

AM-lite & AM-HP2 - New Magnesium Alloys Offer New Opportunities

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ABSTRACT

Two new magnesium die casting alloys, AM-lite and AM-HP2, have been developed which address issues related to magnesium applications. AM-lite offers considerable advantages over the existing general purpose die-casting alloy AZ91D. AM-lite has superior diecastability, significantly improved as-cast surface quality, superior surface definition, and is highly suitable for decorative surface finishing processes including electroplated in a process that is similar to zinc. AM-HP2 is a new creep resistant alloy that provides a combination of good diecastability and creep resistance at temperatures of relevance to powertrain applications.

INTRODUCTION

There are many applications where a metallic article is preferable to plastic and magnesium has for many years been cheaper than zinc on a volume basis. Despite this, more zinc is die cast than magnesium (both by weight and volume) and when zinc loses applications it is more often to plastic than to magnesium. AMT and CAST have developed the new magnesium diecasting alloy, AM-lite, to specifically address the needs of decorative diecast applications where zinc and molded plastics are commonly used.

Powertrain components offer a significant opportunity for reduction of weight at the front of vehicles which contributes significantly to improved performance, vehicle agility and fuel economy. Because of their large mass, engine blocks are components that provide attractive targets for the application of magnesium. This has been recognized by BMW who recently commenced mass production of a 6 cylinder petrol engine with an engine block comprised of an aluminum alloy insert surrounded by a die-cast outer block made from magnesium alloy AJ62^{1,2}.

AMT and its research partner CAST developed the magnesium sand-casting alloy, AM-SC1^{3,4}, that was successfully used for the engine block of the Genios LE three cylinder turbo diesel engine developed by AVL List. This engine recently completed a two year 65,000 km road trial with excellent results in terms of performance and durability⁵. This demonstrated the suitability of AM-SC1 for engine block structures where stiffening inserts are kept to a minimum and cooling channels pass directly through the cast magnesium alloy. Because of its excellent properties for powertrain applications, AM-SC1 has been selected for the engine block of the V6 engine that is currently being manufactured for the USCAR MPCC magnesium intensive engine project.

The success of AM-SC1 has inspired AMT and CAST to develop a closely related alloy, AM-HP2, that is especially suitable for high pressure die casting (HPDC) and which has properties that are very similar to AM-SC1. This development is important because the cost of manufacture of engine blocks by HPDC is lower than by sand-casting and HPDC has become the casting route of choice for many light alloy engine blocks.

AZ91D OVERVIEW

The general purpose magnesium diecasting alloy, AZ91D, is used extensively for functional and decorative applications where castability is very important. In the past, few people have considered the development of alternative alloys to AZ91D to be worthwhile. This is somewhat surprising since AZ91D has some major shortcomings and there is a large potential market for an alloy that alleviates these. For example, the consumer electronics industry, which has rapidly changing demands, has been pushing for thinner and lighter

enclosures combined with high quality surface finishes. AZ91D has been the workhorse magnesium alloy for such applications but seems to have reached its limit and is no longer able to provide the further improvements required by the industry.

Table 1. Problems associated with AZ91D

Issues	Comments
Diecastability	AZ91D is not as diecastable as zinc alloys High reject rates for precision products
Die cast surface quality	Uneven surface - many surface defects Oxidises rapidly, shelf life is short
Surface finishing	Filling and extensive buffing/polishing required Blister defects form during baking Can be electroplated only with difficulty and high cost High reject rates
Melt handling	Typical 4% melt loss in diecasting operations – can be higher Significant dross and sludge for disposal
Recycling	In-cell recycling is difficult Expensive external, or separate, recycling operations
Productivity	Often low (high rejects) because of production/quality issues

The limitations of AZ91D (see Table 1) have restricted the growth of magnesium in the electronics industry and have also prevented magnesium from capturing much of the zinc die casting market. One issue is diecastability with zinc able to cast thinner sections and reproduce greater detail than AZ91D. Perhaps most significant is the extra costs involved in surface finishing of magnesium, especially for electroplated articles. Magnesium can be electroplated by first applying a zinc layer (zincating) and then following the sequence used to electroplate zinc. The additional first step is not a major issue as electroplating involves many layers (cyanidic copper, acid copper, nickel, chromium) and one more step has minimal effect on cost. Because AZ91D cannot be cast with a highly polished surface, extensive finishing operations are required such as filling of surface defects and buffing of the as-cast surface. Another problem is that in order to get good adhesion of the zinc layer on AZ91D a prior etching or electropolishing step is necessary. As a consequence the surface is roughened and a secondary buffing operation is generally needed after the copper plating step. The cost of secondary buffing and the extra handling to remove articles from racks and replace them midway through the process renders electroplated of AZ91D uneconomic in all but a few cases.

AZ91D is widely used for enclosures of cell phones, laptop computers, cameras, projectors, PDA's and many

other consumer products. Zinc is too heavy and costly for these applications and plastics, while used widely, lack stiffness and electromagnetic shielding capacity. Although aluminum alloys have a lower density than zinc, their poor diecastability makes them a non-viable option for such precision diecastings. Despite the natural advantages of magnesium, diecasters often struggle with the limitations of AZ91D. The key issues are problems of castability, surface defects and surface finishing. It is not uncommon for less than 10% of the quantity of magnesium entering the process to end up in finished parts. Casting yields, that is the casting weight divided by the total metal cast at the casting cell, are often 30% or less and many parts are rejected at various stages throughout the manufacturing process. Rejects after finishing are particularly troublesome due to the processing costs invested in the part and the added difficulties of recycling surface finished parts. Even for acceptable diecastings, surface filling is often necessary to cover up defects.

GENERAL FEATURES OF AM-LITE

AM-lite is a new improved magnesium diecasting alloy that has the diecastability of zinc alloys combined with the light weight advantages of magnesium alloys. During development of the alloy, particular attention was paid to addressing the shortcomings of AZ91D that are listed in Table 1 and development of an alloy that is considerably better with respect to all of those issues. A large number of industrial diecasting trials, in a wide variety of different diecasting plants, have now been conducted with AM-lite. These trials have demonstrated the superiority of the new alloy and have enabled establishment of operational procedures for ensuring the production of high quality products with lower reject rates than previously experienced.

AM-lite has improved diecastability compared to AZ91D and the as-cast surface finish of AM-lite is of a much higher quality. Die castings made from AM-lite are very well suited for surface finishing operations. A particular advantage is that the alloy can be readily electroplated at equivalent costs to zinc alloys.



Figure 1. Electroplated mobile phone casing die cast in AM-lite.

In comparison to other magnesium diecasting alloys, AM-lite is oxidation resistant at temperatures in the range of solidification and below. This results in less oxide on the surface of castings and their shelf life is considerably improved compared to castings of other magnesium alloys. One consequence of this oxidation resistance is that the material is easier to recycle than AZ91D and tests have shown that there is a strong potential for in-cell recycling of class 1 return scrap and thus save considerable costs expended on external recycling.

The design strength of AM-lite is considerably higher than AZ91D and zinc diecasting alloys. This, combined with the ability to better diecast thin sections, provides an increased flexibility for designers. Most importantly AM-lite saves costs. Compared to AZ91D these cost savings are estimated to be ~ 50% for surface finished parts and, compared to surface finished zinc diecastings, the savings are 10 – 30%.

DIECASTABILITY AND AS-CAST SURFACE OF AM-LITE

AM-lite exhibits considerably improved fluidity and diecastability compared to AZ91D. Its diecastability is in many ways similar to that of zinc diecasting alloys. The usual difficulties experienced with diecasting AZ91D, such as cracking along flow lines, cold cracks and hot cracks, are significantly reduced with AM-lite. Merging flows of molten AM-lite within the die cavity weld readily with no deleterious effects. Of course normal best practice principles should be applied to the design of the runners and flows in the cavity, as well as the thermal design of the die, in order to obtain as wide an operating window as possible. Because of the higher alloy fluidity the dimensions of runners and volume of overflows can usually be reduced.

As might be expected, the optimum diecasting conditions for AM-lite are different from those for AZ91D. In fact AM-lite's operating window is wider for the production of good quality castings and therefore the alloy provides greater stability of operation in mass production situations and allows for easier automation. This is especially true as AM-lite does not adhere to, or react with, the die (soldering) as does AZ91D. Hence, the usual polishing of dies after a set number of shots with AZ91D is significantly reduced with AM-lite, thus reducing down time and improving automation. Very thin sections are more easily achieved with AM-lite than for AZ91D and the alloy will reproduce very fine detail from the die. This enables the creation of special surface textures on as-cast surfaces.

Because of the lower heat input to the die, the cycle time for diecasting of AM-lite can be reduced by up to 50% compared to zinc. Compared to AZ91D, the cycle time can be reduced in some cases by up to 30% if advantage is taken of smaller runners and overflows and lower die temperatures.

Compared to AZ91D, AM-lite diecastings have an improved surface finish that is smoother, contains less surface defects and is resistant to oxidation for long periods. Indeed, as shown in Fig 2, an as-cast mirror finish can be obtained if diecasting parameters are appropriately optimized.



Figure 2. As-cast mirror finish on diecast AM-lite plate (top half of picture)

SURFACE FINISHING OF AM-LITE DIECASTINGS

The much improved as-cast surface of AM-lite diecastings significantly reduces the need for polishing and buffing prior to surface finishing operations and can eliminate the need for filling of surface defects. This significantly reduces the cost of preparation prior to coating operations and reduces rejects. In addition, because of the alloy's oxidation resistance, AM-lite castings have a long shelf life and this adds further freedom to surface finishing – particularly in hot and humid climates.

AM-lite provides a superior substrate for all surface finishing operations such as electroplating, powder coating, wet painting, electrophoretic coating, and PVD coating. Furthermore, because the alloy has an inherent creep resistance that restricts the expansion of entrapped gases during baking cycles, it is resistant to the formation of blister defects during baking of powder coated and painted articles.

AMT has worked with MacDermid, a world leading supplier of technology and chemicals to the electroplating industry, to develop an electroplating process for AM-lite. The result (Fig 3) is a process that is vastly superior to that which can be used for AZ91D and which produces electroplated finishes that are comparable in quality to electroplated zinc diecastings.



Figure 3. Automotive components diecast in AM-lite and electroplated using MacDermid's electroplating process

MECHANICAL PROPERTIES OF AM-LITE DIECASTINGS

The mechanical properties of AM-lite diecastings are summarized and compared with AZ91D in Table 2. The tensile properties in this table were obtained on 2mm thick die cast plates. Both the yield strength (0.2% offset proof stress) and ultimate tensile strength of AM-lite are higher than for AZ91D. The most important difference in mechanical properties can be seen with reference to Fig 4. AM-lite maintains its linear elastic behaviour to higher stresses than AZ91D. The limit of linear elastic behaviour for AZ91D is ~ 40 MPa while for AM-lite this limit is ~100 MPa. This means that, for stiffness critical parts, the design strength of AM-lite is considerably higher than that for AZ91D.

Table 2. Mechanical properties of AM-lite diecastings compared to AZ91D

Property	AM-lite	AZ91D
Yield stress (0.2% proof), MPa	160-170	120-150
Ultimate tensile strength, MPa	230-250	180-205
Young's modulus, GPa	45	44
Elastic limit, MPa	~100	~40
Tensile elongation, %	3-4	3-4

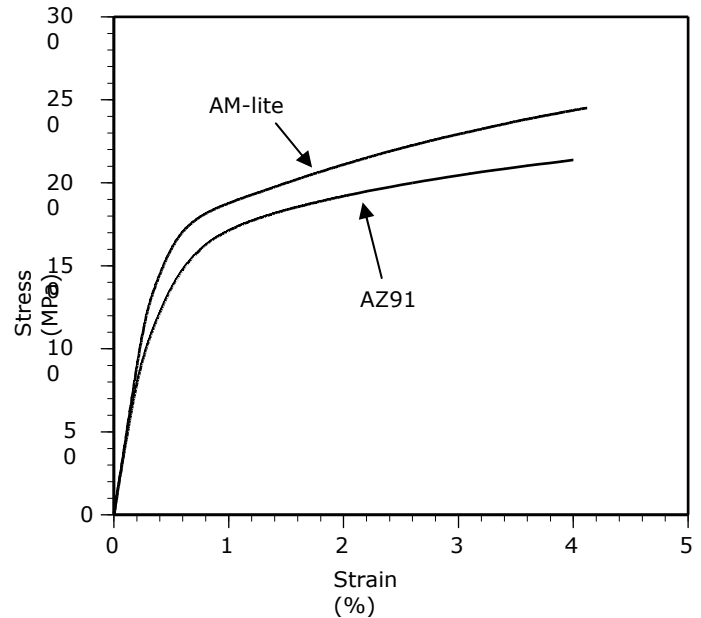


Figure 4. Tensile curves for AM-lite and AZ91D. 2mm thick die cast plates

AM-lite also has better creep strength than AZ91D and zinc alloys. Zinc alloys creep significantly even at room temperature under relatively low loads. As shown in Fig 5, the creep strength of diecast AM-lite at temperatures around 100°C is about 65% greater than AZ91D and 500% greater than a typical zinc diecasting alloy.

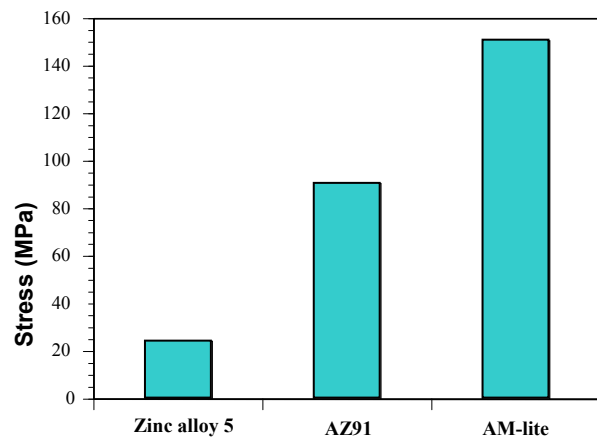


Figure 5. Comparison of creep strength of AM-lite, AZ91D and zinc Alloy 5. Stress required for 0.5% strain after 100hr. at 93°C (200°F)

OXIDATION BEHAVIOUR OF AM-LITE

As stated earlier, AM-lite has a strong resistance to oxidation during solidification. This effect is illustrated in Fig 6 which shows samples of AZ91D and AM-lite that have been allowed to solidify in air in open muffin-cup moulds. Under such circumstances AZ91D oxidizes extensively and eventually burns but AM-lite freezes with a shiny surface.

The oxidation behavior of AM-lite in the molten state and during solidification is responsible for many of the alloy's surface properties. For example, during diecasting, the surface film on a liquid metal influences its flow characteristics and in particular the ability for opposing flows to bond metallurgically during filling of the cavity. The high resistance to oxidation of AM-lite enables such opposing flows to bond effectively during solidification contributing to a much lower defect density. It also allows molten metal to flow smoothly under pressure to fill small interstices created through shrinkage and, in particular, contributes to the smooth shiny as-cast surface of AM-lite die castings whose oxidation resistance persists after casting.

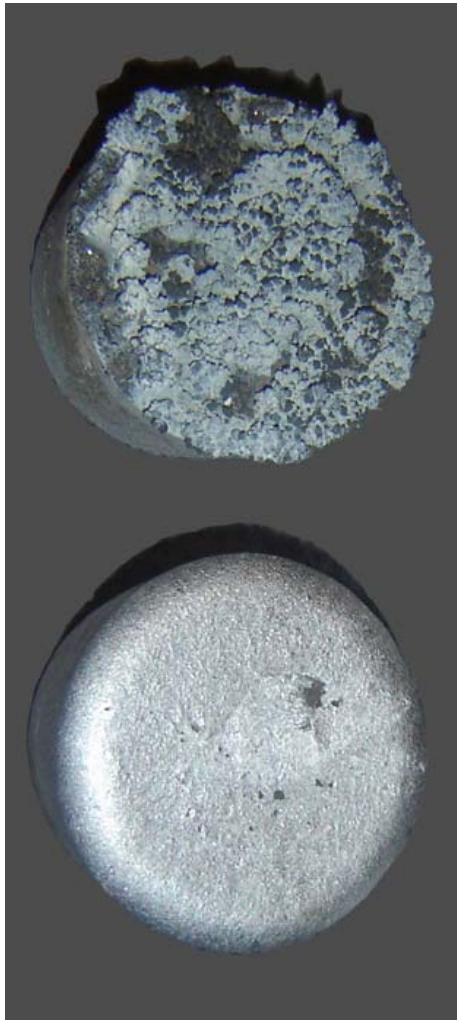


Figure 6. Comparison of oxidation of AZ91D (top) and AM-lite (bottom) solidified in air

The oxidation resistance of AM-lite has other important effects. While use of a cover gas is still required in melt handling, the amount of dross formed is significantly reduced. This may be helped by a furnace temperature that is typically 20°C lower than that for AZ91D. Experience from industrial trials has shown that melt losses due to dross formation are ~75% less for AM-lite than those usually experienced for AZ91D under similar

circumstances. Sludge formation is negligible. Reduced melt losses are an important cost saving for diecasters. Another virtue is that there is a significant reduction of the amount of burning from magnesium adhering to tools when they are removed from the furnace, or when removing dross, leading to less fuming and a cleaner foundry environment.

RECYCLING AM-LITE

Costs associated with recycling of AM-lite are significantly reduced compared to AZ91D. One obvious reason for this is that successful implementation of the AM-lite technology results in a significant reduction in returns due to rejects from the manufacturing process and a higher casting yield due to a reduced volume of runners and overflows. The other reason is that melt losses during remelting of scrap, due to dross formation, are significantly reduced to the extent that there is a strong potential for implementation of in-cell recycling of class 1 scrap and significant reduction of costly external recycling. To date, limited trials have demonstrated the validity of this approach but it has yet to be fully exploited.

WHY AM-HP2?

The sand casting alloy, AM-SC1, was specially developed to provide high temperature properties that are similar to common aluminium alloys, such as A319 and A380, currently used in powertrain applications. Because of the rise in usage of high pressure diecasting for powertrain components it became necessary to develop an alloy with similar properties to AM-SC1 but which could be readily diecast.

The diecastability of a particular alloy determines whether a complex component can be manufactured to specification by HPDC with acceptable reject rates and costs. Because of this, particular attention was paid to obtaining a high level of diecastability during the development of AM-HP2. A special test was developed that could be used on a laboratory die casting machine and which tested all aspects of castability such as flow characteristics, hot cracking, defect levels and surface finish. Die-casting parameters for this diecastability test are presented and compared with those for the standard magnesium die casting alloy, AZ91D. Some critical elevated temperature mechanical properties for AM-HP2 are also presented and compared with the sand-casting alloy, AM-SC1.

DIECASTABILITY ASSESSMENT OF HP2

Castability Die

Laboratory testing of the diecastability of AM-HP2 was carried out on a 250 tonne Toshiba cold chamber die-casting machine with a shot plunger diameter of 50 mm, located at CSIRO Manufacturing & Infrastructure Technology, Melbourne, Australia. A new die was designed in order to severely test the die-casting

performance of the alloy being trialled and provide a quantitative evaluation of high pressure diecastability. This die, shown in Figure 7, was triangular in shape and had oil heating/cooling in both the fixed and moving halves of the die set. A thermocouple was located in the centre of the moving half.

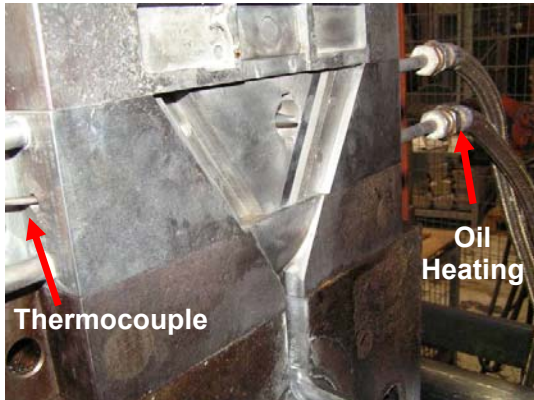


Figure 7: Moving half of the special diecastability test die

The die was designed to give both diverging and converging flow paths. This was achieved by having a fan gate, of dimensions 58 mm x 1 mm, feeding metal from the gate along the flat fixed half (diverging), across the back wall and back towards the gate (converging) (see Figure 8). This flow pattern gives an effective flow length of 130 mm, i.e. twice the height of the casting. The part produced with this die is shown schematically in Figure 9 (a), and a photograph of a casting is shown in Figure 9 (b). The main features of the casting are the large rib and the central boss that are formed along one side of the part. The rib provides a very thick section parallel to the return flow direction which can show up problems of channelling, where metal flows preferentially along such thick sections. The boss is a typical feature of many structural castings and bosses are often difficult to cast with an acceptable level of defects. Sharp corners occur where the boss and the rib meet the casting, so as to maximise the effect of any hot cracking or shrinkage cracking that may occur. Finally, the die has three strips of varying surface finish parallel to the return flow direction: full polish, semi-matte and full matte (EDM finish). These strips provide an indication of the ease with which the alloy will form surfaces of these types.

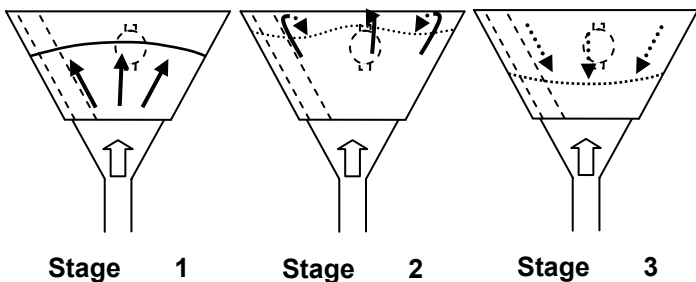


Figure 8: Diagram showing the three stages of flow during filling of the diecastability test die

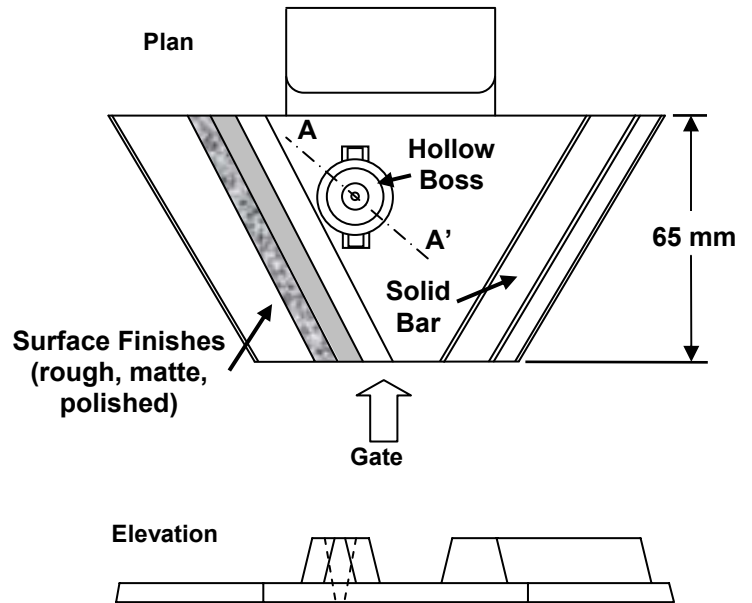


Figure 9: (a) Schematic diagram of the part that is produced with the diecastability test die

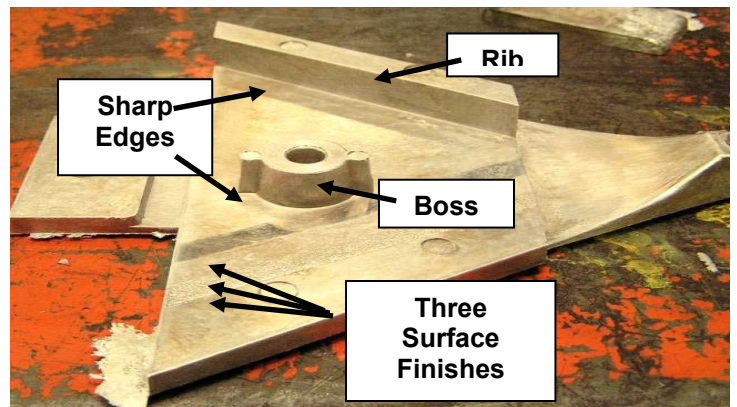


Figure 9:(b) Photograph of casting showing large rib and boss.

Die-Casting Conditions

The die casting conditions were varied over a wide range in order to identify and characterise the best operating window for AM-HP2. The surface finish, as assessed through a simple visual inspection as shown in Figure 10, combined with any evidence of cracking at the sharp corners, were the criteria adopted for defining “good” or “bad” casting conditions. It was found that the diecastability of AM-HP2 and AZ91D was essentially the same, with the relative “widths” of the parameter windows being similar for the two alloys. However, AM-HP2 did have a more rapid change in quality at the edge of the operating window. Under the conditions of the test, AZ91D required a die temperature of 200°C in order to obtain a good surface finish, which agrees with normal production requirements for this alloy. AM-HP2 required both hotter metal and a hotter die and, if insufficient metal was dosed into the shot sleeve leading to a reduction in the molten metal temperature entering the

cavity, then surface quality diminished rapidly. In general, however, the castings made with both AZ91D and AM-HP2 had a high quality surface finish on both faces, which demonstrated that both alloys can flow reasonable distances, although the AZ91D castings did have some surface cold shuts. For both alloys the holding time in the die was also varied so that some idea of the cracking propensity was determined. For AM-HP2 there were no signs of cracking at the sharp edges while for AZ91D there were some signs of hot tearing in one section of the large rib.

Table 3 Best die-casting conditions for cold chamber HPDC of AM-HP2 and AZ91D

Setting	AM-HP2	AZ91D
Melt temperature (°C)	740	700
Slow Speed (m/s)	0.35	0.35
High Speed (m/s)	2.25	2.25
Gate Velocity* (m/s)	76	76
Min Oil Temp (°C)	230	180
Die Temperature (°C)	250	200
Part Cooling Time (s)	8-9	9

$$* \text{ Gate Velocity} = V_{\text{plunger}} \times A_{\text{plunger}} / A_{\text{gate}}$$

The major differences between the two alloys are in the melt and die temperatures. In the particular configuration used in this die casting cell, the length of the transfer tube between the pump and the shot sleeve is long and the melt temperature is in part governed by heat losses occurring over this distance.

CASTING QUALITY

The casting quality was assessed through surface roughness measurements and visual inspection of the internal defect levels in the cast boss (sectioned through A-A' in Figure 9 (a)). The surface roughness comparison was carried out between the surface in contact with the polished strip on the die and the general cast surface, on a single as-cast part, selected at random, for both alloys. The surface roughness profiling was carried out over a line trace length of 5.6 mm. The results for AM-HP2 are shown in Figure 11(a) and, notwithstanding the odd "spikes" in the traces, the two alloys were found to be essentially the same. It should be noted that the comparison in each case was carried out on a single trace from one casting and as such there is no statistical significance in the results. Figure 11(b) demonstrates the quality of the as-cast mirror finish possible with AM-HP2.

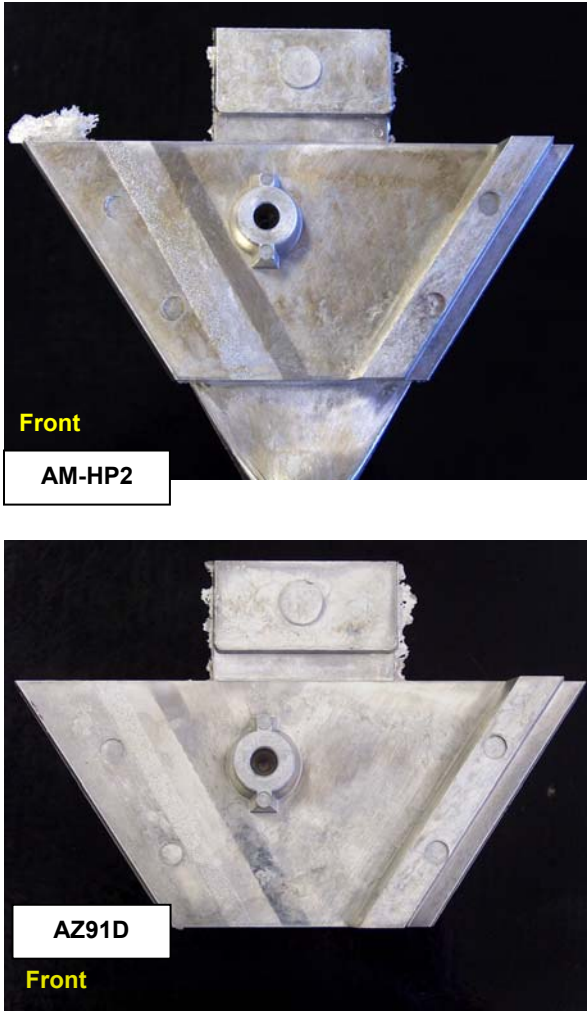
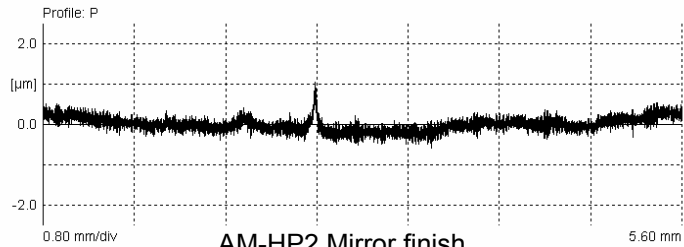
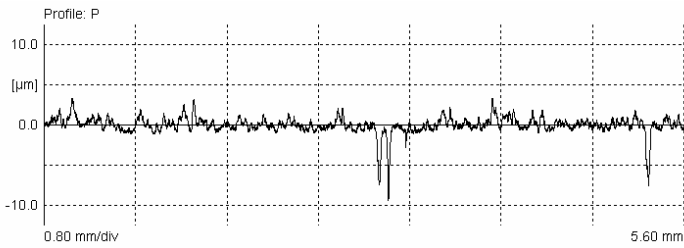


Figure 10 Comparison of surface finish of test castings from AM-HP2 and AZ91D.

On the basis of this assessment, optimum die-casting conditions for this particular die-casting cell and die setup were determined and these are presented for both alloys in Table 3.

R_a 0.56 μm
 R_{max} 10.22 μm
 R_z 4.77 μm

AM-HP2 Cast body finish



AM-HP2 Mirror finish

R_a 0.10 μm
 R_{max} 1.48 μm
 R_z 0.89 μm

Figure 11a: As-cast surface of AM-HP-2 - surface roughness profiles on the body of the casting and the mirror finish surface

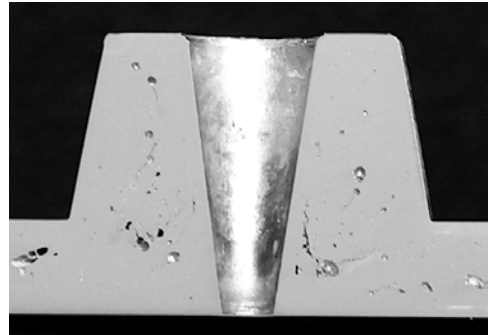


Figure 11b: As-cast surface of AM-HP-2 - an example of the mirror finish achievable on the casting facing the polished section of the die.

The results from a preliminary investigation of the internal structure of the castings are shown in Figure 12, which shows the hollow boss regions of parts cast in AM-HP2 and AZ91D. It can be seen that the porosity in these bosses is similar for both castings and that the

overall level of defects is similar in such sections to other acceptable HPDC alloys.

a)



b)

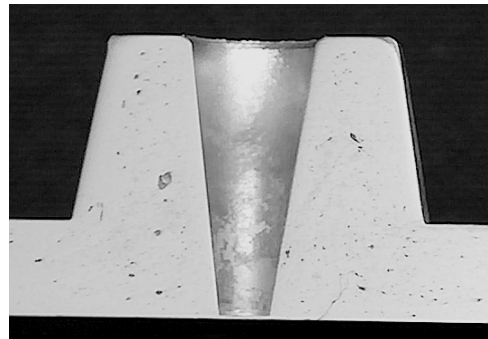


Figure 12: Macroscopic sections through the boss region of castings from (a) AM-HP2 and (b) AZ91D.

ELEVATED TEMPERATURE PERFORMANCE

Having determined the optimum casting conditions for AM-HP2, further die-casting was carried out to produce “dog bone” specimens for tensile strength and tensile creep measurements and a solid boss for bolt load retention measurements. Figure 13(a) shows the dimensions of the tensile test pieces, together with an indication of the relative area of the in-gate compared to the diameter of the casting. The shape of these specimens is such that an alloy susceptible to hot tearing would show internal cracking within the gauge length. Figure 13(b) is a low magnification image of the material within the gauge length of AM-HP2 and it is clear that internal cracking was not a problem with this material.

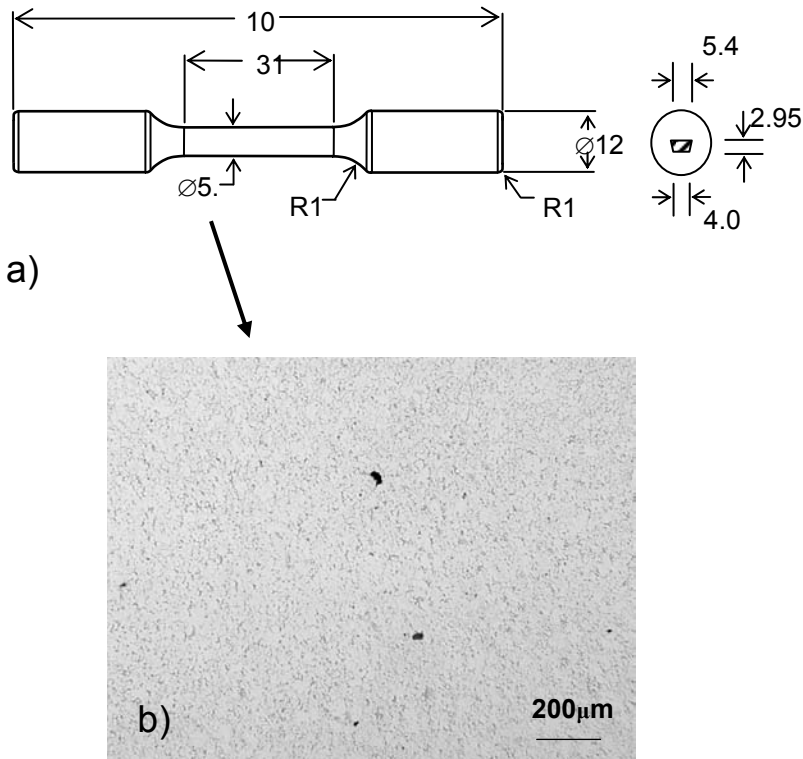


Figure 13: (a) Specimen geometry for both tensile strength and creep measurements (all dimensions in mm) and (b) low magnification image of the gauge length showing only a few small pores and no cracking

TENSILE PROPERTIES

The sand-casting alloy, AM-SC1, was designed for engine block applications, with strength specifications being supplied by engine designers⁶. The critical strength property was the tensile yield strength (TYS), both the magnitude at room temperature and the stability of TYS up to, and including, 177°C. The tensile properties of AM-HP2 have been determined at both of these temperatures (Figure 14). The yield strength of as-cast AM-HP2 is higher than that of fully T6 heat treated AM-SC1, and the thermal stability is slightly better with the decline of the yield strength at 177°C being less than 7%. The ultimate tensile strength (UTS), however, is lower in the high pressure die cast material. This is due to a lower ductility of AM-HP2 compared with fully heat treated sand-cast AM-SC1. In terms of design criteria for powertrain components, it is yield strength that is important and not ultimate strength.

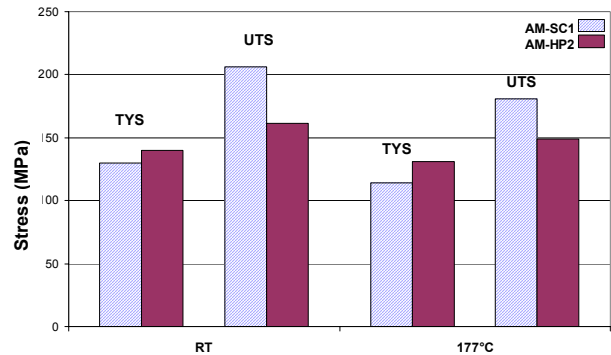


Figure 14: Tensile properties of die-cast AM-HP2 and T6 heat treated sand-cast AM-SC1

TENSILE CREEP BEHAVIOUR

The creep behavior of AM-HP2 has been determined over a wide range of stresses at temperatures between 150°C and 200°C. Here results are shown for a load of 90 MPa at 177°C, and a comparison made with AM-SC1. This particular test condition was chosen after consultation with engine designers. HPDC tends to produce a higher degree of structural variability than sand-casting, resulting in a banding in the mechanical property behaviour and thus it is usually necessary to show the spread of results for a particular property. The creep behaviour, which is shown in Figure 15, is no exception.

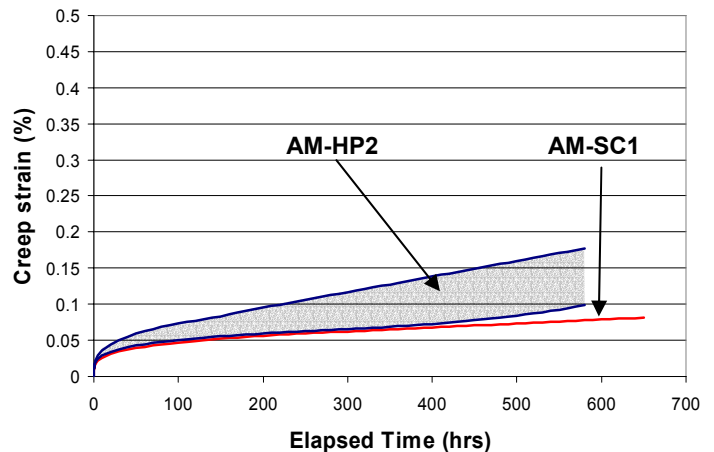


Figure 15: Creep curves for AM-HP2 and AM-SC1 at 177°C and 90 MPa.

The lower bound of the creep behaviour of AM-HP2 at 177°C and 90 MPa is very similar to that for AM-SC1, and the spread of results is within acceptable limits for elevated temperature powertrain applications – the stress to produce 0.1% creep strain after 100 hours at 177°C is well in excess of 90 MPa.

It should be pointed out that the high temperature creep properties of AM-SC1 have been shown to be as good

as common aluminium engine block alloys such as A380 and A319.^{3,4}

BOLT LOAD RETENTION (BLR) BEHAVIOUR

It is important for powertrain applications to consider the relaxation that may occur under compressive loading – in particular at bolts. This can be simulated in a bolt load retention test. The test method involves applying an initial load (11 kN) through an assembly consisting of two identical bosses made of the test material and a high strength bolt instrumented with strain gauges. The change in load over 100 hours at an elevated temperature (177°C) is measured continuously. Figure 16(a) is a schematic of the HPDC boss, which is drilled out with an 8 mm hole and cut to 15mm in length before testing. The significant loads, in terms of defining the BLR behavior, include the initial load at ambient temperature and the load at the completion of the test after returning to ambient conditions. The ratio of these two values gives the load retention at room temperature. Similarly, the ratio of the initial load at the test temperature, T, to the relaxed load after 100 hours at temperature gives the load retention at T. These two loads are also those used to determine the creep relaxation of the material at temperature.

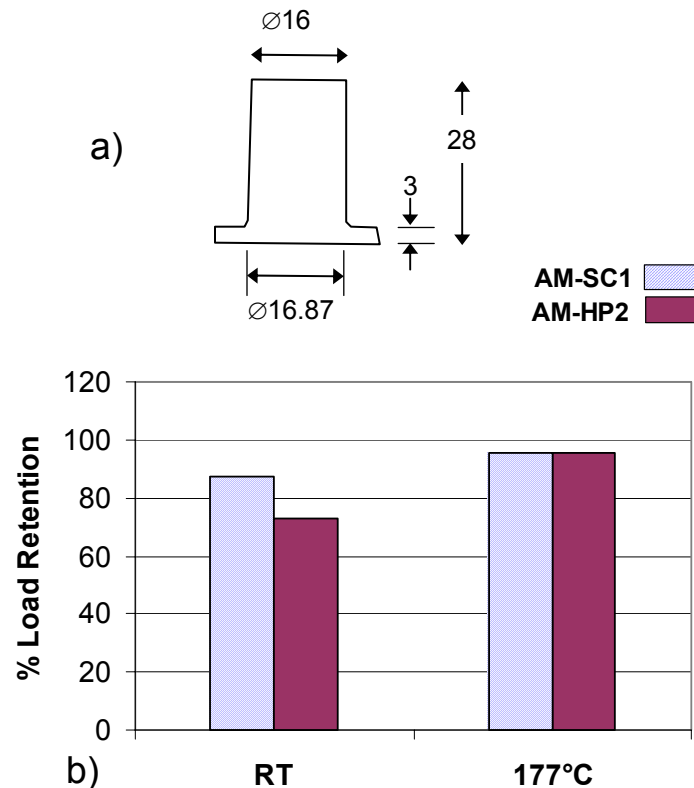


Figure 16: (a) Geometry of the cast bolt load retention sample and (b) retention behaviour after exposure at 177°C and a load of 11 kN. The data for 177°C is the BLR measured at the test temperature and the data for RT is the BLR measured after return to room temperature.

The BLR at the elevated temperature of 177°C has the same high value of 92% for both AM-SC1 and AM-HP2. The creep relaxation of the alloys is, clearly, very low under these conditions. The room temperature behaviour is somewhat better for AM-SC1 than AM-HP2. This is an indication of the overall bolt load retention behaviour, and the difference observed here between the two alloys can most readily be explained as being possibly due to the compressive yield strength of AM-SC1 being higher than that of AM-HP2. This has not been confirmed by direct measurement.

CONCLUSION

AM-lite is an exciting new addition to the range of magnesium alloys available to diecasters. The alloy's attributes are such that it competes very favorably in a wide range of applications with the existing magnesium general purpose diecasting alloy (AZ91D), zinc diecasting alloys, aluminum alloys and plastics. Trials with diecasters and end-users have demonstrated that the alloy fills a much sought after need for a highly diecastable, light weight alloy capable of high quality surface finishing. As summarised in Table 4, the alloy not only achieves these technical advantages but it can also bring about considerable cost savings in comparison to its competitors.

AM-lite is particularly suited for decoratively finished products such as consumer electronics, automotive decorative trim, and domestic and commercial fittings. First commercial sales of the alloy have commenced and it is expected that in the coming year usage of the alloy will grow considerably as the alloy's benefits become more widely known through increased trialing and application to commercial products.

Table 4. Summary of key benefits of AM-lite

Attribute	AM-lite	AZ91D	Zn Alloys 3 & 5
Cost			
Diecastings			
Surface finished	60%	90%	100%
	75%	150%	100%
Electroplating	Yes (readily)	Yes but with difficulty	Yes (readily)
Diecastability	Very good	Fair	Very good
As-cast surface	Very good	Poor	Very good
Surface coating	No filling Reduced buffing Minimised blisters	Filling required Extensive buffing Blister defects	Blister defects
Density	2.0 g/cm ³	1.8 g/cm ³	6.6 g/cm ³
Design strength	100 MPa	40 MPa	15 MPa
Melt loss	~1%	~4%	~1.5%
Recycling	ok	costly	ok

As powertrain applications advance it is critical to not only meet the operational performance criteria but to

also be able to manufacture the part in a cost effective manner. The combined diecastability and high temperature performance of AM-HP2 can be described in relation to other creep resistant magnesium alloys with reference to a castability/creep performance space diagram suggested by Aghion et al.⁸ and shown in Figure 17. This diagram describes the relative positions of various alloys with respect to their ease of casting and their elevated temperature performance. Clearly, the top right hand corner is the preferred position for HPDC powertrain components. With the exception of AM-HP2 the relative positions of various alloys in this diagram are those suggested by Aghion et al. AM-HP2 has been shown to have a diecastability that is comparable to AZ91D and elevated temperature creep properties that are superior to the other alloys and which meet performance demands for one of the most demanding of powertrain applications, the engine crankcase.

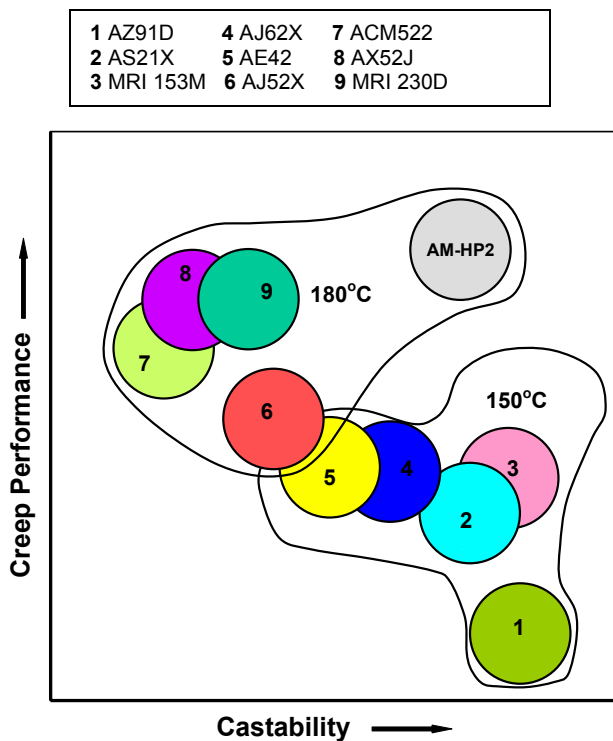


Figure 17: Schematic representation of the castability/creep performance space for current HPDC magnesium alloys (after Aghion⁸). The groupings indicate that the alloys contained within a bubble are suitable for use up to a working temperature of either 150°C or 180°C respectively.

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