Investigation to Production Machinable Austempered Ductile Iron (MADI)

Najmeddin Arab

najmarab@iau/saveh.ac.ir
Department of Engineering, Islamic Azad University, Saveh Branch, Iran

Abstract: Austempered Ductile Iron (ADI) are materials which have attractive properties such as ductility, high strength, hardness and good wear resistance. These properties can be achieved by proper chemical composition, heat treatment and adequate microstructure. The main barrier in progress application of ADI, is low machinability. In this paper, an investigation has been conducted on ADI Alloys with different heat Traetment times and temperatures and measuring of hardness as a criteria for machinability. It was shown that by increasing in Austenizing and austempering temperatures, the hardness decrease, which it is benefit to increase machinability. Based on these results an optimal processing window has been established.

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1. Introduction:

Austempered ductile iron (ADI) is ductile cast iron, heat-treated using a tightly controlled process that produces a unique microstructure [Brandenberg and Cakir]. ADI is five ASTM A897 standardgrades, covering a wide range of strength and hardness characteristics. Figure 1 compare ADI with regular industrial metals.

ADI provided high strength, good fatigue properties, superior wear qualities, excellent toughness and cost-effectiveness. ADI's tensile and yield strengths are at least those of standard ductile iron. ADI 's fatigue strength is typically 50% higher than that of standard ductile irons. It can be further increased by shot peening or fillet rolling. The lower hardness grades of ADI work well in structural applications. ADI's excellent impact and fracture-toughness properties make it ideal for applications such as ground-engaging tools. The higher hardness grades of ADI are excellent for wear applications. Unlike case-hardened materials, typically the ADI is uniformly hardened throughout the part. Also grafite or cementite. When solidification is jast complete, the precipiutated phase is embedded in a matrix of austenite which has an equilibrium carbon concentration of about 2 wt%. On further cooling, the carbon concentration of the austenite decrease as more cementite precipitates from solid solution. For conventional cast irons, the austenite then decompose into pearlite at the eutectoid temperature. However, in grey cast irons, if the cooling rate through the eutectoid temperature is sufficiently slow, than a completely ferritic matrix is obtained with the excess carbon being deposited on the already existing graphite [Ahmadabadi, and Bhadeshia]..

ADI is usually 15% to 20% less costly than steel forgings or castings. It is the most economic way of obtaining tensile, yield, or fatigue strength. ADI often competes favorably with heat-treated and alloy steels for heavy-duty applications where reliability is crucial. It is a useful upgrade from standard grades of ductile iron. In some cases it replaces manganese steel and nickel-chrome iron. Because of ADI's high strength-to weight ratio, it has even replaced aluminum where the design allows reduced section sizes.[Brandenberg]

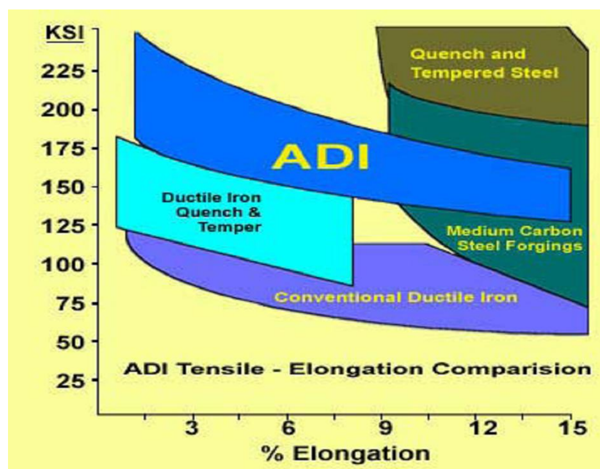

Fig. 1. compare ADI with regular industrial metals

2. Austempering process

Austempered ductile iron is produced by heat-treating cast ductile iron ti which small amounts of nickel, molybdenum, or copper have been added to improve hardenability. Specific properties are determined by the careful choice of heat treating parameters. Austempering involves the nucleation and growth of acicular ferrite within austenite, where carbon is rejected into the austenite. The resulting microstructure of acicular ferrite in carbon-enriched austenite is called ausferrite. Even though austenite is austempered ductile iron is thermodynamically stable, it can undergo strain-induced transformation to martensite when locally stressed. The result is islands of hard martensite that enhance wear properties.

Steps in the Austenitizing Process (Fig. 2)
- Heat castings to austenitizing temperature.
- Hold at austenitising temperature to dissolve carbon in austenite.
- Quench quickly to avoide pearlite.
- Hold at austempering temperature in molten salt bath for isothermal transformation to ausferrite.

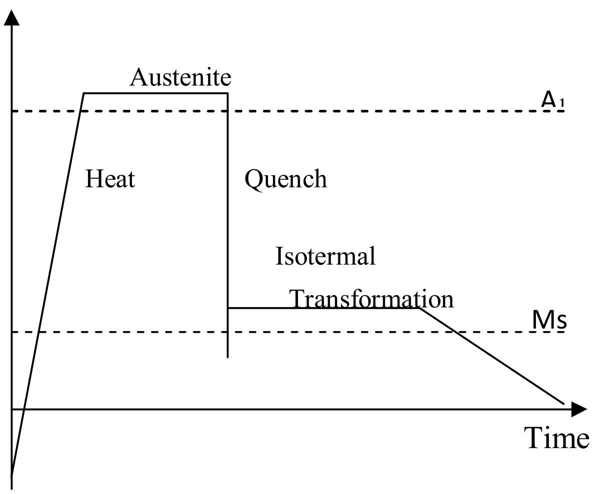

Fig. 2. Shematic Procedure for Austempering Heat Treatment

3. Machinability of ADI

Austempered ductile iron finds application as a replacement for forged steel components in the agricultural, mining, automotive and general engineering industries. For example: Plough tips, digger teeth, springbrackets, gears, knuckle arm, crankshaft, etc. ADI production is growing but its use is limited to some extend by the machinability.

The production of many ADI parts involves machining operation. This operation consist of 2 stages:

- Rough machining operation before austempering treatments

- Fishing (Grinding) operation carried out after austemperig treatment

There are few reasons for this machining procedure:

a. At the as cast or ferritizing annealing treatment, the casting have very good machinability . In this condition, the cost of machining is low.

b. After austempering treatment, the hardness of treated parts is so high (usually 300-500 BHN) which reduce machinability. In this condition:

b-1. The cost of machining is so high.

b-2. Diamentional changes which take place as a result of high temperature heat treatment, may affect diamentional accuracy of parts and scarfp the castings.

The poor machinability in the austempered condition is the main barier in progress of ADI's application.[Chupatanakul, Druschitz and Eric]

4. Machinable Austempered Ductile Iron (MADI)

The properties of austempered ductile irons are dependent on both chemistry and heat treatment, which determine the size, distribution and stability of the phases present in the final microstructure [Warrick]. MADI is a new type of ADI with both good mechanical and machinability properties. It could be machining after austenitizing process**.**

5. Experimental Procedure

Charging material consist of 40% casting scrap and 60% steel scrap. The molten metal were produced in a commercial 500 kg, 250 Hz Medium frequency electric induction furnace. The Molten Metal Treated by 1.3% Fe-(44-48) %Si-(5-6)%Mg Ferro-Silicon-Magnesium alloy. The Molten Metal was poured about 1405˚c into standard Y Block sand molds according to ASTM A-395 standard The chemical compositions of poured metals have been illustrate in table 2. Specimens, austenized for 75 minutes in electric heat resistant furnace followed by rapidly transferred to a salt bath furnace for austempering at 35 minutes and then air-cooled to room temperature. The heat Treatment conditions have been illustrate in table 3. Tensile test specimens with 10 mm in diameter and 30 mm in gauge length and unnotched charpy specimens with 55×55×10 mm were machined from Y blocks. All the hardness tests and metallorgraphy examination were carried out on tested charpy specimens.

Table 1. Chemical Composition of Samples

Sample No.	%C	%Si	%Mn	%S	%P	%Mg	%Ni	%Mo	%Cu
1	3.65	2.53	0.25	0.008	0.038	0.045	0.63	0.54	0.36
2	3.58	2.64	0.28	0.009	0.036	0.043	1.05	0.3	0.81
3	3.62	2.57	0.24	0.007	0.036	0.038	0.88	0.45	0.68
4	3.66	2.48	0.27	0.008	0.038	0.040	0.93	0.48	0.75
5	3.50	2.55	0.29	0.008	0.035	0.037	0.55	0.62	0.45

Table 2. Heat Treatment Conditions for Specimens

Sample No.	Austenizing Temp (˚C)	Quenching Ternp (˚C)
1	850	300
2	875	325
3	900	350
4	925	375
5	950	400

Table 3. Hardness Testing Before and After Heat Treatment

Sample No.	Hardness before HT (BI-1N)e	Hardness after HT (BHN)
1	252	380
2	230	365
3	242	340
4	248	315
5	244	285

6. Results and discussion:

The result of hardness testing before and after heat treatment (HT) illustrate in table 4. The microstructure of sample no 5 illustrate in fig. 2.

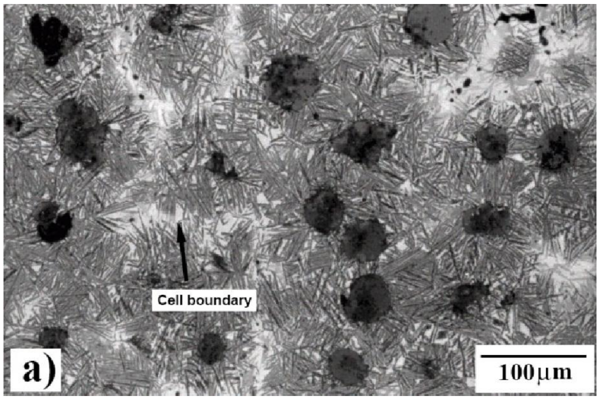

Fig. 2. Microstructure of Austempering Treatment

By increasing the austenitizing and quenching temperature, the hardness of austempering treatment have been decrease. It means that casting parts will have appropriate machinability. But lower ductility of samples in comparison with regular grades ductile irons is an important problem for industrial application of this type of materials.

Corresponding Author:
Najmeddin Arab
Department of Engineering,
Saveh Branch Islamic Azad University,
Saveh, Iran,
najmarab@iau.ac.ir

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