Agricultural Applications of Austempered Iron

Austempering, a heat treating process ideal for many high-wear applications, is not just for ductile iron.

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Several developments have occurred in the past few years regarding the use of austempering applications in the agricultural industry. Farmers, component designers, agricultural equipment manufacturers and aftermarket agricultural component suppliers all have found unique, cost-effective uses for austempered components.

In addition to austempered ductile iron (ADI), austempered gray iron (AGI) and carbidic austempered ductile iron (CADI) increasingly have found applications in agricultural equipment and component applications.

Austempering, a heat treating process performed on iron components after casting, offers manufacturers numerous opportunities to make their iron components tougher, stronger, lighter, quieter and more wear resistant. Because austempering is an isothermal process, it offers several advantages over conventional quenching and tempering and other methods of martensitic hardening. Martensitic transformation takes place when the local material temperature drops below the martensite-start temperature. Therefore, the transformation takes place at different times in sections of differing section modulus. This can result in inconsistent dimensional response and micro- and macro-cracking. However, since the formation of bainite and ausferrite oc-

cur uniformly throughout the part over many minutes or hours, austempered components exhibit consistent dimensional response and no cracking.

ADI is a cost effective, durable alternative to steel and aluminum castings, forgings, weldments and assemblies. AGI combines good wear resistance and noise damping at a total manufacturing cost less than ADI, steel or aluminum. CADI offers extreme wear resistance with a modicum of toughness that gives it performance and cost advantages over conventional abrasion resistant iron components.

Austempered Gray Iron

AGI provides the same excellent wear resistance as its ausferritic cousin ADI. It exhibits higher strength than as-cast gray iron. Fig. 1 shows the tensile strength array of Class 20, 30 and 40 gray iron as-cast and austempered at 700F (371C), 600F (316C) and 500F (260C).

AGI's most salient feature is its ability to dampen noise due to the combination of an ausferritic matrix and large graphite flakes. As the austempering temperature is decreased, the strength of the AGI increases, as does the damping coefficient (Fig. 2). The graphite flakes also limit the strength of AGI, acting as angular voids in the metal matrix and allowing maximum strengths no higher than approximately 450 MPa.

The advantages of AGI are its low cost and excellent castability. This makes it a good material/process combination for applications that require a low cost, complex shape, and good strength and wear resistance, where impact and cyclic stresses are not significant.

The most common application of AGI is in cylinder liners for diesel engines. In that application, the cylinder liners offer good wear resistance and noise damping, as well as improved burst strength over as-cast gray iron liners.

However, the material also has found appropriate application in agricultural products. The complex harvester machine cam in Fig. 3 demonstrates the excellent manufacturability of AGI components. The iron offers good castability and is easily machined. The critical shape of the cam is maintained during the austempering process. The ausferrite matrix provides good wear resistance for cam durability and elevated noise damping.

Austempered Ductile Iron

ADI is produced by austempering a ductile iron (spheroidal graphite iron) material to produce an ausferritic matrix. The spheroidal graphite "nodules" in ductile iron allow engineers to fully exploit the high strength and toughness of ausferrite, as they do not reduce the toughness of the iron like graphite flakes or large carbides in gray iron. ADI is about 10% less dense than steel due to the presence of these graphite nodules. Table 1 shows the properties of the ADI grades specified in ASTM A897/A897M-06.

Engineers and designers have learned that ductile iron can be easily cast into complex shapes. By subsequently austempering these castings, they can exhibit a strength-to-weight ratio comparable to heat treated steel or aluminum. This allows designers to create one-piece designs that might have been previously assembled from multiple forgings, castings, extrusions, weldments or stampings.

ADI's microstructure contains carbon-stabilized austenite that is thermally stable but, when acted upon by a high, normal force, transforms locally to untempered martensite nested in a ferritic matrix. This increases the surface microhardness, giving ADI an abrasive wear resistance that exceeds that implied by its bulk hardness, and making it ideal for many agricultural applications.

In certain angular and rocky soils, ADI plow points, boots and plow shins have been reported by farmers to wear more slowly than hard-face welded and high-chrome wear resistant irons. In other, less aggressive soils, ADI does not perform as well.

The same "strain transformation" phenomenon that increases the surface hardness of ADI also creates compressive surface stress and increases allowable bending stress. The result is an increase in the fatigue strength of both structural and powertrain components, which can benefit from shot peening, grinding or fillet rolling after austempering.

Many types of wheeled agricultural and construction equipment are being converted to rubber tracks for increased versatility and lower weight, cost and soil compaction. In one application, the Toro Dingo TX 413 (Fig. 4), the main drive wheel consisted of an 84-piece welded and bolted steel assembly. Engineers at Toro and Smith Foundry, Minneapolis, collaborated to create a one-piece ADI design that proved to be lower in cost and more durable. Because 84 pieces of steel were replaced with one green sand ADI casting, the wheel reliability was improved by eliminating the variability in cutting, stamping, drilling, bolting and welding the components together.

The earliest agricultural applications of ADI were simple aftermarket plow points and wear shins. Fig. 5 shows a typical ADI plow point that has been

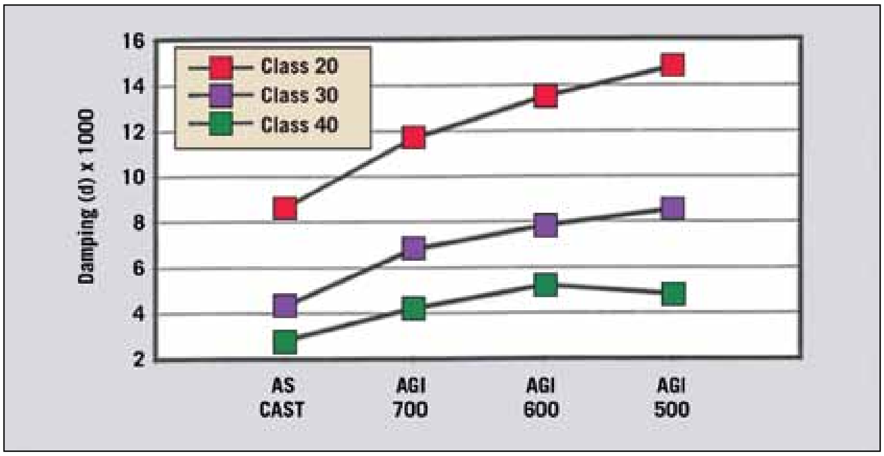

Fig. 1. The tensile strength of gray iron classes 20, 30 and 40 are shown as-cast and austempered at 700F (371C), 600F (316C) and 500F (260C).

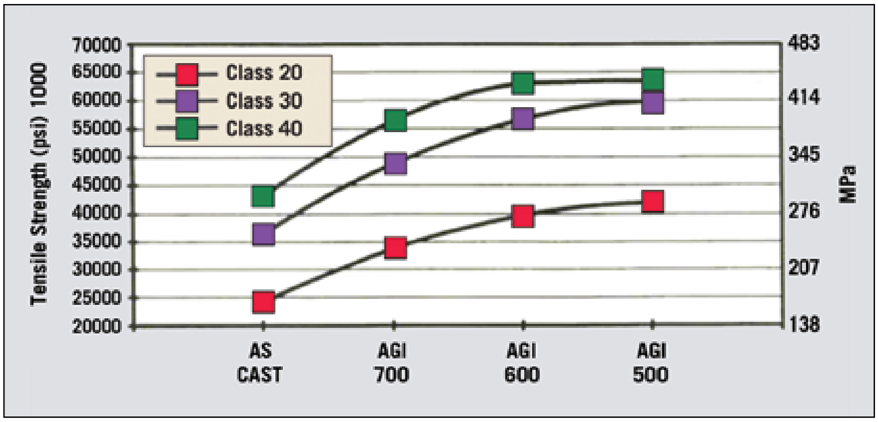

Fig. 2. This graph shows the damping coefficient of three classes of gray iron both as-cast and austempered at 700F (371C), 600F (316C) and 500F (260C).

in production for more than 15 years. These through-hardened ADI ground engaging parts replace hardened and hard-faced welded steel components at a competitive price.

Australian farmers have utilized the prize-winning MitchTip design since the 1990s (Fig. 6). This proprietary ADI design utilizes impacted soil to extend the life of the tip.

Harvesting machines present their own set of challenges to the designer, and the advent of rotary designs has created new opportunities for castings. Many grain rasps, deflectors and other parts used to separate and convey grain within harvesters have been converted to ADI. The complex shape shown in Fig. 7 would be difficult to produce by any other method than casting. The wear resistance offered by ADI allows it to stand up to abrasive grain flow.

Fig. 3. This large austempered gray iron cam wheel is used in a harvesting machine.

ADI also is used in powertrain and sprocket-driven applications. John Deere utilizes an ADI adjuster sprocket on one of its harvesters as a cost effective alternative to a steel sprocket machined from bar stock.

Agricultural components must often withstand impact loading and the abrasive wear characteristics of sandy and/or wet grass, stalks and organic material.

Carbidic Austempered Ductile Iron

CADI is produced by the introduction of carbides into the cast iron matrix during the casting process. The iron is subsequently austempered in a manner that produces a controlled percentage of carbides in an ausferritic matrix. CADI was introduced in 1991 to produce components with better wear resistance than ADI with a price and performance competitive with abrasion resistant irons but with a modicum of impact strength.

CADI also may be produced by mechanically introducing carbides into a casting cavity prior to the introduction of molten metal. The subsequent austempering of the component does not affect the cast-in carbides. Another version of CADI can be produced by casting a part as ductile iron, hard-face welding a locality on the part and then subsequently austempering it, leaving the carbidic hard-face weld unaltered while producing a base matrix of ausferrite.

The first commercial application of CADI was introduced in 1991. A small agricultural implement manufacturer then using ADI needed more wear resistance on a fully-supported plow point (Fig. 8). The manufacturer, Carroll Agricultural, worked with G&C Foundry Co., Sandusky, Ohio, and an austempered iron consultant to develop a casting process to produce an as-cast iron matrix containing mixed spheroidal graphite and carbides. The carbides were subsequently partially dissolved during austenitizing. The material was then austempered. The resulting wear resistance was suitable

Table 1. Minimum Properties of the Six ADI Grades Specified in ASTM A897/A897M-06

Tensile Strength (MPa / ksi)	Yield Strength (MPa / ksi)	Elongation (%)	Typical Hardness HB_W
750 / 110	500 / 70	11	241 – 302
900 / 130	550 / 90	9	269 – 341
1050 / 150	750 / 110	7	302 – 375
1200 / 175	850 / 125	4	341 – 444
1400 / 200	1100 / 155	2	388 – 477
1600 / 230	1300 / 185	1	402 - 512



Figs. 4, 5, 6 & 7. Clockwise from top left: A one-piece ADI main drive wheel replaced an 82-piece steel welded and assembled component in the Toro Dingo TX; this typical ADI plow point has been in production for more than 15 years; Australian farmers have utilized ADI MitchTips since the 1990s; this grain deflector for a harvesting combine is produced in ADI to stand up to abrasive grain flow.

for the customer's application, and the parts exhibited adequate toughness to survive impacts with stones.

Fig. 9 shows the John Deere LaserRip ripper points, which utilize CADI for wear resistance and toughness in highly abrasive, rocky soil. The material provides better wear resistance than standard steel points and better impact resistance than high-chrome, abrasion resistant steels and irons.

Harvesting machines pose interesting challenges for design engineers. If the handling and thrashing components are too soft, they will wear out, causing downtime at critical harvest times. If those same components are too brittle, they may break, causing the machine to be offline at a critical time. Engineers have found that CADI rasps, thrashing tines, flights and buckets can withstand the impacts sustained in grain harvesting and provide sufficient wear for a full season and more. *METAL*

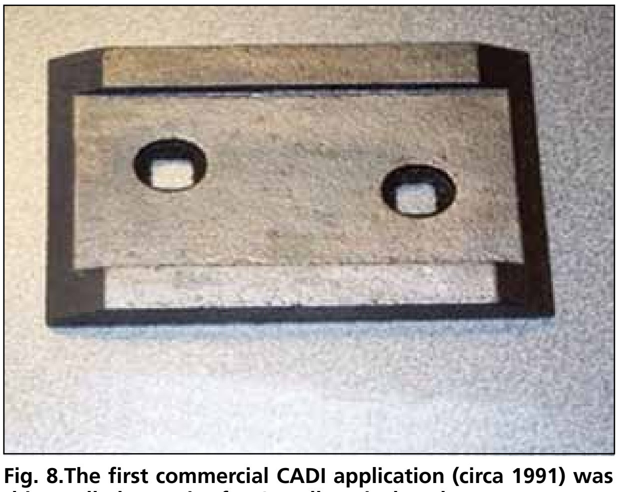

Fig. 8.The first commercial CADI application (circa 1991) was this small plow point for Carroll Agricultural.

Fig. 9. These John Deere LaserRip ripper points were produced in CADI for wear resistance and toughness in abrasive, rocky soil.