The Development of Machinable ADI in Italy

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ABSTRACT

In 1982, Zanardi Fonderie learned of the existence of ADI. Since that time, numerous applications of a machinable ADI have been developed. This paper presents the chronological story of the production of ADI at Zanardi Fonderie in Italy.

THE COMPANY BEFORE ADI (1931-1981)

Zanardi Fonderie is a family Company, situated in Italy, near to Verona. Figures 1 and 2 show the location as well as a photograph of the foundry.


We first learned of the existence of ADI in 1982. We found the proposal of Dr. Muehlberger and Germanite patent as being a good opportunity for profit from our base metallurgy and from our reputation in the Italian market. Furthermore, we understood that Italy would be an interesting place to explore the potential of ADI in a quick and efficient way. In fact, in many cases, it has been our experience that the decision to convert a component into ADI has been a matter of mutual trust between two CEOs.

Since the beginning, we have understood, and stated, that the desired ADI market will have been developed only if we will have been able to move the jobs relatively easily through the machining shop. The Germanite patent process, essentially based on a low manganese iron with low carbon in the primary austenite, and relatively expensive alloying proved to be the right tool to achieve this goal. As a result, low strength grades of ADI such as ADI 800 and ADI 900 (corresponding to Grade 850-550-10 of ASTM A897-90) were developed.

We were successful developing the following families of applications:

- Steerable, front stub axles for tractors (weight 5-10 kg), that replaced steel forgings. Machining required consisted of turning only.
- Compressor crankshaft, (weight 5-20 kg), replaced induction hardened steel forgings. Machining operations included turning, drilling, threading and grinding.
- Carrier planet, (weight 40-70 kg), replaced steel castings. Machining operations included turning, milling, drilling and threading.

At the end of this period, we were producing 100 tons/year of ADI.


During the period from 1988 to 1994, we developed an important co-design and experimental project with a major track manufacturer, developing the following families of applications in ADI 800 and ADI 900:
A torsion bar bracket (weight 10-20 kg) is an example of upgrading of an existing ductile iron casting to one capable of superior loads. Machining operations included: milling, drilling, threading and reaming.

A swing bracket for trucks (weight 50-70 kg) replaced a ductile iron/steel forging assembly. Machining operations included: milling, drilling, threading and boring.

In ADI 1050 (Grade 2) we developed:

- A leaf spring seat for trucks (weight 3-15 kg). Machining operations included: milling, drilling, threading and reaming.


During the period from 1994 to 1996, we developed an important co-design and experimental project with a gear manufacturer, developing the following families of applications in ADI 800:

- An epicyclical adapter body (weight 10-20 kg) which replaced case hardened steel forgings or ferritic nitrocarburized pearlitic ductile iron. Machining operations included: turning, drilling, threading and broaching.

Broaching was the most critical operation. We got the right solution only when we realized that the main factor affecting ADI machinability is in the ability to achieve a constant narrow process range. Chemistry, nodule count, as cast matrix and heat treatment have to be as consistent as possible. Brinell hardness on the castings has to be kept inside a range of 20 points for each machining batch and must not vary in a range greater than 30 points for the long term total delivery time.

In this case, we were able to establish the relative tool life comparing normal pearlitic ductile iron, our ADI castings and the alternative supply of a competitor. The relative tool life of the three was 100:70:30 for pearlitic ductile iron, Zanardi ADI and the competitor’s ADI, respectively.


During the period from 1993 to 1995, we developed an important co-design and experimental project with a major undercarriage manufacturer, developing the following families of applications in ADI 1050 (Grade 2):

- A chain link for track layer (weight 3-15 kg), replaced a welded forging. Machining operations included boring only.

- An idler for a miniexcavator (weight 5-30 kg) replaced either an induction hardened steel casting or a weldment. Machining operations included: turning and lapping

- A sprocket wheel for a miniexcavator (weight 5-30 kg) replaced either an induction hardened steel casting or a forging. Machining operations included: turning and drilling.

- A roller for a miniexcavator (weight 3-15 kg) replaced an induction hardened, friction welded steel forging. Machining operations included: turning and lapping.

In 1994 – 1996, we produced 700 tons/year of ADI castings.

CONSOLIDATING THE TECHNOLOGY WITH NEW INVESTMENTS (1995 – TODAY)

All we learned about the ADI (and its future) have given us the fundamental guidelines for each investment we have made since 1995, at a rate of 20% of the total turnover. We consolidated all the process activities in one plant, from engineering design to ADI heat treatments, painting and machining while easily maintaining all the process control and traceability. Last, but not least, the high investment rate and management efforts have been dedicated to the work environment and ADI research programs. In fact, employee motivation and the low turnover have played a fundamental role in keeping the process parameters at the narrowest possible variability range. A schematic of the Zanardi facility is shown in Figure 3.

Figure 3: A schematic of the Zanardi Fonderie facility.
WHERE WE ARE TO-DAY

We currently produce 14,000 tons/year of ductile iron which includes ferritic grades, pearlitic grades and 4,500 tons/year of ADI castings which are all machined after heat treatment. The foundry total capacity is 21,000 tons/year. Heat treatment is performed by using two AFC-Holcraft UBQA 36x72x36 furnaces. A third furnace is ready for the new business developments. Photos of the furnaces are shown in Figure 4.

Our machining experience is shown in the map in Table 1. We have developed information about the machining of ADI 1200 (ASTM A897 Grade 3), even though industrial production is currently not running. Deep drilling and machining of ADI 1400 are the subject of an on-going research program.

The actual production percentages are given in Figure 5 with ADI 800 and ADI 900 comprising 60% by weight with the remaining 40% being ADI 1050 (Grade 2).

Our machining experience is shown in the map in Table 1. We have developed information about the machining of ADI 1200 (ASTM A897 Grade 3), even though industrial production is currently not running. Deep drilling and machining of ADI 1400 are the subject of an on-going research program.

Table 1: Map of Machining Experience in Italy

<table>
<thead>
<tr>
<th></th>
<th>ADI 800</th>
<th>ADI 900</th>
<th>ADI 1050</th>
<th>ADI 1200</th>
<th>ADI 1400</th>
</tr>
</thead>
<tbody>
<tr>
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<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>Milling</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>Drilling</td>
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<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>R&amp;D</td>
</tr>
<tr>
<td>Threading</td>
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<td>OK</td>
<td>OK</td>
<td>OK</td>
<td>R&amp;D</td>
</tr>
<tr>
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<td>NA</td>
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<tr>
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<td>R&amp;D</td>
<td>R&amp;D</td>
<td>R&amp;D</td>
<td>R&amp;D</td>
<td>R&amp;D</td>
</tr>
</tbody>
</table>

The typical values of the machining process parameters are indicated in the Figures 6 - 9.

Turning : cutting speed \( V_c \) vs HB

\[ f_s = 0.25 \text{ mm/rev}, a_p = 2.5 \text{ mm}, \text{ tool life } = 15' \]

Figure 6: Cutting Speed versus Brinell Hardness for turning.

ADI heat treatment : n° 3 AFC UBQA 36x72x36

![ADI Heat Treatment](image1)

Figure 4: Views of an AFC-Holcroft UBQA 36x72x36” furnace.

![ADI Grades Percent Weight](image2)

Figure 5: ADI Market shares in Italy. ADI 800 and ADI 900 have a 60% share while ADI 1050 has a 40% share.
Figure 7: Cutting feed versus Brinell hardness for drilling.

Figure 8: Cutting speed versus Brinell hardness for threading.

SUMMARY

Cost competitive machining of ADI after heat treatment is possible and, consequently, opens up the ADI market. In order to be successful with machining after austempering, it is mandatory that all the metallurgical processes, both in the liquid and solid state are performed at the best level of the available technologies, involving all the investments necessary to ensure consistent and reproducible quality. A high nodule count and a narrow range of hardness are the first indexes to be monitored. This will, at the same time, assure the safety of the casting design.

Once metallurgical processes are in good control, actual technology in tool manufacturing and in tool machines construction along with the on-going intensive investigation in progress by the machining shops and research institutes is sure to result in even more cost competitive knowledge in this field.

ADDITIONAL RESOURCES
+ Zanardi Fonderie - internal research
+ www.zanardifonderie.com