Case Histories of Cast Iron Machinability Problems

Five more actual cases reveal that cast iron ‘machining’ problems aren’t necessarily foundry-related.

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As we described last month in the first of this two-part series, iron machinability case histories, quite often iron “machinability” problems are not related to the castings. This article features five additional foundry case histories detailing the careful investigation that must be taken to truly find the solution to machinability problems.

The 10 case histories that appear in these two articles were gathered and presented to the APS Casting Congress as an APS Cast Iron Division panel in 1995. Panelists include: Steve Goulet, A.E. Goetz, Lake City, Minnesota; Greg Miskins, Waupaca Foundry Plant 3, Waupaca, Wisconsin; Larry Helm, Blackhawk Foundry & Machine Co., Davenport, Iowa; Ray Staral, Grede Foundries-Reedsburg Div., Reedsburg, Wisconsin; James Mullins, RTZ Iron & Titanium, Beloit, Wisconsin; Scott Gledhill, Waupaca Foundry Plant 4, Mariette, Wisconsin; and William Shaw, Iron Casting Research Institute, Columbus, Ohio.

6. Provided by RTZ Iron & Titanium America

Problem: Grade 1 125-80-10 austempered ductile iron (ADI) castings. Chemistry consisted of 3.5% Carbon, 2.6% Silicon, 0.20% Manganese, 0.7% Copper and 0.25% Molybdenum. Normal austempering heat treatment 1620F (882C) and 670F (354C). Section size was 1.6 in., and hardness was about 300 Brinell hardness (HB).

Problem: The problem occurred upon drilling a 7/16 in. hole approximately 2 in. long. At first, the customer said that the material was not very machineable, which is somewhat true due to the high strength nature of the matrix. (Note: The customer had never machined an ADI casting before.) However, after some trial and error, it was able to turn and mill the castings after heat treatment. (It was ready to machine before heat treatment, until a consultant intervened and stated that doing so wasn’t necessary, provided that procedures were corrected.)

However, there was still one major problem—drilling—one of the most difficult of all machining operations. During the high pressure drilling operation, the matrix structure was actually being changed due to stress transformation of the high carbon-remained austenite in the matrix into martensite. This transformation produces a much greater wear and machining-resisted matrix-martensite. Hence, the drilling nearly stops and soon the drill is “fried.”

Solution: Increase the feed rate and slow the turning rate so that any material that is transformed will be removed as the transformation is occurring. Thus, a hardened layer won’t develop under the tool. Structures are shown in Fig. 1.

Fig. 1. Described in case history 6, shown here are the microstructures of ADI at 700F (4) and ADI with transformed martensite. The martensite condition was created during high-pressure drilling and caused “fried” drills. Altering machining cycles alleviated the problem.

Fig. 2. Case history 7 described a crankshaft that was cast in 65-45-12 ductile iron. Shown here are the microstructures for that ferritic grade (I) as well as a pearlitic grade, which was what the machine shop was accustomed to machining for these parts. The 65-45-12 was too soft to be machined in this way, and ultimately the job was specified for a better suited material for the application.
7. Provided by RTZ Iron & Titanium
Product: Ductile iron crankshaft.
Problem: A manufacturer ordered a small crankshaft casting from a foundry. The specification of material was left to the foundry, which after considering the application, decided to produce the casting in a Grade 65-45-12 ductile iron because the customer erroneously implied that the mode of failure would be due to bending, which was associated by the customer as having low ductility. This material would not be the correct choice where good fatigue strength and some wear resistance (such as required in a crankshaft) would be necessary.

After the castings were approved for initial dimensions, the foundry produced a few thousand of the ductile iron crankshafts and sent them for machining. The machine shop machined these castings as it would a pearlitic crankshaft material and found that it couldn't hold dimensional tolerances as well as it did on the previous crankshafts. The relatively soft crankshafts made from the ferritic grade 65-45-12 were actually moving due to excessive machining pressures.

Solution: After a number of meetings between the crankshaft and the machine shop, the crankshaft was changed to a more appropriate material. The machining difficulty wasn't actually related to the casting quality but was related to the selection of materials.

Comments: The foundry should conduct the investigation of the final use and requirements of a casting before assisting the customer with material selection. Actually, in this instance, it was fortunate that the problem was caught in the machine shop rather than in service, where it could have caused premature failure in a final product. Figure 2 shows the comparisons of the microstructures.

8. Waupaca Foundry-Plant 4
Product: Ductile iron casting for a diesel braking system.
Problem: Figure 3 shows the component and the extensive machining for oil passages and cylinder bores that was required. In the past, high hardness problems in the thicker section where the steps were located had caused the gun drill operation to wander. This hardness problem was corrected by increasing the cooling time in the mold. Yet after nearly a year of running this casting successfully without machining problems, the customer reported that the problem was back. Checking the casting revealed no high hardness.

Solution: To alleviate the problem, the customer changed tools and reported that the parts were machining fine. The customer related their find- ings to the foundry as follows: This operation consists of a gun drill with an external guide. The tool is made of high-speed tool steel. It has multiple flutes and coolant is flushed through the tool to remove drilling. The company had installed a cost savings program by sharpening the bits themselves. This particular bit was found to have a wrong cut angle. Several more bits were found with the same problem and sharpened. A different jig was made for sharpening and this issue was resolved.

Comments: Make sure to dig into the facts every time a problem occurs. If it had been assumed that the same hardness problem was the cause for the difficulty, an extensive amount of time and money would have been spent on useless work.

9. A.E. Goetz
Product: Class 35 gray iron cylinder liner. The part was 4 in. long, 2.5 in. diameter and had a wall section of 0.140 in. It wasn't heat treated.

Problem: The inside diameter honed surface was too rough to meet specification. The appearance was not acceptable—it looked like it was full of pits or holes. This condition was referred to as "open grained." The condition appeared at the start of a basket of castings. Samples of the defective castings were analyzed in an outside lab. The material was obviously at fault—"nothing had changed in the machining process."

Samples were taken from "good" and "bad" parts for comparative analysis. The chemistry, microstructure and hardness of both sets of samples were nearly identical. More castings were produced and machined and the condition still existed. Although all of the information indicated that the problem was centered around the machining process, it was decided that the casting was still at fault. Several experimental batches of castings were produced with no success in reducing or eliminating the problem.

A consultant was hired to determine what the foundry was doing wrong to create the "open grain" condition. He spent several days in the plant observing the operation and gathering samples. The samples were taken back to the outside laboratory and analyzed.

Fig. 3. These photos illustrate the ductile iron brake component and extensive oil passages and cylinder bores required, as described in case history 8. A hardness problem revealed that the bit in use was being incorrectly sharpened by the machine shop.
The consultant returned to the plant and explained his results: The "good" and "bad" parts are identical in every aspect except for the surface finish on the inside diameter. The parts that exhibit the "open grain" have a torn or gouged appearance. In the lab's opinion, something had changed in the machining process to cause the problem.

For two days, the machining process was closely analyzed. Comparisons were made of feed speeds, stock removal rates, and tools, before and after the problem started. The only significant difference uncovered was a decreased amount of stock left on the inside diameter for the honing operation. The surface texture of this stock had also been changed. The reason for these changes were to decrease the amount of time to hone the sleeves and reduce hone stone usage.

**Solution:** The amount of stock for honing had been reduced from 0.003 in. per side to 0.0015 in. The speed of the stock removal prior to honing had also been increased slightly to make the surface rougher. This helped the stones to "work" faster. These changes produced a ripped and torn surface that could not be "cleaned up" by the honing process. This condition appeared as "pits" or "open grain" on the inside diameter surface. When the stock was increased and the operating speeds reduced, the "casting" problem disappeared.

**10. Provided by Iron Casting Research Institute**

**Product:** Gray iron refrigeration compressor housing.

**Problem:** Unacceptable surface finish in the top bore surface after honing of the casting, as shown in Fig. 4. The finish on the bottom bore was acceptable. Note the apparent difference in surface finish of the two bores in the scanning electron microscope (SEM) photographs in Fig. 5. Machining operations on the bores included a rough and final cut followed by honing. The question was whether there was any metallurgical difference in the two bores that would cause the difference noted in surface finish.

Based on examination of the casting via stereo-scope, conventional metallography, and finally SEM, it was concluded that the machined surface problem was not related to the microstructure or properties of the iron. The microstructure in both bores was predominantly ASTM Type A, size 4-5 graphite flakes with an almost fully pearlitic matrix and minimal amounts of free ferrite. The casting hardness was approximately 220 HB externally and 170-187 HB internally. This structure and hardness level could be expected to permit the attainment of almost any reasonable finish requirement using established machining tools and procedures.

Because the microstructures of the two bores were essentially identical (as would be expected from the casting geometry), and since honing would not likely remove such coarse tool marks, it was apparent that there was some difference in either the rough or final cuts of the twin bores. With this information presented, the customer agreed to review the machining operation as the likely cause of the problem.

**Solution:** In this case, tools and procedures for the rough and final cuts prior to honing were studied to determine the cause of the difference in these otherwise identical bores. While coarse graphite, generally due to excessive carbon equivalent, can lead to graphite tear-out on machined surfaces, this was clearly not involved here. Machining practices that can result in rough machined finishes include dull tools and inadequate depth of cut. A number of references, including A.D. Lamb ("Material and Technical Factors in the Machining of Iron Castings. Gray and Ductile Iron News, April and May issues 1967) suggest a minimum finish cut depth of 0.010 in. to provide for a good finished surface.

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