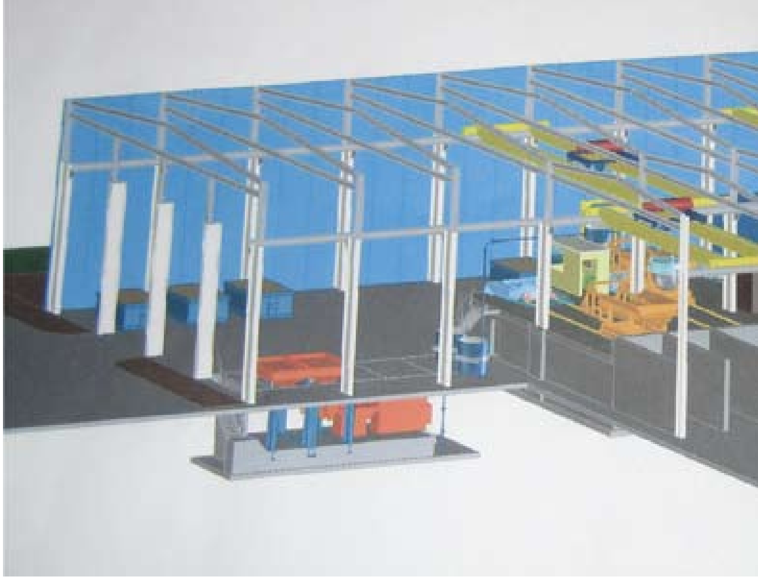
Automotive

A new perspective on cast tooling manufacture

Press tools manufacture for the automotive industry has an annual market value of €17 billion, the tooling cost for a single car model being some €140 million.

Using the 'Camito' method, it is possible to reduce lead times by 30%, thus saving time and freeing up capital more quickly. Camito tools are machined as single pieces, resulting in reduced transport needs and corresponding environmental benefits.

Zoltan Tiroler from the Swedish Foundry Association/SweCast (Swedish Institute of Casting Technology) profiles a leading exponent of the process.



Soon the new foundry will be ready

In southern Sweden lies the small town of Hästveda, the gravestone inscriptions in the churchyard highlight that this has been a farming region for many centuries. However, the village is now the home of a very modern foundry. Originally called Hästveda Gjuteri, its new name of Camito Technology Center AB is an outward sign of recent upgrading.

The foundry's new president, Bengt Karsten, recalls how, in the autumn of 2006, NovaCast Technologies AB invited him to build a new foundry based on the Camito method for the production of single-piece tooling.

'My own company was doing well', recalls Mr Karsten, 'but if I had declined the opportunity to build a completely new foundry I would never have forgiven myself. It is not every day that a new foundry is built, and this is one of the biggest foundry projects undertaken in Sweden in modern times. It also involves a new technology that is not comparable to any other.'

Dual role caster

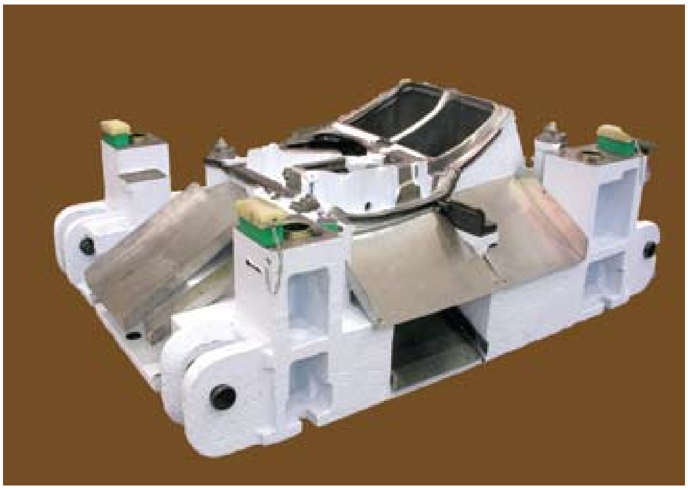
The existing foundry continues to serve its old customers, main products being grey iron parts for counterweights, press weights, supporting stands, keels, mooring posts and machinery, all cast using the lost-foam technique.

The new foundry was built adjacent to the old one, the first heat being poured in October 2007. Liquid metal is supplied from two Inductotherm furnaces of two and 10 tonnes capacity. The €9 million project was co-ordinated by the Dutch firm, Gemco, with Bengt Karsten as the on-site project leader.

Mr Karsten is certain that 'things are going to happen pretty fast' when the Camito system is fully installed. Current plans are for the existing foundry to maintain an annual production of around 4,000 tonnes, the new foundry being expected to eventually produce about three press tools per day - some 10,000 tonnes per year. The new foundry will also use the lost-foam method, usually without cores.

A typical press tool weighs around 10 tonnes, moulding boxes, including sand and casting, weigh up to 50 tonnes.

The Camito Technology Center will not only be a production foundry it is also to serve as a training centre for the Camito method for the 30 or so foundries around the world that are to become certified suppliers of Camito tools. To date, three certification agreements have been signed.



Example of a Camito tool. This one is for producing doors for cars

Ready to cast using the lost foam method in the existing foundry

The Camito method and its potential

The Camito method (Cast Mix Tooling) was described fully in the 4/2006 edition of *Gjuteriet ('The Foundry')*, the magazine of the Swedish Foundry Association and you will have read about it in the news pages of **Foundry Trade Journal.** Briefly, it is a patented method for casting grey and/or ductile iron together with steel, achieved by extremely precise control of temperature and other parameters for the molten metal.

The process is carried out in one step, enabling the production of tools as single pieces, instead of assembling them by screwing many small steel components onto a framework of grey iron. The production time for an average tool is cut by around 30%, a saving of three to four months in production time for a new car model.

A typical car model requires around 750 press tools for the manufacture of chassis parts. The world market for such tools is about €17 billion annually - and it is fast growing because new car models are being introduced and old models phased out with increasing frequency.

Camito is focused on the segment that includes the largest and heaviest tools, accounting for some 25% of the market or €4 billion. Based on a realistic projection that Camito products take 20% of that market segment, total sales value would be €0.8 billion.

Lower total costs

Although the purchase prices of Camito tools are higher than for traditional alternatives, total costs are lower due to their great advantages. Volvo and Audi have already begun to produce cars with the use of Camito tools, and interest is great among other auto manufacturers. In fact, demand is so great that it cannot be met with existing capacity.

That problem will be alleviated by the Camito foundry in Hästveda and a number of other foundries located near car manufacturers that will eventually be certified. Staff from Camito Technology Center AB are in the process of selecting partners to be certified as Camito foundries. Sales will be made via Camito AB, co-operating foundries paying a licence fee.

Partners are also being acquired in other production areas. Thus far, they include Sandvik Coromant and Sandvik Tooling for machining, and Uddeholm Tooling which supplies the steel and the steel granulate used in the casting process. Co-operation with all three companies embraces both technology and marketing to the automotive industry.

For more information see www.novacast.se

Left: A few months ago the site for the new foundry did not look much

Right: Counterweight for a fork truck, an important product for Hästveda Gjuteri

Combining complexity with weight reduction

This cylinder puller assembly, was a winner for Aristo-Cast, Inc in the USA-based Investment Casting Institute's 2007 Casting Contest.

Production of several complex parts, reducing weight by more than a half and casting threads with no machining are among the benefits achieved by the investment casting.

The cylinder puller assembly, cast in 4140 low alloy steel, is used to remove the steel cylinder liner from a diesel truck engine.

Automotive

New guidelines for ADI gears

Dr Arron Rimmer from ADI Treatments, recalls that commercial application of ADI in gear manufacturing can be sourced to 1962 when the Central Foundry Division of GMC began to develop the material for hypoid rings and pinions.

The work was driven initially by the search for lower cost solutions. After a lengthy project and proving trials, components were incorporated in 1976 Pontiac vehicles. The effort proved fully worthwhile delivering cost reduction, through energy and materials savings, plus performance enhancements.

This seminal work[1] earned Robert Grindahl the ICS design award in 1977 and led to wider exploitation of the technology; ADI gears can now be found in everything from diesel engines to wind turbines[2].

Information sheet published

While many successful examples are running currently, there remains no industry standard for ADI gear production. However, the American Gear Manufacturers' Association (AGMA) has recently issued a comprehensive Information Sheet[3] that contains background and guidance for specification, purchase and manufacture of ADI components.

Whilst the document is not a gear rating standard, it deals usefully with the metallurgy of ADI, relevant factors in its production, allowable stress numbers, and stress cycle curves. Additionally, references, relevant standards and evaluation methods are provided.

AGMA's document notes the versatility of ADI, its properties and many benefits. The major advantage is a high strength to weight ratio, allowing it to replace steel forgings, castings and fabrications at equal, or lower weight. For a given level of ductility, ADI can deliver twice the strength of conventional ductile iron while fatigue strength is similar to cast and forged steels.

Its Young's Modulus is 20% lower than that of steel, so for a given load the contact area is greater due to the increased conformance. In some cases, this has been shown to reduce contact stress and noise.

Since most ADI gears are produced from engineered, cast blanks, they can be nearer net shape than those produced from bar stock and can have cast-in design features. Other material attributes include good fracture toughness and low-temperature properties.

Since the 1970s, extensive development work has been carried out on ADI gears in North America, Europe and Asia

Process verification

Establishing the correct process is considered critical to the successful use of ADI. The process should include the inspection, testing and verification of the as-cast and austempered materials. AGMA advise collaboration between the gear manufacturer, casting supplier and heat treater.

From its Birmingham operations, one specialist heat treater, ADI Treatments Ltd, provides contract austempering services to castings suppliers and users throughout Europe. The company also advises on material selection and process parameters to optimise microstructure and properties.

Although the microstructure is thermally stable to near absolute zero, when subjected to a high normal force ADI can undergo a strain transformation that greatly increases the residual compressive stresses in the affected area. Therefore gears that are shot peened, ground or fillet rolled after austempering will exhibit higher resistance to bending fatigue. Due to the nodular graphite dispersed throughout the microstructure, ADI exhibits better noise damping than steel, and unlike many materials damping increases with tensile strength.

International development

Since the 1970s, extensive development work has been carried out on ADI gears in North America, Europe and Asia. AGMA's information draws on studies by the ASME Gear Research Institute in particular to describe the pitting resistance stress cycle factor.

The guidelines also detail the six standard SAE J2477 grades of ADI and indicate their suitability to various gear applications. Grades are differentiated by hardness so the designer can estimate the gear rating properties. For example, AD750 (241--302 HBW) is a more readily machinable grade with the lowest hardness, but its performance exceeds that of ductile iron gears and competes favourably with through hardened steel gears of similar hardness.

AD750 has excellent bending fatigue strength and is more flaw-tolerant than the other ADI grades.

At the other end of the scale the hardest grade, AD1600 (402--512 HBW), is used where high yield and pitting resistance, or improved wear resistance, or both are required. AD1600 competes favourably with nitrided steels in allowable pitting resistance. This grade can sometimes replace carburised steels at lower cost, if the applied stresses allow.

ADI Treatments Ltd; tel: (+44)121 525 0303; fax: (+44)121 525 0404; e-mail: arron.rimmer@aditreatments.com www.aditreatments.com

References

1. Design Award Winner 1977, Modern Casting, January 1978.
2. Internal document, *Austempered Gears and Shafts – Tough Solutions,* 03 Jan 2001, Applied Process Inc, Livonia MI, *www.appliedprocess.com*
3. AGMA 939-A07, *Austempered Ductile Iron for Gears,* published by the American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314, *www.agma.org*

Higher output and quality of brake discs using vertical greensand moulding

Globalisation, increasing pressure on price and higher quality demands have caused many automotive component foundries to take a new look at how they can increase output with higher quality standards and at the same time cut costs.

Leading automotive companies worldwide are increasingly relying on DISA foundries to meet their demand for brake discs and many other automotive castings. One of these is the Pohang Foundry Plant of Sungwoo Automotive Co Ltd in Korea.

The Pohang foundry employs 360 people and has an annual output of 90,000 tonnes of automotive castings. Seeking to increase output of higher quality brake disc castings, Sungwoo Automotive opted for a DISA 240-C moulding machine with DISA New Generation technology and a mould size of 600x850mm. Installed in May 2005, the machine has more than fulfilled the expectations of the Pohang foundry.

'We decided on the DISA 240-C for the production of brake discs because of DISA's impressive track record at other major foundries around the world,' says Mr Sung-Yong Hong, project general manager at Sungwoo Automotive.

'The machine dependent mismatch of the DISA 240-C of under 0.15mm has significantly reduced our finishing costs compared to our other moulding processes.

With an output of 330 moulds per hour and a high yield percentage, the DISA 240-C is a successful addition to the Pohang foundry plant

In addition, we have achieved an exceptionally low scrap rate, which we believe we can reduce even further. The DISA 240-C has proven extremely reliable with an average uptime of 99.5% since it was installed.'

Quality and performance at low cost

'Brake discs are a safety-critical component demanding dimensional accuracy and the right microstructure and metallurgy for matrix, strength and hardness properties. In addition to meeting these requirements, the DISA 240-C has delivered on its promise of high output and low operating costs. The new design with far fewer moving parts and in-chamber spray means significantly less wear and tear, thus dramatically reducing wear part maintenance requirements', Mr Sung-Yong Hong continues.

In addition to the DISA 240-C moulding line, DISA also supplied the complete sand plant and pouring furnace solution

Another aspect that is essential in order to ensure many years of successful operation is easy access to qualified customer service and the availability of spare parts.

'The knowledge that we can get in touch with a DISA expert at any time in order to obtain guidance or place an express order for spare parts is invaluable', Mr Sung-Yong Hong concludes.

There are now well over 100 DISA New Generation vertical moulding machines in operation around the world, meeting challenging demands of speed, precision, castings integrity, uptime and cost optimisation in the production of a wide array of different castings, not least brake discs.

DISA Industries A/S
Tel: (+45) 44 505050;
Fax: (+45) 44 945225;
email: disa.industries@disagroup.com
www.disagroup.com

Aluminium helps cut emissions at the point of consumption

If you thought rationing was a thing of the past, don't look now as it is back and this time it is carbon dioxide. Stephen Weller, communication manager at the European Aluminium Association fills in the details.

In their efforts to mitigate the effects of global warming, policy-makers are becoming increasingly active in regulating the amount of emissions from both industry and consumers. The legal framework for limiting the production of carbon dioxide is strengthening, and carmakers are among the first downstream industries to be caught in the crosshairs.

In Europe in 2007, the EU commission proposed binding targets on the automotive sector to produce cars that emit no more than 130g of carbon dioxide per km by the year 2012, current average emissions being 162g per km. In the USA, a recent Supreme Court decision found that the Environment Protection Agency has the right to regulate emissions of carbon dioxide under the Clean Air Act.

Greenhouse gas generation

According to the International Energy Agency, about 19% of man-made greenhouse gas emissions globally are generated by the transport sector. Most of these emissions are generated during the use-phase of a vehicle when it is actually on the road. Logic dictates that if you reduce the weight of a vehicle, you reduce the amount of fuel used and therefore the amount of emissions.

This is where aluminium comes in. Recent studies have shown that each kg of aluminium used saves approximately 20kg of greenhouse gas emissions over the average lifetime of a car.

Aluminium has a long history of light weighting in transport. A recent study by Knibb, Gormenzo & Partners in co-operation with the European Aluminium Association shows that the weight of aluminium used in new European cars has risen from 50kg in 1990 to 132kg in 2005 and is predicted to grow by another 25kg by 2010.

A study by Ducker Worldwide commissioned by the US Aluminum Association found that passenger vehicles in North America now contain an average of 145kg of aluminium representing a 16% increase from 2002 data, placing aluminium second only to steel in automotive applications.

In 2005, two million tonnes of aluminium components, in the form of castings, extrusions, forgings and sheet, were put on European roads in new passenger cars. It is estimated that the weight savings achieved will lead to an annual fuel saving of 1billion litres of fuel, which will save roughly 40m tonnes of carbon dioxide emissions over the life spans of these vehicles.

These calculations are based on the assumptions that a car's lifespan is 200,000 km, that 0.35 litres of fuel is saved on every 100 km for every 100 kg of weight reduction and that 2.835kg of carbon dioxide per litre of fuel is the mean value for petrol and diesel, including pre-combustion (carbon dioxide generation during fuel production).

Multiple applications

In the car body bonnets, doors, front structures and bumper beams account for most of the aluminium components. In the chassis and suspension section they are mainly wheels, suspension arms and steering components. In the drive-train most aluminium can be found in cylinder heads, cylinder blocks, engine covers, pumps and radiators. There is a particular growth in aluminium closures, doors, bonnets and boots, aluminium in the body structure and chassis applications.

But reducing the carbon dioxide emissions of a vehicle is not as simple as just reducing the weight. It is only when the whole life cycle of the vehicle is taken into consideration that a true picture of its environmental impact emerges.

Each component requires its own life cycle study to calculate the real savings. There is a life cycle model based on ISO 14044, and developed by the aluminium industry, which can be used for component-specific calculations. The model considers all the greenhouse gases emitted during the production of the metal, the use of the car and what happens to it at the end of its useful life, whether or not it is recycled for instance.

Approaches that take the total life cycle of products into consideration enable the amount of aluminium contained in the material loop to be optimised and reduce any losses. This is the way to truly understand the environmental footprint of a product.

End-of-life considerations

The end-of-life stage is particularly important for vehicles since in Europe, according to the *End of Life Vehicle* directive, at least 85% of the car must be recycled. Aluminium is 100% recyclable with no loss of quality and re-melting it uses only 5% of the energy required to make primary aluminium. With so much energy invested in it, aluminium is a valuable commodity, since the mid-1990s, approximately 95% of all aluminium used in cars is collected and recycled.

The European Aluminium Association concludes that the emissions saved by aluminium light weighting in cars and recycling much more than compensates for the emissions produced when smelting the primary aluminium used in those cars.

Aluminium is part of the solution to reaching the EU's 130g per km target. The industry has always worked closely with automotive designers to help them achieve their objectives with aluminium and more improvements are in the pipeline.

Potential for the use of more aluminium lies, amongst others, in a recent study by the Institute fur Kraftfahrwesen Aachen, Germany. This found improved safety characteristics when using the metal for the front section of a typical C-class vehicle such as a Peugeot 307, a VW Golf or an Opel Astra.

Aluminium not only saves weight and emissions, but can also improve structural performance and safety. It is a particularly good material for light, safety-relevant applications such as wheel guiding control arms, wheels and sub frames, passenger cells requiring high strength and stiffness and front structures requiring high strength and ductility for crash absorption.

The introduction of an aluminium front section in five million C-class cars could save 2.2m tonnes of carbon dioxide over the lifespan of the vehicles, equivalent to saving 770 million litres of fuel.

Weight-saving considerations

The weight of trucks and buses is also reduced through the use of aluminium. One kilogram of aluminium in today's average articulated truck saves 28kg of $C0_2$ and 1kg in a city bus typically saves 40-45kg of $C0_2$. Also, the strength values for aluminium normally give 40-60% weight savings over other materials when designed for equivalent or superior strength, stiffness and lifespan.

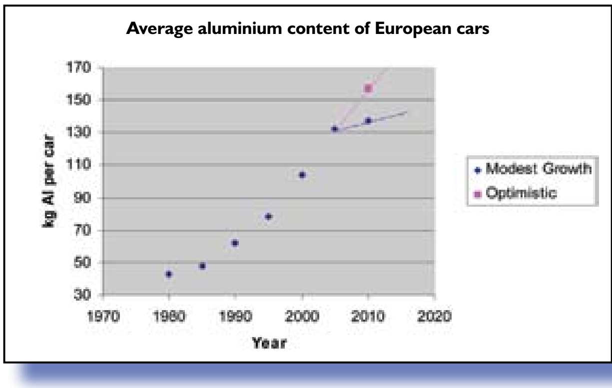
Over the coming years, health and safety, fuel efficiency and reduced emissions will all play a key part in vehicle design. The rationing of emissions has begun and the consumer will increasingly demand low-emitting vehicles without compromising performance, luxury or safety.

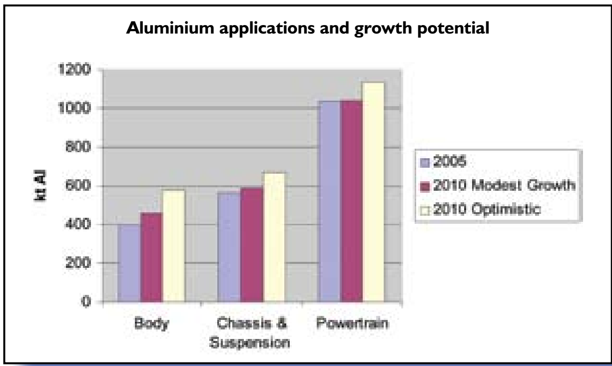
These are some of the challenges being posed by regulators and consumers to the makers of modern vehicles. Aluminium is a material that can help solve some of these design problems by providing versatility, strength, absorption, weight reductions and limiting the environmental impact of a vehicle over its entire life cycle.

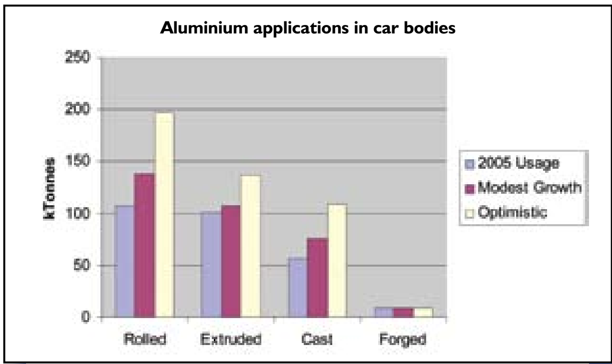
The innovation to meet these design challenges takes place between the aluminium supplier and the customer. The proximity of the aluminium supply chain to the customer means that the innovation relationship is efficient and productive. However, the current high cost of energy, particularly in Europe, is forcing the relocation of many primary operations to parts of the world with lower energy costs.

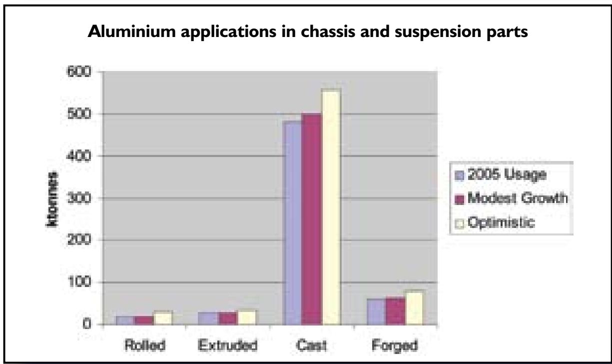
Being further away from the customer could make innovation more difficult and regulators should include this factor when formulating future industrial policy to encourage innovation.

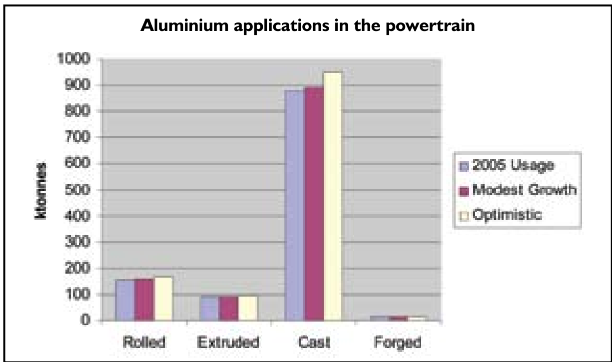
European Aluminium Association
Tel: (+32) 2 775 6345; Fax: (+32) 2 779 0531;
email: weller@eaa.be www.aluminium.org











Joining metal and composites makes good sense

Frida Hallström from SweCast says that there is a need to manufacture competitive and low weight castings. A possible way to achieve this is to combine several different materials and functions in the same product. Combining metal and composites is the method currently being developed in a research project called Castcomp.

One problem today is to join a polymer and a metal in an easy and cost-efficient way, usually a special attachment or a glue joint is required to produce a durable bond. Attaching other materials to a composite often creates problems, as it is difficult to make the attachment sufficiently strong. This problem therefore often leads to solutions where parts are oversized to compensate.

Castcomp was initiated to solve this problem by joining the two materials, metal and composite, through a shrinkage fit, the metal being cast around a composite detail.

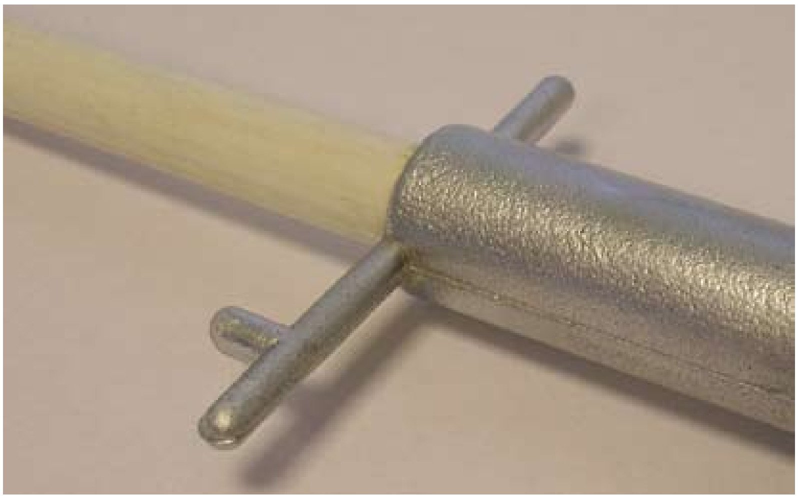


Fig 1. Aluminium cast onto a composite made of glass fibre and vinyl ester

Fig 2. Test bar embedded into a pressure diecast part

Fig 3. Test involving fibres in pressure diecasting

The aim of Castcomp is to develop a new and innovative manufacturing concept based on casting lightweight metal, including zinc, onto a polymer matrix composite. The concept will be developed into a practically verified method and an analysis of the advantages and disadvantages with the method will be performed. The goal of the project is that the method should be sufficiently developed and tested for use in commercial products.

Industrial applications

The technique has uses in several industrial applications and is estimated to have an extensive market potential if results are as successful as expected. An implementation of the technique is expected to result in both weight and cost savings without any extra limitations on function.

One example of application is the production of rods in cars. Rods are today manufactured with forging, sheet metal pressing and/or welding, there being some 15 to 20 rods in a typical vehicle. If it was possible to manufacture rods with metal attachments cast onto a composite, there would be a potential manufacturing rate around 20 million pieces annually in Sweden alone.

Both gravity and pressure diecasting have been used in the project. The tests with gravity diecasting were performed with a mould made for the purpose so that the necessary test such as tensile strength could be performed. The geometry of the mould was designed to fit test bars with a diameter of 10mm (fig.1). Two inserts with different sizes were used so tests involving different amounts of metal and temperatures could be performed.

None of the test bars showed bonds strong enough to match glue joints.

Tests with bars and cloths

Tests using pressure diecasting have been made with test bars (fig.2) and fibre cloth (fig.3). No additional mould was needed, all the tests having been performed in available pressure diecasting machines at the production sites of the industrial project partners. Pure carbon and Kevlar fibres have been tested. No visible damages could be seen on the composites in the tests with fibre cloth, so that test was very successful. The test with bars has not yet been evaluated.

During the process of casting metal onto composites, thermal degradation of the polymer will occur. Although several one-dimensional models exist that describe this thermal process, to take into account the multi-dimensionality of a real product, these models have to be further developed.

In this work, the models are implemented and solved using a general purpose FE-package called ABAQUS. The applicability of the code to complex geometries is demonstrated by analysing the shrinkage fit resulting from casting a metal ring onto a composite axle.

To succeed in manufacturing of this type of joint, a delicate balance between thermal loading, metal shrinkage, composite degradation and the overall cooling must be considered. The FE-model proposed in Castcomp provides the spatial distribution of these field variables, allowing for accurate optimisation of the shrinkage fit.

Weight and cost reduction

Results from tests have shown potential in several areas depending on metal and composite used. Expectations, based on these early tests are that production using the proposed method can:

- Reduce weight by 50% compared to current manufacturing method
- Decrease or at least retain production costs
- Reduce 90% of the machining costs
- Retain product strengths, compared to traditional glue joints
- Enable production of batches over 100,000 parts annually.

Castcomp will continue throughout 2008 with more tests in pressure diecasting. Several other composite materials with magnesium and zinc will be tested. As a result of this development, it is hoped that it will be possible to manufacture more complex multi-material parts with a reduced weight and at lower cost.

SweCast Tel: (+46) 3630 1200; Fax: (+46) 3616 6866;
e-mail: fh@swecast.se www.swecast.se

Convinced by quality

The Hyundai Motor Company has awarded an order for 12 complete diecasting cells for manufacturing high-grade engine blocks from aluminium to Buhler Die Casting.

The first eight high-tonnage diecasting cells have been up and running since August 2006, four additional ones are scheduled for installation and start-up in the coming months. Once this project has been completed, the Korean Hyundai Motor Company (HMC) in Ulsan will be operating 12 diecasting cells with locking forces ranging from 2700 to 4200 tonnes - and will be the world's most advanced diecasting facility for manufacturing engine blocks.

Quality and strength

The engine block is the heart of a car with the quality and strength of this diecast component being crucial for the life cycle of the entire engine. Consequently engine builders and automobile manufacturers around the world are constantly on the lookout for improvements in diecasting processes and systems.

Hyundai has set itself the goal of manufacturing the best engines in the world. This applies not only to those incorporated in its own vehicles, but also to those it sells as a vendor to other carmakers. In line with this objective, the people at Hyundai went searching for a diecasting process that would be capable of satisfying the high quality requirements.

Buhler's Die Casting division set up an agency in Korea in 2002. Up until the initial order with Buhler, Hyundai had always purchased its diecasting systems from Japanese manufacturers.

In August 2005, the 15-member team from Buhler Die Casting started installing the first diecasting system in the 10,000m^2 hall of the former iron foundry in Ulsan. The subsequent systems were delivered at regular intervals.

Installation completed

In August 2006, all eight diecasting systems, including the peripheral equipment comprising robots, spray devices, molten metal feeder units and the aluminium supply system, had been completely installed and tested. Since then, an aluminium engine block leaves one of the eight machines every three minutes. The ultimate goal is to achieve 'round-the-clock' operation and when this happens, the eight casting cells will manufacture 850,000 engine blocks a year.

Hyundai ordered four additional complete diecasting cells in the summer of 2006 that will go into productive service shortly.

Buhler Die Casting in Uzwil Tel: +41 (0) 71 955 30 79;
Fax: +41 (0) 71 955 25 88; email: dan.lloyd@buhlergroup.com
www.buhlergroup.com

Below: The new diecasting systems operated by Hyundai in the old iron foundry

An example of the company's brake discs and cores

Investment and expansion for a positive future

The EURAC group, established in 1992, is one of Europe's leading independent high volume producers of grey cast iron components for the automotive industry, with an annual turnover of some £45 million and the capacity to produce some eight million castings a year.

The group currently operates two high volume Disamatic foundries, Precision Disc Castings (PDC) located in the UK and Brzdové Automobilové Kotouče (BAK), a foundry with dedicated on-site machining facilities in the Czech Republic. Both sites specialise in the production of brake disc castings and are accredited to ISO TS 16949.

In order to offset some of the pressures faced by a foundry group operating in Europe, EURAC has implemented a significant programme of technical development and expansion. Increases in raw material costs resulted in PDC performing an evaluation of the melting methods and procedures, and BAK is currently undergoing a major expansion.

In-depth investigation

Over a two-year period, PDC performed an in-depth technical investigation based on the fundamentals of cast iron melting and solidification in an attempt to understand the many variables inherent in a typical electric melting process. Areas such as raw material composition, charge make-up, melter charging sequence and furnace additions were studied in detail. Inoculating materials and application techniques were also investigated and studied in detail whilst modern thermal analysis equipment was purchased to support this detailed process study.

As a result of this detailed investigation, process variables were identified and their effects quantified and understood, process procedures were introduced to control melt quality and mitigate the effects of identified variables. A cost rationalisation process was also undertaken, resulting in significant cost savings without adversely effecting product quality. Late metal stream inoculation using powder injection techniques was also introduced to both replace and complement the use of metallurgical wire injection techniques developed by PDC in1991.

PDC now has the capability to fine-tune both inoculating method and treatment material to each individual component, thus maximising inoculation efficiency and producing components with superior metallurgical structures; a feature of paramount importance when manufacturing safety critical components such as brake discs.

Major development programme

BAK, which was commissioned for production by EURAC in 2002, is currently benefiting from a major development programme, which commenced in 2006. A €12.2 million investment will see major items of capital plant and equipment being installed in both the foundry and machine shop.

The programme started with the installation of a Disa 230B moulding machine, new shot blast equipment, auto fettling and core making in the foundry and two new CNC machining cells in the machine shop.

Two new Inductotherm medium frequency melters, and increased shot blasting capacity have been installed along with extensions to both Disa moulding lines. Moulding sand has also been increased and an Eirich Rotocontrol installed in the moulding sand system to continually monitor and adjust green sand properties.

A new Hessap CNC machining cell has also been integrated into the machine shop at BAK.

In 2008, it is expected that one of the Disamatic moulding lines and the core making facilities will be up-rated, and in 2009 two new machining cells installed in the machine shop. At the end of this period of significant development and growth, EURAC will be in a position to produce 100,000 tonnes of grey iron a year and supply some 10 million brake disc castings to the European automotive industry.

EURAC Group Tel: +44 (0) 1202 715050;
Fax: +44 (0) 1202 715068;
email: malcolm@eurac-group.com
www.eurac-group.com

CGI – the ferrous response

Dr Steve Dawson of SinterCast puts the case for compacted graphite iron.

As the increases in engine loading began to exceed the strength capabilities of conventional grey iron (GJL 25), foundries and OEMs responded by adding alloying elements and hardening agents such as chromium, nickel, copper, tin and molybdenum.

In order to further increase the strength of grey iron to satisfy the 300MPa minimum tensile strength objective (GJL 30), the carbon content of the iron was also reduced from approximately 3.2% to 3.0% to make the graphite flakes smaller, thus reducing the risk for crack initiation and propagation. The alloying and reduced carbon content provide a 10-20% increase in mechanical properties, but simultaneously consume many of the core advantages of conventional grey cast iron including castability, heat transfer, machinability and significantly, cost.

The properties of conventional grey cast iron (GJL 250), alloyed grey cast iron (GJL 300) and CGI (GJV 450) are summarised in table 1.

Castability: During solidification, the formation of graphite flakes in conventional grey iron provides an expansion effect that counteracts the natural shrinkage tendency of the iron. However, the lower carbon content of alloyed grey iron reduces the extent of this beneficial effect. Additionally, many of the alloying elements (Cr, Cu, Sn, Mo) segregate to the last areas of the casting to solidify and promote shrinkage porosity and intercellular carbide formation.

The net effect is that the castability of alloyed grey iron, including feeding requirements, is effectively the same as that of CGI. This is particularly true for complex castings such as cylinder blocks and heads.

Heat transfer: The addition of alloying elements to grey iron reduces thermal conductivity. Typical GJL 30 levels of 0.3% Cr and 0.3% Mo reduce the thermal conductivity of grey iron by 10-15%.

Further, since grey iron relies on the highly conductive graphite flakes to provide natural conduits for heat transfer, the lower carbon content of alloyed grey iron also detracts from the heat transfer capability. The net effect is that the thermal conductivity of alloyed grey iron is only about 5% higher than that of an unalloyed pearlitic CGI (GJV 450).

Machinability: The alloying elements added to increase the strength of grey iron also increase the hardness and wear resistance. While the strength of alloyed grey iron is only 10-20% higher than that of conventional grey iron, the hardness can be more than 30% higher.

Depending on the alloy content, the hardness of alloyed grey iron can frequently be higher than that of CGI. While there is a significant difference in machinability between conventional grey iron and CGI, the machinability of alloyed grey ion and CGI are effectively the same.

Cost: The shrinkage sensitivity (feeding requirements) and machinability (tool life) of alloyed grey iron both impact the total cost of alloyed grey iron. Beyond these operational concerns, consideration must also be given to the cost of the alloying elements. For example, the market prices of molybdenum and nickel have increased more than tenfold since 2005. For a 100kg GJL 30 casting with a 70% mould yield and a 0.3% Mo content, the molybdenum cost alone is approximately €20 per casting.

Alloyed grey iron may have been the best material for heavily loaded cylinder blocks and heads until recently, before CGI was proven as a viable high volume material. However, as a result of the recent advances in foundry process control and manufacturing technology, it is no longer necessary to accept the trade-offs associated with alloyed grey iron.

If engine designers are willing to incur the production difficulties of alloyed grey iron, they could also specify CGI and realise the benefits of 50% higher tensile strength, 30% higher stiffness and at least 75% higher fatigue resistance. These incremental properties provide additional opportunities for improved engine performance, reduced emissions, increased durability and, perhaps most importantly, growth potential throughout the life cycle of the engine.

SinterCast AB Tel: +46 (0) 8 660 7750; Fax: +46 (0) 8 661 7979; email: info@sintercast.com www.sintercast.com

Property	Units	Grey iron (GJL 250)	Alloyed grey (GJL 300)	CGI (GJV 450)
Tensile strength	MPa	250	300	450
Elastic modulus	GPa	105	115	145
T. conductivity	W/m-K	46	38	36
3-PT bending fatigue	MPa	150	170	300
Carbon content	%	3.2	3.0	3.7

Table 1. Typical properties of grey irons and CGI

Listing the best materials

The October 2007 issue of SAE International Newsletter refers to a list from the Journal of Materials and Manufacturing of what the latter considers to be the 'best 119 materials and manufacturing-related SAE technical papers of 2006' for automotive applications.

It is good to see that high up on the list is ferrous and non-ferrous metals plus diecasting materials and applications.

Order on line at customersales@sae.

Magnesium supports drive for improved fuel efficiency and reduced emissions

Graham D Wardlow MBA, BEng, ARSM, deputy managing director – UK Operations of Magnesium Elektron fills in the details.

Magnesium is the lightest of all structural materials, a quarter the weight of steel and a third lighter than aluminium. Racing vehicles have used magnesium since the 1920s and today the high performance ELEKTRON alloys are still used extensively in all forms of motor sport and for high-end premium vehicles.

For commercial vehicles, use of the material peaked in the 1970s with Volkswagen using over 20kg in the VW Beetle, the material being used for both the crankcase and transmission housings. The alloys used at this time, however, displayed poor corrosion resistance in comparison to aluminium and generally magnesium fell out of favour by the end of the 1970s.

Improvement through development

Alloy development work in the mid-1980s by Norsk Hydro and Dow Chemical identified that the corrosion resistance of the traditional commercial alloys could be dramatically improved by reducing impurity levels. By the end of the 80s, a new generation of high purity diecasting alloys became available at a time when the US car industry first introduced its Corporate Average Fuel Economy (CAFÉ) regulations.

From an almost zero base, the use of magnesium grew rapidly.

With the material displaying excellent diecasting characteristics and significantly improved die life in comparison with aluminium, magnesium found favour for large complex castings that enabled parts, traditionally manufactured from many steel pressings, to be cast in a single shot. In addition to offering a lightweight solution, such processing technologies also brought about cost savings.

In Europe, the Kyoto agreement of 1996 put extremely challenging environmental targets on the European automotive industry, reducing CO_2 emissions from 185g/km in the base line year of 1995 to 140g/km for vehicles manufactured in 2008.

With improved safety and comfort features being added all the time, lightweight component design became an essential element in driving towards the required targets.

European growth

In 1995, the Volkswagen Group of companies led the growth of magnesium in Europe with the introduction of the AZ91D (Mg – 9%Al – 0.5%Zn) transmission housing used on the VW Passat and Audi A4/A6 platforms. Although other magnesium components had been specified before this, the transmission housing was the first commercial power train application specifying magnesium since the introduction of the high purity generation of alloys.

When the transmissions were introduced, they offered a 25% weight saving over the previous generation aluminium housings. Today, the latest generation transmissions still use the AZ91D alloy and are cast at the main VW diecasting plant in Kassel, Germany.

Other manufacturers using the material include Mercedes Benz, BMW, Ford and Jaguar for applications including instrument panels, intake manifolds, steering components and cylinder head covers.

Extending the boundaries

In 2004, the boundaries of magnesium alloy and design technology were pushed further when BMW introduced the 'composite' three-litre, straight six, engine block. The block encompasses an aluminium hypereutectic alloy insert (AlSi17Cu4Mg), incorporating the cylinder liners and water channels, encased within a magnesium diecast jacket.

BMW three litre engine block using lightweight magnesium

ELEKTRON's AJ production facility in Manchester, UK

When we think of lightweight castings in automotive construction, we normally consider aluminium as being the material of choice. More recently, however, lightweight magnesium alloys are once again finding favour as the drive to reduce weight and improve fuel efficiency is met with advances in magnesium alloy technology.

Introduction of the engine block followed a four-year development programme between BMW and Noranda Magnesium (Canada) and involving Magnesium Elektron for the production of all experimental alloy derivatives.

The magnesium diecast jacket operates at elevated temperatures and therefore uses the latest generation creep resistant diecasting alloy, AJ62, based on a magnesium-aluminium-strontium alloy system. The alloy is produced at both of Magnesium Elektron's production facilities in the UK and the Czech Republic.

Both operations supply BMW's engine casting plant in Landshut, Germany, and diecaster Brabant Alucast Products in the Netherlands, the company responsible for the manufacture of the lower crankcase. Today, over 500,000 blocks are cast every year.

The engine offers a 24% weight saving over the outgoing aluminium block and is specified across the whole spectrum of BMW vehicles, from the 1 Series to the 7 Series.

Globally, the last 20 years has seen magnesium use in automotive applications grow by more than 10% per annum. With this there has been a significant increase in the number of diecasting foundries casting magnesium in the US, Europe and more recently in the Far East. It is only in the last five years, however, that the new generation of high-temperature diecasting alloys has become available.

With this latest development, the range of potential applications exploiting the favourable diecasting characteristics of magnesium increases significantly. With the successful use of the AJ alloy system by BMW, the future looks promising for the increased application of this lightweight material as the drive continues to minimise weight, increase fuel efficiency and reduce emissions.

Magnesium Elektron Tel: +44 (0) 161 911 1000;
Fax: +44 (0) 161 911 1020;
email: graham.wardlow@magnesium-elektron.com
www.magnesium-elektron.com

ELEKTRON's AJ alloy ingot used in the BMW engine block programme