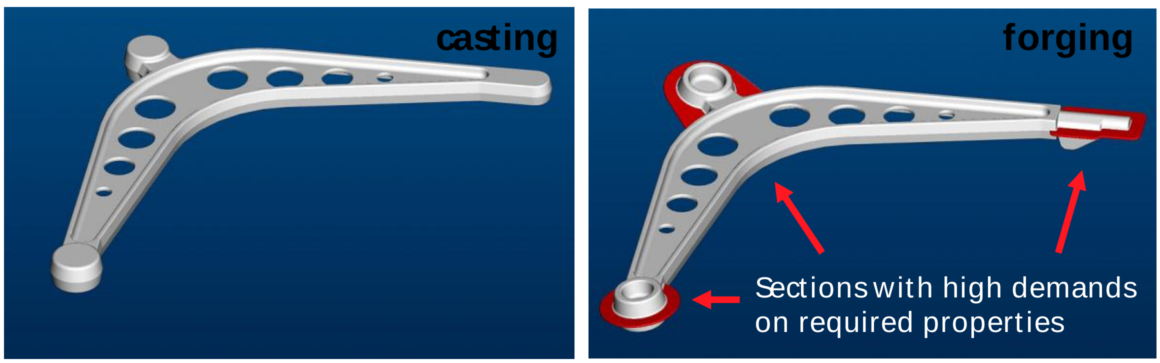
CastForging for production of components with tailored geometry and strength.



Project within Hållbar produktionsteknik

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Content

FFI in short

FFI is a partnership between the Swedish government and automotive industry for joint funding of research, innovation and development concentrating on Climate & Environment and Safety. FFI has R&D activities worth approx. €100 million per year, of which half is governmental funding. The background to the investment is that development within road transportation and Swedish automotive industry has big impact for growth. FFI will contribute to the following main goals: Reducing the environmental impact of transport, reducing the number killed and injured in traffic and Strengthening international competitiveness. Currently there are five collaboration programs: **Vehicle Development, Transport Efficiency, Vehicle and Traffic Safety, Energy & Environment and Sustainable Production Technology.**

For more information: www.vinnova.se/ffi

1. Executive summary

The aim was to identify the potential of a new production method where components are produced by partial forging of ductile cast iron.

CastForging is a method that combines the high strength properties of Forgings with the greater geometric degree of freedom of Castings. The idea is to first utilize casting in order to produce the part to near net shape and then to forge the part in a single forging stroke to the final shape. The forging step may be a single blow of the complete part or at selected zones with high demands of mechanical properties i.e. partial forging.

The practical trials on test bars showed good forgeability and less dispersion in static strength compared to cast test bars. The fatigue life tests indicated 50% improved fatigue strength compared to cast test bars. Several chassi- and transmission components were identified with very high potential for CastForging. The study also showed good possibilities to simulate CastForging and pore closures.

CastForging is expected to eliminate faulty parts, provide material savings of a minimum of 30% and energy savings of at least 20%.

The pre-study indicates great possibilities to develop strong, light and low cost vehicle components, using CastForging, and a FFI continuation project is recommended.

2. Background

Future requirements in terms of cost-efficient production of light and strong automotive components with a minimum environmental impact will increase. CastForging has the potential to realize this and may create unique competitive advantages for the Swedish automotive industry and its suppliers.

3. Objective

The objective was to investigate the possibility of partial forging of ductile cast iron with the support forging of test bars followed by tensile tests and fatigue life tests.

The project work was carried out in collaboration with an SME-project ”Manufacturing of components in steel with support from CastForging” (Dnr 2012-02627). In this project Igelfors Bruks AB was the project manager whereas Swerea IVF and Swerea SWECAST carried out the research. The collaboration resulted in great coordination profits for both of the projects.

4. Project realization

The work was carried out in the form of literature studies, development of round and flat test bars made of ductile iron, practical forging trials with various degrees of forging and at different temperatures, tensile tests, fatigue life tests and preliminary tests with simulation of CastForging, a survey of possible components as well as a survey of potential energy, material and cost savings.

Swerea IVF was project manager and the project team which consisted of Volvo Truck, Scania, Igelfors Bruks AB, Swerea IVF och Swerea SWECAST, all worked actively in the project. Volvo and Scania contributed with the survey of possible components to be CastForged, Scania contributed with fatigue life testing and all of the test forgings were carried out at Igelfors Bruk, who also created a special tool for forging of flat fatigue test bars. Swerea contributed with development of test bars, tensile tests, simulation and expertise knowledge etc.

The practical forging trials were carried out on round testbars in ductile cast iron (EN-GJS-500-7). Tests regarding forgeability at different degrees of forging and at different temperatures were carried out with Igelfors excenter press, see Figure 1. The tensile tests were carried out on the round CastForged forged test bars and compared with tensile tests on cast test bars.

Fig. 1 test arrangement at Igelfors

Tests with CastForing simulation was carried out where simulation of porosity after the casting of the round test bars were conducted in ProCast. The output data was reformatted to Deform where forging simulations were conducted. It was thereby possible to detect porosity change due to the forging step, see Figure 2.

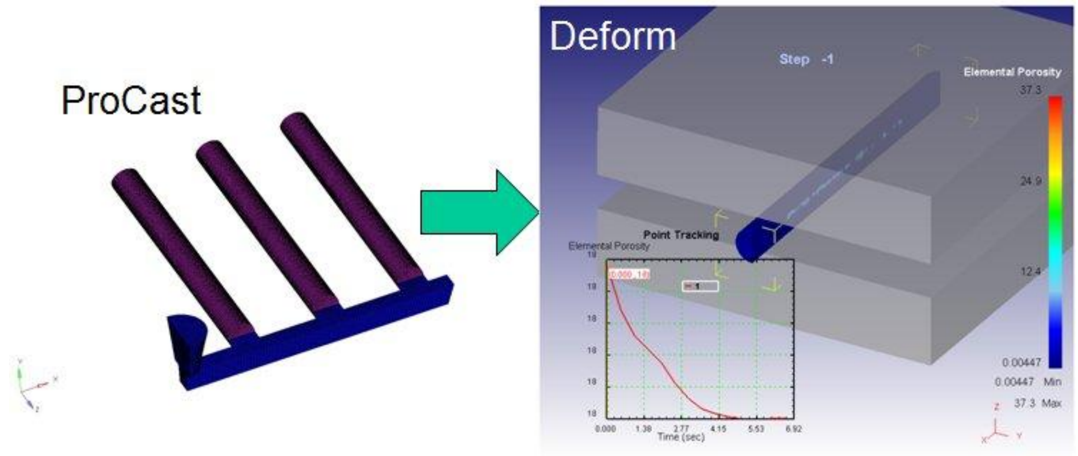

Fig. 2 Simulation of occurence of porosity after casting and casting + forging

Practical forging trials were carried out at Igelfors Bruks AB with cast flat fatigue bars which were forged in the middle by 2 mm (1+1) and 4 mm (2+2) respectively, see Figure 3. The forgeability was investigated at both 734 ˚C and 1120 ˚C. Fatigue life tests were then carried out at Scania CV.

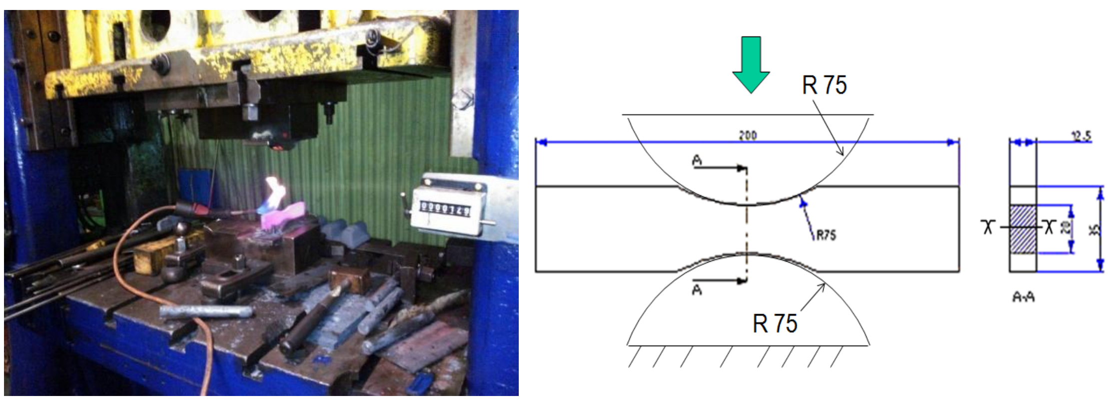

Fig. 3 Test arrangement at Igelfors and tool outline

A survey of load carrying components suitable for CastForging was carried out by Scania and Volvo Truck.

Possible materials savings in the production was analyzed with the help of a schematic example where forging of a component with a final weight of 1.0 kg was compared with a similar cast and a CastForged component, see Figure 4. The comparison was based on the need of input material.

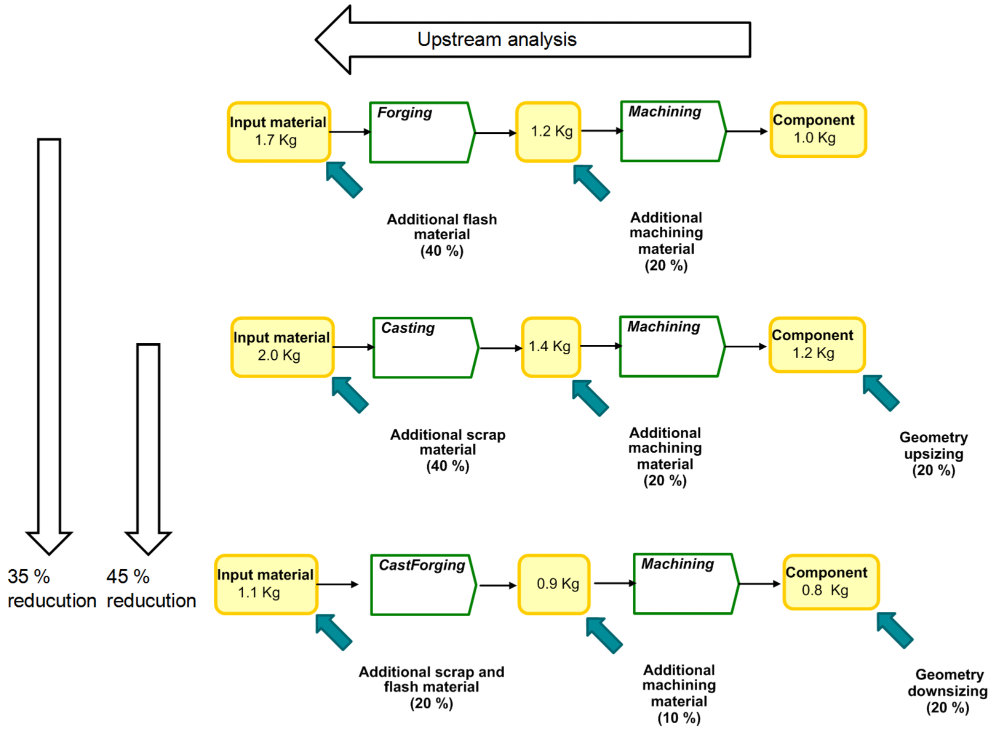

Fig. 4 Schematic analysis of materials reduction with CastForging

The cast component was upsized by 20 % in order to carry the same load as the forged component. The geometry of the CastForged component was downsized due to better possibilities to optimize geometry and e.g. create cavities in zones subjected to minor loads. Furthermore, it is assumed that waste in feeders during casting, flash after forging and material in the subsequent machining is reduced compared to conventional methods. The upstream analysis of the material need indicated 35 % lower materials consumption compared to conventional forging and 45 % lower compared to conventional sand casting.

Possible energy savings in production was analyzed using the same schematic example. The primary energy consumption for each step was detected (source Ecoinvent v2.1) and multiplied with the material consumption in the different steps. It was assumed that CastForging generates more energy than casting but less energy than casting + forging. The schematic example indicated energy savings of 28 % compared to conventional casting and 44% compared to conventional forging.

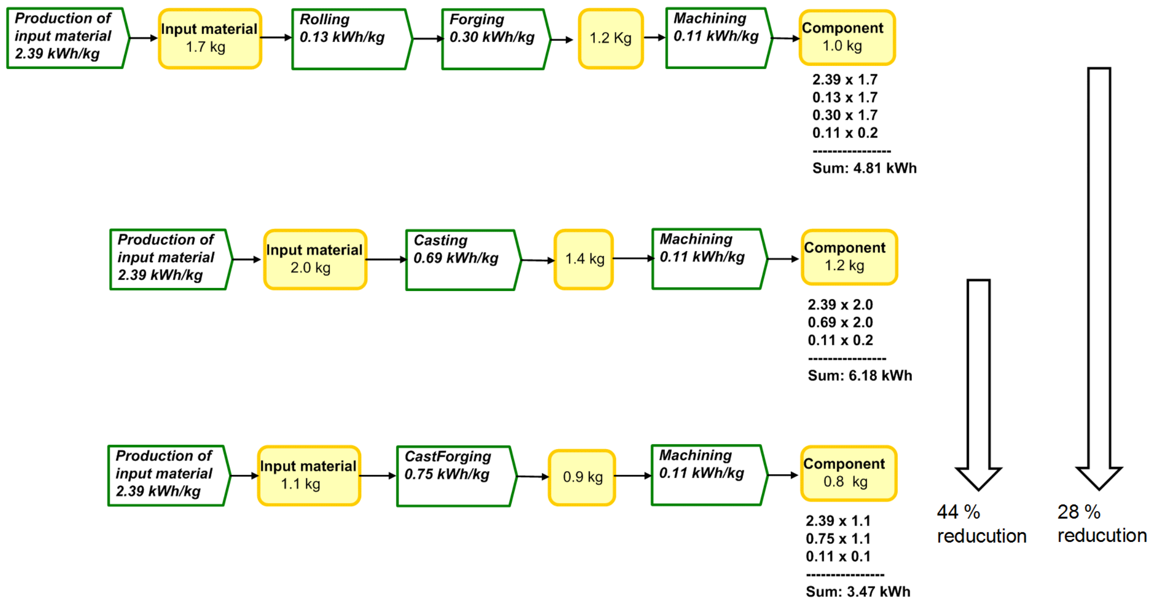

Fig. 5 Energy consumption during CastForging compared to conventional casting and forging

5. Results and deliverables

State of the Art: The literature study showed that there has not been any previous attempt made at partial forging of ductile cast iron. The project's news value is therefore great.

Forgeability: The forgeability of the round test bars was good at 1100 ˚C and for the flat test bars both at 700 ˚C and 1100 ˚C.

Static strength: The tensile strength of the round CastForged test bars was about the same as for the cast test bar whereas the spread of the results, particulary after a high degree of forging, was less compared to the cast test bars. An examination of the microstructure showed that the graphite nodules were flattened after the forging step.

Fatigue strength: The fatigue strength of the flat CastForged test bars was improved by up to 50 % compared to the cast test bars.

Simulation: The preliminary simulation tests demonstrated good possibilities to simulate CastForging and to transfer data concerning mesh and porosity from cast simulations to forging simulation and thereafter simulate the change in porosity due to forging.

Automotive components: Several categories of components were identified with a high potential for CastForging like e.g. cast components made of ductile iron and grey cast iron, forged components, bar stocks and stamped and pressed details. The following advantages (among others) were found:

- Increased strength will result in decreased need of material in order to take load, a fact that will downsize geometry and reduce weight.
- CastForging will result in a larger geometrical freedom for component design than forging only and may open up for the design more rigid constructions with enforcement on load carrying sections
- CastForging opens up for the possibility of hollow constructions and cavities, which make it possible to reduce material and weight.
- CastForging may reduce proceeding machining operations like drilling and milling and the method has a potential to create the required geometrical tolerances in the forging step.
- CastForging opens up for the possibility to integrate functionality in a single component and several traditional components may be merged into one CastForged component, e.g. integration of pipes in consoles.

Materials- and energy savings: CastForging is expected to result in materials savings by at least 30% and energy savings in production by at least 20% compared to conventional casting and forging. CastForging may result in the following savings in Europe (Ref. Swerea IVF uppdragsrapport 23944 “FFI-Gjutsmidning av segjärn – Förstudie”):

- 1 Million tons/year in material
- 800 GWh/yes in energy
- 340 Million tons CO_{2eq}/year in climate
- 420 Million Euro/year in costs

5.1 Delivery to FFI-goals

The positive project results can contribute to continued competitive vehicle industry in Sweden. The project has resulted in knowledge development in a new area - CastForging. CastForging has contributed to reach the following intermediate goals within sustainable production:

Effective flexible production: CastForging may develop components adapted to customer needs concerning geometry and strength.

Light materials and new processes: A literature study shows that CastForging of ductile cast iron has not previously been tested. The project has also shown that the strength properties of ductile cast iron will be improved with the help of the forging step.

Environmental neutral production: CastForging is expected to result in materials savings of about 30% and energy savings by at least 20% compared to conventional casting and forging.

6. Dissemination and publications

The project results will be presented at the FFI cluster conference in Katrineholm 20-21 May 2014. The project results will also be disseminated in Swerea IVF's news magazine ”Teknik och tillväxt”.

7. Conclusions and future research

The project results have so far resulted in an application to the EU Horizon 2020 research programme. The application, “CASTFORGE”, was submitted in March 2014. The aim is here to develop a ”proof of concept demonstrator” of a CastForging machine. The consortium consists of Volvo Truck, Swerea IVF (coordinator) and Swerea SWECAST from Sweden, Fraunhofer Institute for Machine Tools and Forming Technology IWU, Kokitechnik transmission systems GmbH and ACtech GmbH from Germany and Slovenian Tool and Die Development Centre (TECOS), Kovinar D.O.O and Tehnos from Slovenia.

The project results will also lead to a larger FFI application to Vinnova in June 2014 with focus on CastForging.

8. Participating parties and contact person

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