



对生产 ADI 等温淬火球墨铸铁铸造厂商的几点建议

Suggested Foundry Requirements for Ductile Iron that is to be Austempered ADI

ADI 能用相当宽的化学成份范围以及各式形状的球墨铸铁件成功生产。虽然没有 ADI 铸件的最佳配方，但按下列参数已生产出优质的 ADI 铸件。

ADI can be produced successfully from ductile iron castings with a wide range of chemistries and configurations. Although there is no optimum recipe for ADI castings, those produced to the following parameters have been shown to yield excellent results.

铸件质量

Casting Quality

铸件应没有非金属夹杂物、碳化物、缩松和夹渣。正确的采购、贮藏和使用炉料能将产生碳化物和气体缺陷的概率降到最低。正确的造型控制可以把铸件的表面和皮下缺陷减到最少。铸件的浇注系统应正确设计、在浇注过程中应采用稳定和有效的球化和孕育技术以获得没有缩松的铸件。任何与前述不一致的情况都会降低 ADI 零件的“韧性”（即使适合于常规球墨铸铁）。下列参数是推荐的最小值：

The castings should be free of non-metallic inclusions, carbides, shrink and dross. Proper purchasing, storage and use of charge materials will minimize the occurrence of carbides and gas defects. Proper molding control will minimize surface defects and other sub-surface discontinuities. The castings should be properly gated and poured using consistent and effective treatment and inoculation techniques to yield shrink free castings. Any of the aforementioned non-conforming conditions will reduce the “toughness” of an ADI component (even if adequate for conventional ductile). The following should be met **as a minimum**:

石墨球数 / Nodule Count	100 / mm ²
球化率 / Nodularity	85%

碳当量

Carbon Equivalent

碳当量（CE）可按如下公式表示：

The carbon equivalent (CE) can be expressed as follows:

$$CE = \%C + 1/3 (\%Si)$$

碳当量应按下列参数控制：

It should be controlled as follows:

<u>截面尺寸</u> <u>Section Size</u>	<u>碳当量范围</u> <u>CE Range</u>
0 - 13 mm (0 - 0.5")	4.4 - 4.6
13 - 51 mm (0.5" - 2")	4.3 - 4.6
大于 / Over 51mm (2")	4.3 - 4.5

化学成份控制

Chemistry Control

好的球墨铸铁生产方法应优先应用于 ADI 铸件。对于大断面要淬透的零件才需加入 Mo、Cu 和 Ni 这些合金元素（例如壁厚大于 19 mm / 0.75”）。需要增加“淬透性”只是为了避免在淬火过程中形成珠光体。最终所需的合金量（如果需要）取决于原铁水的合金成份、零件的形状以及采用的等温淬火工艺。正确的合金配比应由铸造和热处理工厂共同决定。如在不需要的情况下加入上述合金元素，不但不能提高 ADI 的性能，反而会增加铸件成本。推荐的化学成份如下：

Good ductile iron practice should prevail for ductile iron that is to be austempered. Alloying elements such as Mo, Cu and Ni should be added only when additional hardenability is required for a heavier section, (i.e. greater than 19mm / 0.75”). This increased “hardenability” is required only to avoid the formation of pearlite during quenching. Ultimately the amount of alloying required, (if any), will be a function of the alloys in one’s base metal, the part configuration and the austempering process used. The proper alloy configuration should be determined jointly by the foundry and the heat treating source. Addition of the aforementioned alloys when not required does not enhance the properties of ADI but merely adds to the cost of the iron. The following composition guidelines are recommended:

元素			推荐值	典型控制范围	
Elements			Suggested Target	Typ. Control Range	
C	碳	Carbon	3.6%	+/- 0.20%	
Si	硅	Silicon	2.5%	+/- 0.20%	
Mg	镁	Magnesium	(%S x 0.76) + 0.025%	+/- 0.005%	
Mn	锰	Manganese	最大 截面 > 13 mm	0.35% 最大 / maximum	+/- 0.05%
			Max. section > 13 mm		
			最大 截面 < 13 mm	0.60% 最大 / maximum	+/- 0.05%
Max. section < 13 mm					
Cu	铜	Copper	0.80%	最大（仅在需要时） maximum (only as needed)	+/- 0.05%
Ni	镍	Nickel	2.00%	最大（仅在需要时） maximum (only as needed)	+/- 0.10%
Mo	钼	Molybdenum	0.30%	最大（仅在需要时） maximum (only as needed)	+/- 0.03%
Sn	锡	Tin	0.02%	最大（仅在需要时） maximum (only as needed)	+/- 0.003%
Sb	铋	Antimony	0.002%	最大（仅在需要时） maximum (only as needed)	+/- 0.0003%
P	磷	Phosphorus	0.02%	最大 / maximum	
S	硫	Sulfur	0.02%	最大 / maximum	
O	氧	Oxygen	50 ppm	最大 / maximum	
Cr	铬	Chromium	0.10%	最大 / maximum	
Ti	钛	Titanium	0.040%	最大 / maximum	
V	钒	Vanadium	0.10%	最大 / maximum	

元素 <u>Elements</u>			推荐值 <u>Suggested Target</u>
Al	铝	Aluminum	0.050% 最大 / maximum
As	砷	Arsenic	0.020% 最大 / maximum
Bi	铋	Bismuth	0.002% 最大 / maximum
B	钡	Boron	0.0004% 最大 / maximum
Cd	镉	Cadmium	0.005% 最大 / maximum
Pb	铅	Lead	0.002% 最大 / maximum
Se	硒	Selenium	0.030% 最大 / maximum
Te	碲	Tellurium	0.003% 最大 / maximum

其它“球化元素”（像铍、钙、锶、钇、镧和铈）只能适量加入以替代球化元素镁。在任何情况下，镁加上这些球化元素的残留量总和应小于 0.06%。有些铸造厂认为铈有助于球化处理它与镧、钙、硫和氧相互作用可生产出高球化率和石墨球数的铸件。

Other “nodulizing elements”, (like beryllium, calcium, strontium, barium, yttrium, lanthanum and cerium), should be present only to the extent that they are used to replace Mg in nodulization. In any case, the amount of residual Mg plus the amounts of these elements should not exceed 0.06%. Some work suggests that Ce aids in affecting the nodulization treatment and that a mixture of La, Ca, S and O in the post inoculant produces high nodularity and nodule formation throughout solidification.

上述建议向我们的客户提供了生产 ADI 铸件有用的参数。另外，还有一些铸造厂用他们特有的方法成功地生产了 ADI 零件，但是无论如何上述的这些准则是切实可行的。所有推荐的参数不保证零件的最终性能。

The preceding guidelines have been prepared to give our ADI customers useful parameters for production. Some have successfully produced ADI from iron not meeting these criteria, however, these criteria represent practices known to produce good results. They do not constitute a guarantee of final properties.

J. R. Keough

2004 年 4 月 / April 2004