New ADI-production technology

Dipl.Ing. Matti Johansson
Componenta CPC,Finland

ABSTRACT

After three years research work a new ADI-production technology was developed to enhance the productivity and the properties of the castings. The idea was to benefit the expansion force of the solidification. By using this means, two different components were produced and tested. The results were amazingly good. The main reason for the excellent properties of the castings was a very fine microstructure with low segregation and no porosity or defects. This new production technology will also make the production costs lower and the foundry environment better than conventional sand cast technology. The new production line makes it possible to develop new products with reduced weight and costs, replacing steel forgings and aluminium components.

INTRODUCTION

Austempered ductile iron was first developed for heavy loaded gear wheels and the production started in Finland in 1973. Soon after that, many wear resistant components such as spring seats, wear plates and rail wheels were produced. Additionally, other high loaded components in the car industry were developed. Some of these applications were of limited use because of safety reasons or production costs. In this work, new ideas were used to solve the problems of ADI-production. The aim was to make better products with less money. The most important consideration in making a high strength material is to minimize the defects inside and on the surface of the castings. That gives us the possibility to increase the fatigue strength and, as a result, save on the weight of the component. Near-net-shape casting technology will, thus, reduce the costs of the production.

BACKGROUND

Austempered ductile iron has been a very promising material for many kinds of applications. When utilizing high strength properties, the quality of the castings must be much higher than conventional ductile iron grades. The safety reasons and the production costs have become more important in high series production. That is why we started to study some sand cast applications, which had high production costs. As an example, a ring gear was taken for the preliminary testing. The properties of an ADI ring gear are interesting, for example in an automatic transmission because the noise reduction is remarkable. But when using the sand cast process, very big feeders have to be used to guarantee the soundness of the casting**, Figure 1**.

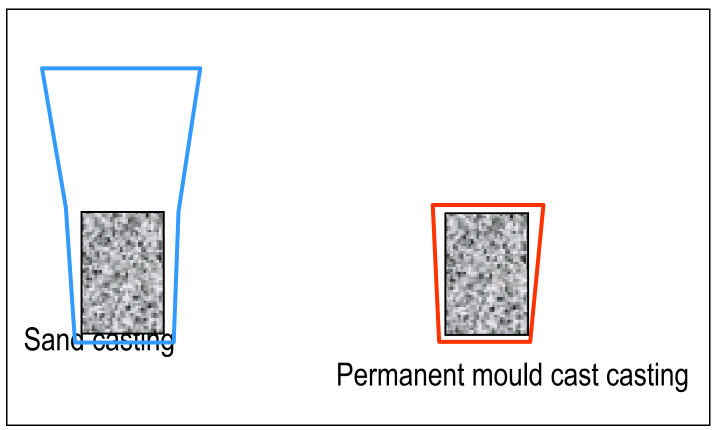

Figure 1 : Sand casting compared to permanent mould casting.

In the first preliminary permanent mould castings, only a small feeder and an ingate system were needed. The mechanical test results were good enough, but sometimes porosity was also found in this process. Because of promising results, a new project was started to develop squeeze cast technology for the production of ADI. The goal of the project was to decrease production costs, reduce

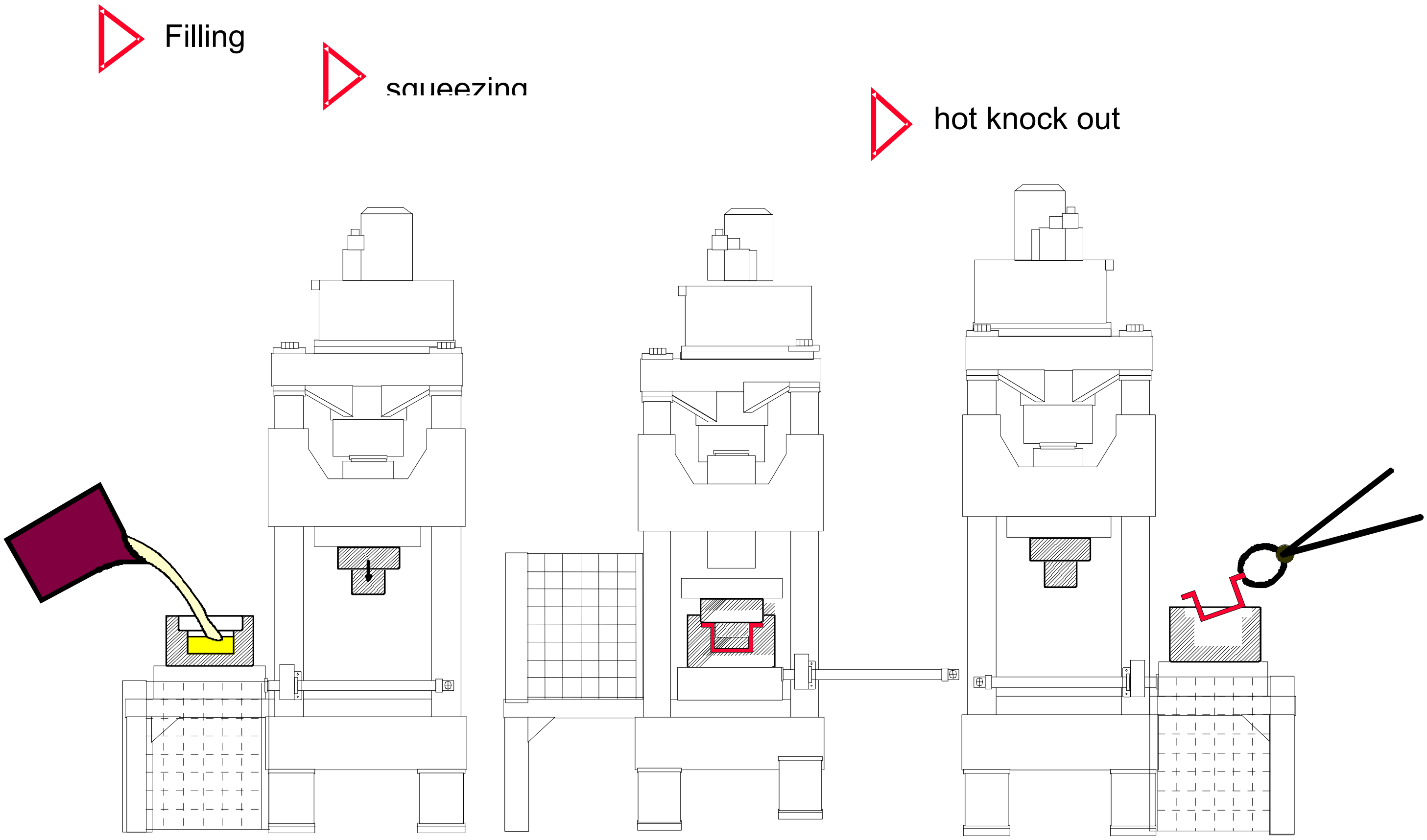

Figure 2 : Squeeze casting process

the weight of the components and to use the damping properties of ADI for the reduction of the noise in the gears. In addition, the goal was to make a better environment in the foundry as well as get more reliable and near-net-shape castings.

PROCESS DEVELOPMENT

In the squeeze cast process, the expansion of the solidification was used to obtain sound castings without feeders and gating systems. The casting process is described in the **Figure 2**. The iron was poured in the metal mould and squeezed in the press. Because no sand is used, the direct heat treatment can be made without cooling the casting. This makes the process time short and decreases the energy needed.

The ring gear was the first real component in this project. Compared to the earlier experiments with sand and permanent mould processes, a much better microstructure was achieved. The graphite nodule size was small and the distribution was fine, **Figure 3**.

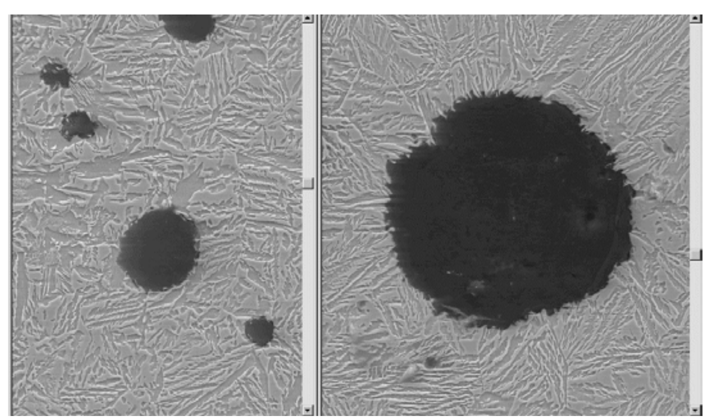

Figure 3 : Microstructure of squeeze casting (left) and sand casting (right)

Additionally, no porosity or other defects were found in the optimized casting process.
Due to the fine microstructure, the mechanical properties were much better than sand cast and austempered ductile iron. Elongation and ultimate tensile strength were much higher. This will mean that fatigue strength also increases compared to sand cast material, **Table 1**.
A very important feature is the surface structure of the casting, **Figure 4**. There is no surface defects like we have usually seen in sand castings. The surface of the squeeze castings is clean like the machined surface. Graphite nodules are under the thin skin of the casting and we can estimate that this makes the component more resistant against fatigue loads.

Table 1. Some tensile test results of squeeze cast test samples compared to EN standard .

	Test 1	EN	Test 2	EN
Tensile strength MPa	1238	1200	1115	1000
Yield strength MPa	968	850	839	700
Elongation %	13,4	2	15,3	5
Hardness HB	388	340/440	363	300/360

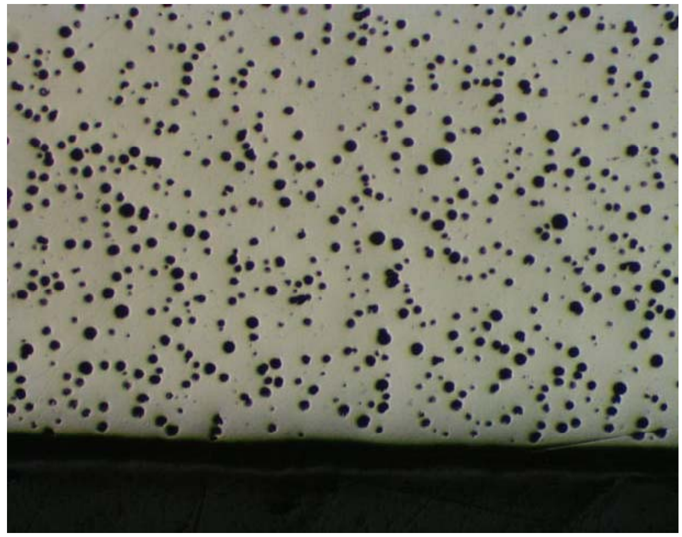

Figure 4 : The surface of the casting is without defects, which increase the strength of the component.

COMPONENT TESTING

A ring gear was tested in the Valtra tractor both in field and bench tests. The tested tractor was loaded with maximum engine power in the bench test. After 296 hours (corresponding 10,000 hours average use), the test was stopped because of pitting in the case hardened steel gear and some other failure in the transmission. Testing showed us that the ring gear was good enough and not the weakest part of the power transmission. The field test is on-going. The same result was proved with another analog test machine in RWTH Aachen. The roll testing machine was operating with the rotational speed of 2870 r/min and the mating roll is case hardened steel. For the testing of gear material, 24% slip was used. With the Herzian pressure of 1350 MPa, no pitting was seen after 50,000,000 cycles. In the microscope, small cracks were seen starting

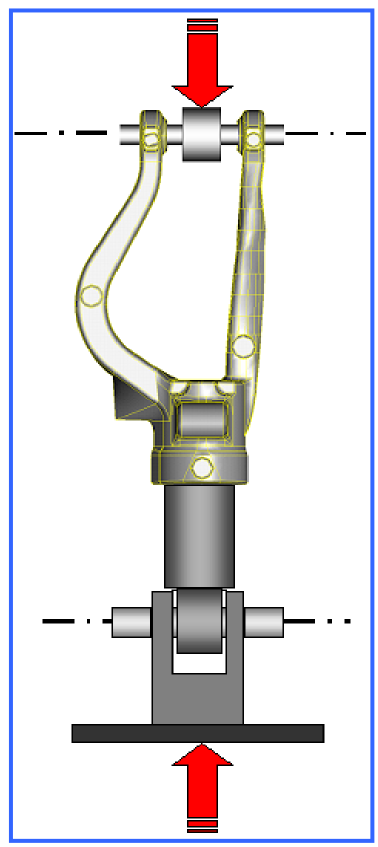

Figure 5 : Fatigue testing of the suspension fork

from the surface usually ending at the graphite nodules.

Another component was tested by Fiat. A suspension fork was optimized and the reduction of weight was 21 % compared to GJS 600-10 (special elongation limit). Only 8 pieces were cast because of the simple mould technique, which made the continuous casting process difficult to carry out. All these castings were used to analyse the microstructure and mechanical properties. All specimens from different parts of the suspension fork were homogenous in microstructure. No carbidic or martensitic microstructures were seen. Some larger nodules were found in the middle of the section. Also, some porosity was seen, with a maximum size of 125 µm in those two castings in which we found cold runs. Other components were sound and good. The component has to pass the test without cracks loaded with 2500 kN and life time 300,000 cycles. In this case, with squeeze cast forks, the load was 5000 kN and all tested components were without failure after 3-10,000,000 cycles, **Figure 5**. A tensile test bar was taken in the fork, **Figure 6**. Test results were much higher than pearlitic ductile iron or even better than microalloyed steel. No martensite or carbide was seen in the microstructure.

Table 2. Comparison of different suspension fork materials.

	GJS-600-5	SQ ADI (tested)	Microalloyed steel
σ_R MPa	600	950	1000
σ_y MP	370	750	550
ε %	10	11	12

As a summary, the test showed very high strength properties for squeeze cast ADI. Yield strength was much higher than steel and elongation about the same, **Table 2**. The Ausferritic structure was fine and without porosity. Bench tests showed very good fatigue strength with the weight reduced component and the material was machinable after the heat treatment.

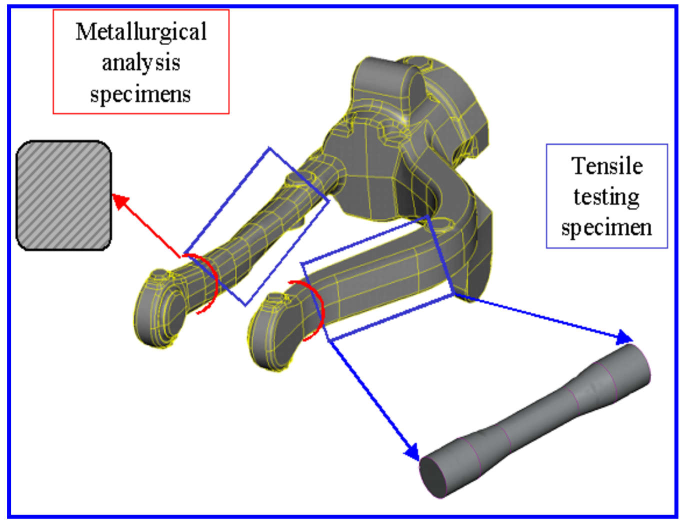

Figure 6 : Tensile test specimens were taken from the fork.

ADI has the properties, which can be compared with steels. The squeeze casting technology makes it possible to increase the strength and reliability of the ADI components. In the future, the designers will be able to reduce the weight of the components by using squeeze casting technology which is also an economical and environmentally friendly process.

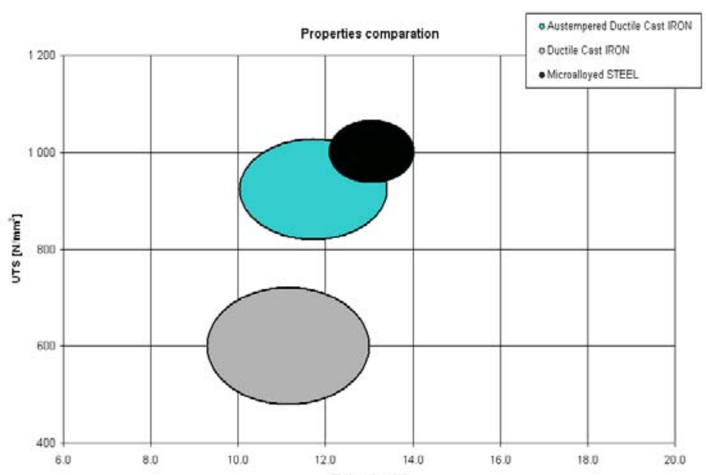

Figure 7 : ADI can replace microalloyed steel in the automotive industry.

SUMMARY

Squeeze casting technology was developed and two different applications were tested with very good results. As the conclusion of the results, the following features could be mentioned.

- Excellent yield strength/elongation combination
- Excellent fatigue strength of the components
- Good contact fatigue strength
- Better machining properties than sand cast ADI
- Low production costs
- Environmental benefits of the foundry process

Squeeze cast ADI has properties never seen before.

ACKNOWLEDGMENTS

The auther gratefully acknowledge the financial support of the European Comission within the Brite EuRam project ADITECH.
The coordinator of the project Aditech thanks all the partners involved in the project.
The paper is a part of the work done by the following persons:
Dipl.-Ing. Rainer Kaiser and Andreas Flesch, RWTH Aachen Foundry Institute
Dipl.-Ing. Carsten Klöpper, RWTH Aachen WZL (machining laboratory)
Dr. Manfred Dresselhaus, Reis Robotics
Eng. Reinhold Binder, Ulrich Flötzinger Werkzeugbau
Dr. Mario Tului, Centro Sviluppo Materiali
Dipl.-Ing. Giovanna Nicol and Daniele Bassan, Centro Ricerche Fiat
Dipl.-Ing. Arto Hietanen and Jukka-Pekka Lepistö, Valtra Inc.
Dipl.-Ing. Harri Nordlund and Matti Johansson, Componenta CPC

ADDITIONAL RESOURCES

+ matti.johansson@componenta.com
+www.componenta.com