ADI — A Designer Gear Material

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If someone were to tell you that he had a gear material that was stronger per pound than aluminum, as wear-resistant as steel, easier to machine than free-machining steel and capable of producing gears domestically for 20% less than those now cut from foreign made forgings, would you consider that material to be "high tech"? Probably. Well, throw out all the pre-conceived notions that you may have had about "high tech" materials. The high-performance material they didn't teach you about in school is austempered ductile iron (ADI).

Cast irons and "high tech" scarcely have been uttered in the same breath. . . until now. The common perception of cast iron is based on gray or flake graphite iron. With a maximum tensile strength of 50 ksi and virtually no ductility, it is perceived to be a low-strength material suitable only for low-performance applications. However, ductile irons (or spheroidal graphite irons), with strengths up to 100 ksi and reasonable ductility, have been commercially available for many years. Yet even ductile irons cannot be used in most gear applications. Today, a new member of the cast iron family is available to design engineers even for high-performance applications. That material, ADI, is a specially heat treated iron that offers the gear designer manufacturing flexibility, low weight, excellent fatigue strength and wear resistance, all at a significantly lower price.

Grade Number	Tensile* Strength	Yield* Strength	Elongation*	Impact Energy**	Typical Hardness
ASTM 897-90 (English Units)					
	(ksi)	(ksi)	(%)	(ft-lbs.)	(BHN)
1	125	80	10	75	269-321
2	150	100	7	60	302-363
3	175	125	4	45	341-444
4	200	155	1	25	388-477
5	230	185	n/a	n/a	444-555
ASTM 897M-90 (Metric Units)					
	(MPa)	(MPa)	(%)	(Joules)	(BHN)
1	850	550	10	100	269-321
2	1050	700	7	80	302-363
3	1200	850	4	60	341-444
4	1400	1100	1	35	388-477
5	1600	1300	n/a	n/a	444-555
* Minimum value ** Un-notched Charpy @ room temp.					

Fig. 1 — Available grades of ADI and their minimum properties.

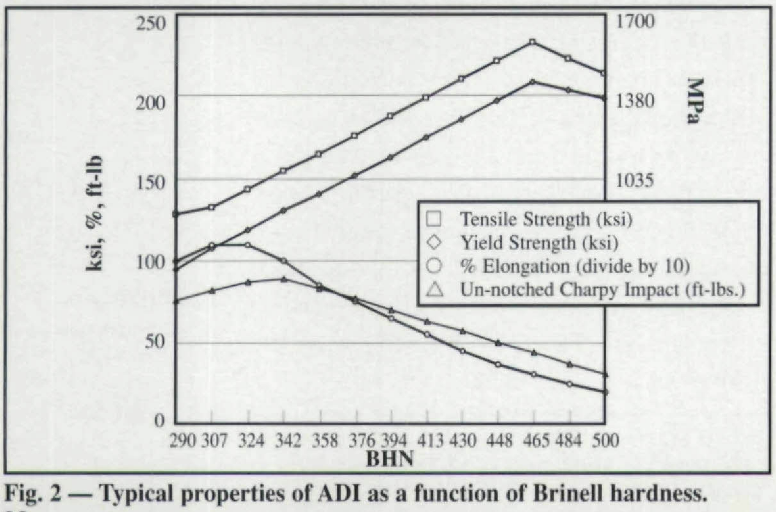

Fig. 2 — Typical properties of ADI as a function of Brinell hardness.

Ductile iron is 10% lighter than steel. It is easily cast into complex shapes. When subjected to a specially designed austemper heat treatment, it can exhibit remarkable properties. The available grades of ADI and their minimum properties are outlined in ASTM 897-90 and 897M-90 (Fig. 1). Fig. 2 shows the *typical* properties obtained in commercial ADI.

Because the heat treatment is isothermal in nature, the growth during the process is very predictable and repeatable. In fact, most parts can be finish-machined before austempering (accounting for volumetric growth), and they will grow predictably to specifications. This allows the manufacturer to use a very machinable grade of ductile iron for the casting, thus reducing machining costs even when compared to free-machining and leaded steels. (Ductile iron also produces a discontinuous chip during machining for easy chip handling.)

The fatigue properties of ADI are comparable with those of various heat treated steels. Single tooth bending fatigue data for grades 150-100-07 (Grade 2) and 230-185-00 (Grade 5) are shown in Fig. 3. Additionally, all grades of ADI *exceed* the notched-impact-resistance and low-temperature properties of carburized and hardened 8620 steel.

Because the "ausferrite" matrix in ADI goes through a "strain transformation" under high normal stresses, the contact fatigue resistance also is excellent. It can be greatly improved by rolling, grinding and shot peening. Contact fatigue data for grades 150-100-07 (Grade 2) and 230-185-00 (Grade 5) are shown in Fig. 4. The data clearly shows that Grade 5 ADI can replace carburized and hardened steel in gear applications with contact stresses up to and in some cases exceeding 250 ksi.

ADI can be produced with hardnesses ranging from approximately 30–50 Rc. As can be seen from Fig. 5, however, the wear resistance of ADI for a given hardness level is superior to that of many conventional materials. In fact, in many applications ADI with 42–46 Rc has replaced 60-Rc carburized and hardened 8620 with equal or better performance.

In addition to the aforementioned properties, ADI has superior damping to steel. This is related to the presence of graphite nodules in the matrix. These graphite nodules also improve the lubricity of the material. In some cases this has resulted in measured reductions in frictional losses.

Although ADI costs less per pound than most steel gear materials, the true manufacturing cost savings are more subtle. ADI is 10% less dense than steel; therefore, if you replace a steel gear with an ADI gear of the same configuration, it will weigh 10% less. (Oddly enough, ADI is starting to replace aluminum for weight savings in many applications because of its high strength-per-pound characteristics). Furthermore, modern casting techniques allow us to produce gears and gear blanks that are much nearer net shape, greatly reducing the amount of metal removal required.

ADI is a commercially available alternative to steel for gear applications. It has the strength, wear resistance and manufacturing flexibility desired by gear designers. It can be produced domestically at 15 to 50% less than materials produced by conventional means. The use of ADI in gear applications is certain to rise as engineers become more familiar with its advantages. ✪

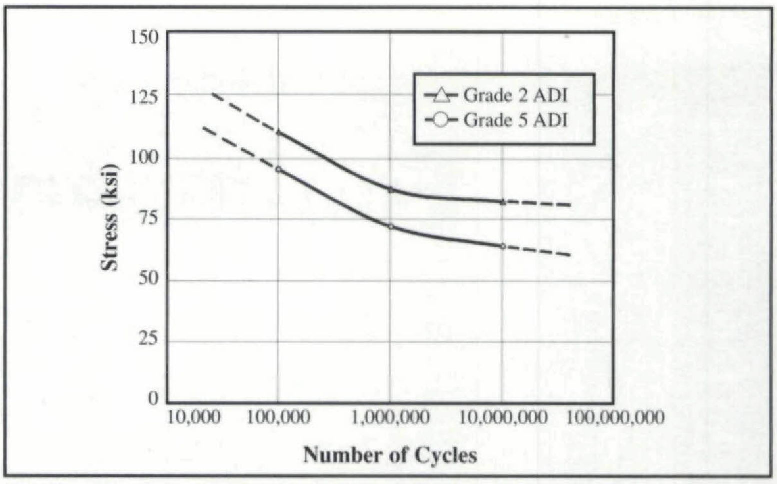

Fig. 3 — Single tooth bending fatigue (90% confidence limits). From ASME Gear Research Institute[1].

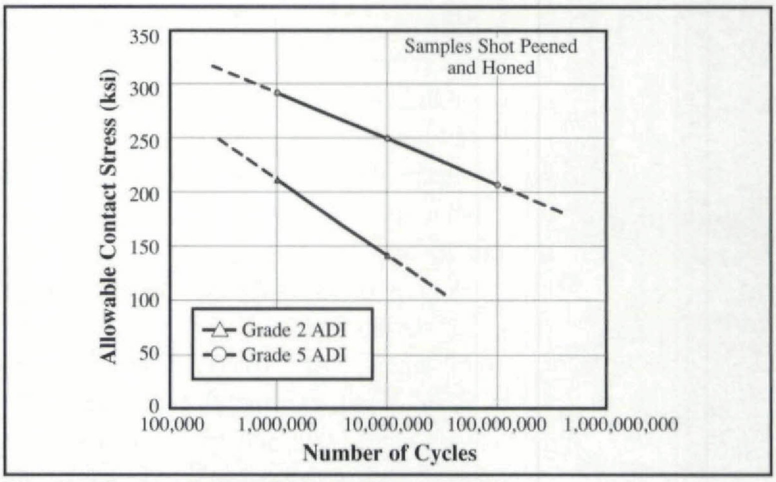

Fig. 4 — Contact fatigue (90% confidence limits). From ASME Gear Research Institute[1].

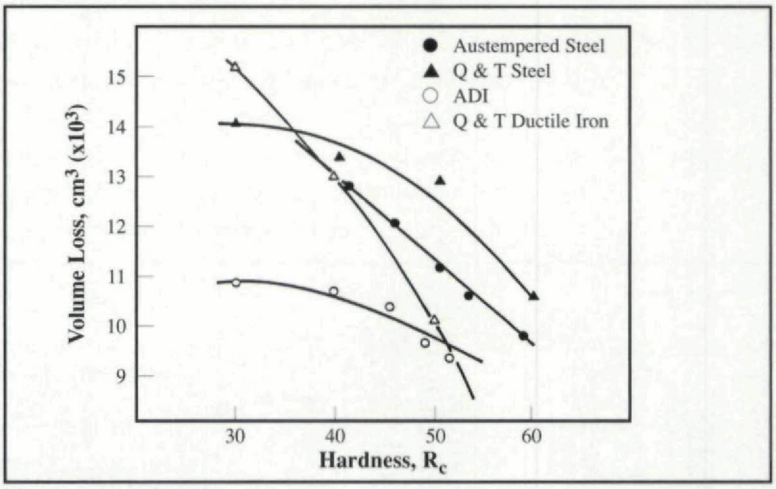

Fig. 5 — Pin abrasion test.

References:

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5. Keough, J.R. "The Marketing of ADI." Keith Millis Symposium, Ductile Iron Society, October 1993.

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