# Liquid pressure forming of aluminium matrix composites

The MCM Series 2 machine for manufacturing high performance Aluminium Matrix Composite (AMC) components by Advanced Liquid Pressure Forming (ALPF) has been developed by Composite Metal Technology Ltd (CMT) to provide materials solutions for next generation engineering systems. The development and advantages of AMCs are described.

MCM casting machine

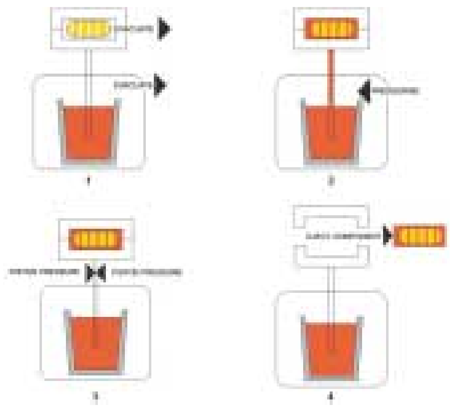
Aluminium Matrix Composites are an advanced class of metal matrix composite, composed of an aluminium matrix and a ceramic reinforcement in the form either of particles or of short or continuous fibres. They offer significant weight and performance benefits over conventional unreinforced materials. According to Dr Roger Bushby, CMT's Technical Director, "AMCs with continuous alumina fibre reinforcement can offer mass savings of up to 60 percent compared with steel, and increases in stiffness and strength of over 200 percent when compared with high performance wrought aluminium alloys - essentially AMCs can be as strong and stiff as steel but have less than half the weight". These composites also have a much higher temperature capability than polymer based ones, which makes them an ideal candidate material for elevated temperature applications, such as engine components. Fully or selectively reinforced near net shape AMC components can be produced economically by ALPF, because of its fast cycle time of 2 min. Also, CMT has the capability to provide design and engineering support for the development of new components for potential customers and end users.

CMT is located on the Cody Technology Park in Farnborough, Hampshire, occupying factory and office accommodation within QinetiQ's Structures and Materials Centre (SMC). Although financially independent, it has a teaming agreement with QinetiQ under which it can access engineering and scientific expertise to support component development and prototyping programmes. The original LPF technology was developed by the UK's Ministry of Defence. It was licensed to CMT which has made a subsequent investment of over £4m. Together with a SPUR grant from the DTI, this has been used to finance the development of the company's MCM production machinery and die tooling technology. As a consequence, a significant amount of proprietary intellectual property relating to AMC component manufacture and processing has been created, which has superseded the MoD's licensed technology and has considerably more commercial relevance. Some elements are the subject of an international patent application.

CMT location on the Cody Technological Park, Farnborough

In addition to receiving SPUR funding CMT has won a prestigious DTI Research and Development (SMART) award which is presented to those companies which have shown outstanding innovation in their products and processes in order to promote rapid growth. The award is a further indication of the importance that the DTI places on the successful industrialisation of the company's ALPF technology, which falls within their Metal Matrix Composite (MMC) priority technology area for the UK. CMT is also a member of the DTI's MMC Working Group, which was established to help promote MMCs in UK industry by providing a strategy for developing and growing the technology. The work of the group is expected to provide a significant boost to the MMC industry by raising awareness of the technology and providing direction for Government funding initiatives.

A proprietary ALPF process has been developed specifically to overcome the difficulties of producing AMCs via a casting route. The process includes positive reinforcement (preform) location, promotion of matrix reinforcement wetting, control of rate of liquid metal infiltration, and control of cooling to give the desired solidification profile. The ALPF process comprises four main stages, which may be represented schematically as:



Schematic of the ALPF process

1. Evacuation of reinforcement 'preform' and liquid aluminium
2. Gas pressurisation of liquid aluminium and preform infiltration
3. Piston pressurisation of solidifying metal in die cavity
4. Cooling and ejection of cast AMC component

Potential areas of application for AMCs are wide and include ground transportation, power generation, aerospace, defence and ordnance, high speed machinery, marine and sub sea, sport/leisure and other engineering sectors. All of these are becoming increasingly focused upon improved energy efficiency and/or performance, which relies upon both improved component design and the use of light weight materials. In response to customer requirements CMT has focused initially on the development of tubular components primarily for rotating or reciprocating applications, since these parts offer the highest performance and efficiency benefits from the significant weight reductions achievable. Advanced preforming techniques are also being developed to enable the manufacture of more complex AMC components by ALPF.

Of the components that are under development, the most commercially advanced are AMC drive pins for high speed machinery applications. For this application, replacement of the conventional standard steel pin has resulted in a much higher critical whirling speed

Steel coated AMC gudgeon pins (18 mm dia)

of 72,000 rpm, enabling the component test envelope to be increased by 50 percent. This application also relies upon the excellent shear properties and thermal stability of the AMC, factors which precluded the use of other high performance materials such as carbon fibre reinforced polymers. CMT is also in the process of commercialising lightweight AMC gudgeon pins. Demonstrator components with hard wear resistant coatings have been produced that are currently being subjected to engine tests. The first applications being targeted are in the automotive racing sector, but longer term uses could include high performance engines for commercial and domestic vehicles.

Another energy saving application has involved the development of a high speed induction generator as part of a £1.1m EU CRAFT programme made up of a consortium of industrial partners. The project called for the design, manufacture and testing of a high speed prototype electrical generator using CMT's innovative AMC rotor, which was shown to increase the safe operating speed from 3,600 rpm for a standard generator rotor to 30,000 rpm, potentially allowing the direct coupling (without a reduction gearbox) of the generator to a gas turbine engine in order to achieve higher operational efficiency whilst rationalising the overall design. Development of this new technology has led to the filing of an international patent application to protect the intellectual property rights of the Consortium. The application is now at a stage where novelty has been established by the European Patent Office. In addition to the electricity generating industry, the innovation could find uses in power generation sets for cruise liners, merchant vessels and naval ships, oil platforms, remote industrial/civil power plants and emergency electrical back-up systems.

Also, the company has produced AMC demonstrator parts for lightweight ordnance, the concept being to incorporate them into the structure so as to reduce overall weight. Although such applications are relatively low volume, this helps generate greater visibility of AMCs in the area of defence and in other engineering platforms and systems. This opportunity has been facilitated by virtue of CMT's location inside QinetiQ, which has given strong support to the company's activities in developing AMC components for defence applications.

AMC induction generator rotor tube (150mm dia, 300mm long)

Regarding the company's future, Neil Collins, CMT's Chief Executive explains, "We are in the process of securing additional investment to fund the wide scale market exploitation of the ALPF process technology and manufacturing systems, and are actively seeking development partners to jointly produce new types of AMC component. There is also the potential of applying ALPF technology to other casting systems, in order to extend their production capability to AMC components. We would welcome enquiries from diecasting machine manufacturers and other interested parties who may wish to assist us in the commercialisation of this leading edge technology."

**Reader Reply No.35**

# Dry cleaning improves performance

A die before Cryonomic cleaning

A die after cleaning with the Cryonomic dry ice system

Following a change to dry ice cleaning a leading Belgium based aluminium foundry system has reduced the cleaning time of each of its moulds by 480 percent. By installing the technologically advanced Cryonomic® system, which replaces the use of wire brushes, the Hassel foundry has also substantially increased the life expectancy of the moulds and helped improve the quality of the cast products. Situated in Flanders, Belgium, Hassel produces a range of aluminium products for pan-European companies such as Siemens, General Electric, Hansen Transmission as well as guttering and housings for smaller companies. The company operates nine ovens with an overall capacity of 450kg and uses a range of dies weighing from 200grams to 40kg.

Moulds become covered with coating, dirt and other build up that interferes with the quality of castings to be produced. Before purchasing the environmentally friendly and cost effective Cryonomic dry ice cleaning system, Hassel had to undertake the weekly cleaning of the moulds using iron brushes. This was not only labour intensive, but was such an unpopular task that the company was experiencing a significant turnover of staff. Also, the use of iron brushes eroded the metal moulds, which had to be replaced frequently, and left a residue, which meant the final product was not always a hundred percent perfect.

Using the more efficient Cryonomic dry ice blasting machines, debris is remove by blasters using compressed air to shoot small dry ice pellets at the surface to be cleaned. When the pellets hit the surface their kinetic energy causes them to penetrate to the base material. At that point, they shatter, blasting fragments in all directions, which releases the mould coating from the base material. The dry ice fragments turn from a solid to a gas, and this expansion of carbon dioxide ($CO_2$) adds a lifting force that speeds the removal of the mould coating. The debris falls away, and the $CO_2$ gas returns harmlessly to the atmosphere.

Cleaning can be performed on hot moulds directly in the moulding machine. Trials at the Hassel factory showed that it had reduced the cleaning time from eight hours to just 10 minutes because it was no longer necessary to spend time removing moulds or waiting for them to cool before cleaning. In addition, as the Cryonomic system uses C02 pellets, the blasting has no wearing effect on the die surface and is environmentally clean - it leaves behind no leftover material in the atmosphere, on the floor or on the machines. Since the dry ice method returns the mould to its original shiny and clean state, the final product is faultless.

Hassel has also found a further use for the Cryonomic dry ice cleaning system. The degassing filters used within the process had to be thrown away every week, as they could not be cleaned. The Cryonomic system is now cleaning these filters so that they can be reused, which is providing the company with substantial savings.

**Reader Reply No36**