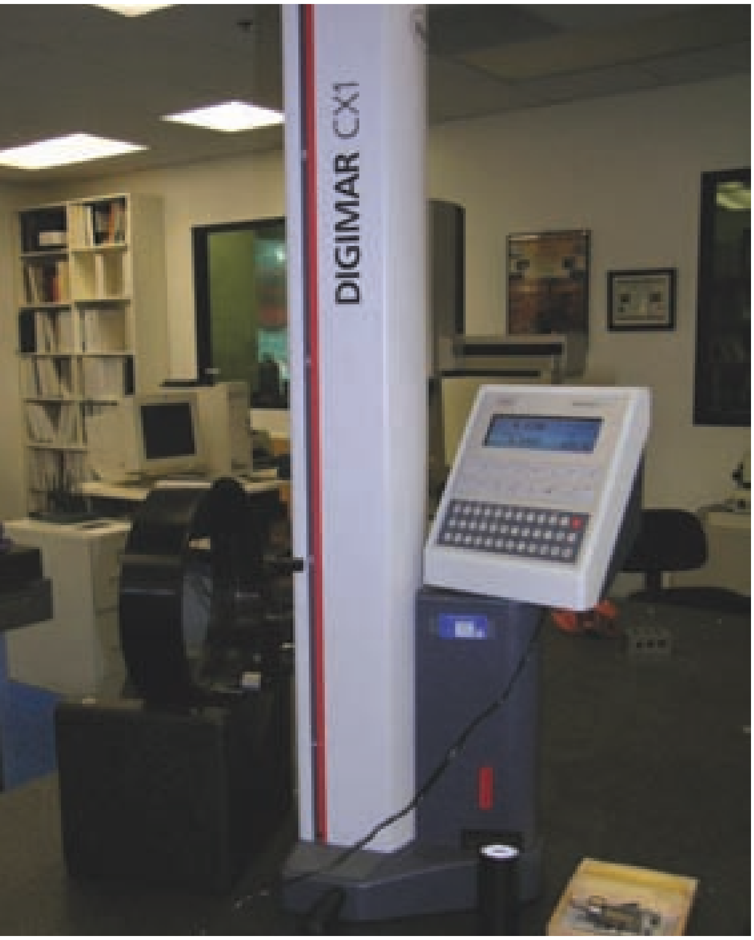
Mahr Federal's Digimar Height Gage

OUTPACES CMM AT GERHARDT GEAR

Gerhardt Gear, a manufacturer of specialty gears for aerospace and military applications in Burbank, CA, bought a Digimar CX1 height gage from Mahr Federal, expecting it to replace some of its height gages and handle the 500–1,000 piece production runs that previously required hand tools such as pin and height gages, calipers, etc.

Gerhardt Gear had three height gages prior to purchasing the CX1. The Mahr Federal gage had appeal because it could check linear dimensions as well as diameters in a single machine. It also inspects length, and sometimes Gerhardt uses it to check and compare MOW (measurement over wire) in sector gears.



When the company ordered the CX1, it never intended for it to replace its larger CMMs. And, although the CMMs are still useful in the sense that they work accurately and independently, employees at Gerhardt Gear were surprised that the Digimar CX1 height gage was faster than anticipated. General manager John Kim cites one instance in which it took the CMM more than 20 minutes to check a part's tolerance to within 0.001" or less. The CX1 completed the same measurement in less than one minute.

"In reality, the checking itself doesn't take that long, but a CMM is much more complicated. A CMM is good for multiple dimensions at once, but a lot of times that isn't necessary, and you just need to check a couple of things. The CX1 is much more user-friendly for that. The way the CX1 program is designed, it makes it almost impossible to make a programming mistake," he says.

When a part requires inspection of inside or outside diameter, it usually takes a few seconds to check one piece and provide a reading, Kim says.

The Digimar CX1 is part of a family of motorized, programmable height measuring systems that's suitable for gage lab and production measurement use. Additional features include fully motorized measuring slides that minimize operator influence on part probing for greater measurement precision and repeatability. Key measurement functions are activated with the press of a button, and readily programmable measuring routines enable sample batches of mass-produced parts.

"CX1 helped us in a lot of different ways, but one thing that it really helped us [with] is checking distance between centers on two holes, especially when they are offset. It usually takes about five minutes per part using manual methods, but it only takes about 10 seconds using a CX1. Not to mention that it's very accurate," Kim says.

Gerhardt Gear says its CX1's accuracy is +/–0.0001". Specialties of the CX1 include the measuring of planes, grooves, bores and shafts as well as the calculations of distances and symmetries. Max.-min. measurements are supported, as are perpendicularity measurements in conjunction with a digital dial indicator. Canned routines for basic features and simplified teach-and-learn techniques make it easier to program for a variety of measurement tasks.

Rory Neill, product manager at Mahr Federal, says customer interest in the Digimar CX1 has been positive across the board. The CX1s have been popular with both automotive and gear companies.

"It's pretty simple," he says. "If you have a surface gage doing measurements, you should have a height gage right along with it. Otherwise, if you have one small CMM, the person has to wait for free time to put his part on the CMM."

Kim says that the company is seriously considering purchasing a second Digimar CX1 for use on the shop floor.

"Operators aren't as kind to equipment as the folks in the lab, but we think the Digimar is rugged enough and so easy to operate that it will do just fine. And because measurement is programmable, it should really help our in-process inspection," he says.

Kim elaborates on the Digimar CX1, "It's not cheap. But, in the long run, we've found it to be well worth it." ■

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