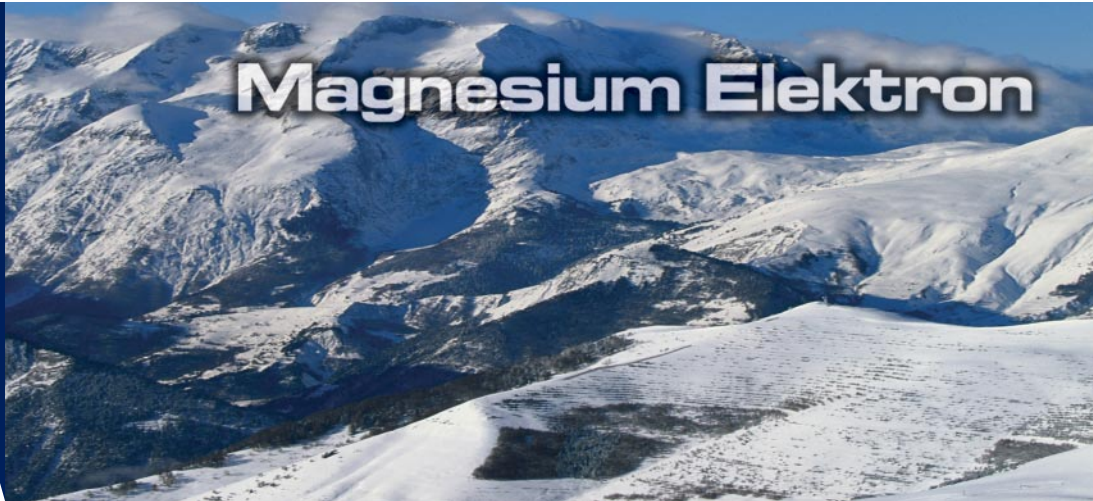


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Magnesium Recycling Brief



$$\sigma_y = \sigma_o + K_y d^{-1/2} !$$

Or, Why the Die Casting Process Favours Magnesium



The formula above will be instantly recognisable to most engineering graduates. Essentially, it explains the interdependence of the (yield) strength of a metal and the grain size from which the metal is composed.

The formula, when displayed graphically, is easily understood; see Fig 1; whereby σ is the basic strength of the metal under consideration, K is a constant which is different for each metal, and d is the diameter of the grains. In effect, ' $K_y d^{-1/2}$ ' is the additional strength that can be bestowed on a metal by reducing the grain size. It can be seen that small changes in the grain size of a metal will lead to a significant change in the strength.

This relationship was first reported by Messrs Hall and Petch, and is still referred to as the 'Hall-Petch' equation.

By understanding the Hall-Petch equation and the nature of the High Pressure Die-Casting (HPDC) process it suddenly becomes very clear why there has been such a dramatic growth in the use of magnesium die-castings in the automotive industry.

In the die-casting process, molten metal is injected at high speed into the steel die cavity. The atomisation of the metal stream as it passes through the gate area and the rapid cooling of the atomised metal as it solidifies in the cavity gives rise to a very fine 'grain refined' structure in the casting, which has significantly improved strength.

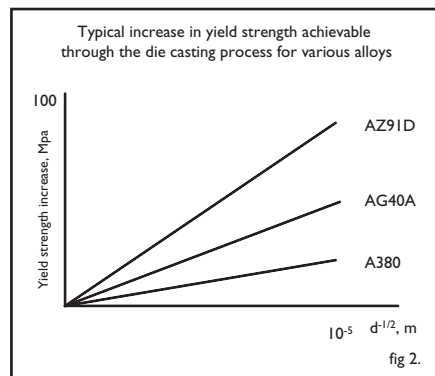
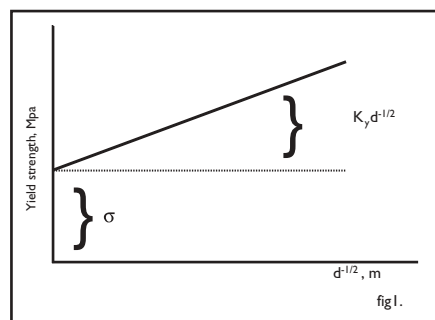
This 'grain refining' will occur in all of the die-casting alloys. However, magnesium has two significant benefits over zinc and aluminium.

Firstly, magnesium has a lower heat capacity per unit volume (the amount of energy stored in a material when its temperature is raised) than zinc or aluminium. The liquid magnesium is therefore more rapidly chilled on contact with the relatively cool steel die, resulting in a

finer grain size and therefore higher degree of strengthening than is achievable in the other metals.

Secondly the constant 'K' is higher in magnesium than for both zinc and aluminium. The significance for magnesium here is that a given reduction in grain size will import a greater amount of strengthening into a magnesium alloy than would be achievable in zinc or aluminium; see Fig 2.

It is the complementary joining of magnesium's basic physical properties with the characteristics of the HPDC process which has ensured magnesium's rapid ascension as one of the materials of choice for automotive die-castings.



Profits?

Although the volume of sales in the UK car market is about the same this year as it was last year, there are some question marks over how well the automobile industry is doing financially. Overall, Western European car sales are in decline, meaning more manufacturers are being forced to offer good deals to the customer in order to make sales. This, coupled with the euro's strength against both the dollar and sterling, is making a big impact on the automotive industry's operating profits.

Leaving aside the profitable parts business (approximately equivalent to an additional €1 billion operating profit for each European manufacturer), the 2003 second quarter operating profits posted by many of the big manufacturers paint a seemingly bleak picture.

At the time of writing, Fiat have not yet

published their results, but their struggle is well publicised. The Chrysler section of the DaimlerChrysler partnership is also battling hard against unfavourable market conditions, leading to Chrysler reporting an operating loss of €948 million, equating to a 62% drop (to €641 million) in second quarter operating profits for DaimlerChrysler. Ford Europe reported a \$525 million loss, GM Europe a \$3 million loss (although this is a significant improvement over GM's previous year's figure of \$115 million loss). Volkswagen reported a 46% drop to €616 million and Peugeot-Citroën reported a 12% drop to €869 million. However, Renault has bucked the trend by improving net profits by 30%, up from €894 million to €1.18 billion, with help from the 44% stake in Nissan. BMW had not published their results at the time of writing.

Magnesium Elektron Acquires Magnesium Spectrulite Assets

MANCHESTER: 12th August 2003: Luxfer announced today the acquisition of the magnesium assets of Spectrulite Consortium Inc. (SCI) based in Madison, Illinois and Findlay, Ohio.

SCI is a manufacturer of magnesium alloy billet, slab, rolled products and the world's only fully integrated producer of magnesium photo engraving plates.

Brian Purves, Chief Executive of Luxfer Group commented, "The acquisition of SCI's magnesium assets is another important step in our strategy of expanding our business internationally and fills a gap in the range of magnesium products offered by our Magnesium Division."

Chris Dagger, Managing Director of Magnesium Elektron added "The combination

of SCI's technical skills in rolled products, supplemented by Magnesium Elektron's experience in advanced magnesium alloys and manufacturing excellence, backed by the financial strength of the Luxfer Group, will create a very strong business. We are particularly excited by the magnesium graphic art market and the long term growth potential for magnesium alloy sheet."

"The acquisition of these assets will enable Magnesium Elektron to develop a range of rolled products that will extend the use of magnesium into a wide range of new applications, exploiting the inherent light-weight and other advantages of magnesium."

The operation will trade as MAGNESIUM ELEKTRON WROUGHT PRODUCTS and MAGNESIUM ELEKTRON GRAPHIC ART PRODUCTS.

Looking back...

Magnesium Elektron is heavily involved in the development of magnesium alloys, and in the 1950's was investigating rare-earth containing alloys. The MSR alloys, or QE22 for the U.S designation, were groundbreaking alloys combining high yield strength and good castability. In addition, the alloys possessed good creep properties and excellent fatigue strength at elevated temperatures. Never before had a magnesium alloy system been based on a magnesium-didymium-silver-zirconium alloying combination. (Where didymium is a

minimum 80% Neodymium mischmetal)

This group of alloys was created in the search for very high strength alloys to meet the requirements of the aircraft engine designers. Usually, some sacrifice in castability had been demanded when specifying high strength alloys. With the new MSR alloys, this sacrifice had been minimised, resulting in an alloy appropriate for use in high quality, high strength applications in aircraft engines. MSRB and QE22 are still in use today.



Do You Value Your Magnesium Dross & Sludge?

Maximising the value of the products and by-products of the die casting process is essential in today's competitive environment. Reduction of the formation of dross & sludge, followed by the maximisation of their value are two key elements in maintaining a cost efficient process. Dross is formed from the surface oxidation of the liquid magnesium in the crucible. Sludge is formed at the bottom of the crucible, mostly containing iron-manganese-aluminium(Fe-Mn-Al) intermetallics, as well as oxides settling down from the surface.

Reduction of dross

A well sealed crucible, coupled with an accurately controlled and monitored shield gas system will help reduce surface oxidation. The distribution of the gas over the melt surface is also critical.

- Is the shield gas stronger around the area where the ingots are introduced to the melt, to offset the dilution effect of the crucible access hatch being opened?
- Is the hatch of a suitable size, and well sealed? Allowing air (oxygen) to access to the melt surface will only increase dross formation.
- Is the shape of your crucible efficient, in terms of only creating a small melt surface area for the volume of metal contained?
- Are the magnesium ingots free from oxides?

Reduction of sludge

Due to the differences in solubility of manganese in the magnesium at different temperatures, thermal cycling within the crucible is a major factor in the production of sludge. If the temperature within the crucible is unstable, the manganese will react with the aluminium and the iron to form intermetallic precipitates. These extremely hard compounds then fall to the bottom of the crucible, but can be accidentally injected into the part.

- Does your furnace feature a high level of control, with a good distribution of heating elements/burners giving an even temperature around the complete crucible?

- Is your crucible an appropriate shape? Crucible shape is also an important factor in the reduction of thermal cycling; certain shapes lead to undesirable cool spots and temperature gradients across the melt.
- Are your ingots sufficiently pre-heated to reduce cold spots where they are added to the crucible?

A high quality magnesium should be used, such as ELEKTRON ingot, where the manganese levels are specifically kept at the low end of the allowable ASTM range.

However, there will always be some dross & sludge formed in the magnesium die casting process. To extract the maximum value out of these by-products, it is necessary to find another industrial process which uses these by-products as feedstock. Should this prove difficult, the dross can either be returned for recycling, or disposed of in an environmentally approved manner.

As environmentally approved disposal costs rise, it is of interest to the die-caster to maximise the recyclability of the drosses & sludges. As the compositions of drosses and sludges vary considerably with each die-caster, the recyclability of these by-products also varies. However, there are some basic actions the die-caster can take to increase the amount of recoverable magnesium.

The surface dross is usually the more valuable of the two by-products, as more useful magnesium can be recovered from it. Ideally, the die-caster should store the dross and the sludge separately, as the sludge contaminates the dross, reducing its value.

Dross or sludge should be placed in a small mild steel bucket, and a thick metal lid placed on top, pressing down on the by-product. The lid can then act as a heat sink to stop the burning/oxidation of the magnesium metal within. No sand or flux should be spread onto the dross or sludge. The dross & sludge should then be stored in a dry area.

These fairly simple actions can have a great impact on the recyclability of these by-products, and hence on their values. A die-caster should see a useful impact on his profitability if he can reduce the formation of these by-products to an absolute minimum.



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A BALANCING ACT

In addition to overcoming the increasing environmental regulations that the automotive manufacturers must consider, there is also the issue of creating a product that the customer actually wants to buy.

Against a background of stringent environmental regulations, automotive manufacturers are constantly striving to improve vehicle dynamics in a bid to create a product that rides more smoothly, steers more accurately, accelerates more quickly or remains more stable under braking. The dynamic abilities of any car are being independently benchmarked against the current class leaders, and the results widely distributed to the customers.

The remarkable success of the Ford Focus, a single platform vehicle with excellent dynamics, has produced sales volumes that can be compared to many multi-platform vehicles. Arguably this has inspired the more quality orientated VW Golf Mk4 to evolve into a sharp handling, quality VW Golf Mk5. Dynamics sell.

In addition to technological solutions, weight reduction is a major positive element in the quest to further refine the dynamic qualities of a vehicle. Magnesium, a strong, light material appears to be an ideal solution. However, as cars become ever lighter, they are also becoming more unbalanced. The powertrain still remains as a concentrated weight, normally over the front axle. Ideally, for a front wheel drive car, a maximum 60% of the weight of the vehicle should be over the front axle. A 50%:50% weight distribution is ideal.

Removing weight from the front of the vehicle becomes critical. The value, in terms of customer benefit, of reducing the weight of the front of the car is all round improved dynamics, coupled with better tyre life, improved emissions and a safer car.

As issues with magnesium such as corrosion resistance, lack of technical data and insufficient physical properties are increasingly being resolved, you can expect to see some exciting developments in the use of magnesium within the front sections of vehicles.

Magnesium Conferences in 2003/2004

11th Magnesium Automotive and End User Seminar
September 25-26, 2003
73430 Aalen, Germany

Light Metals Technology
September 18-20, 2003
Brisbane, Australia

6th International Conference on Magnesium Alloys and their Applications
November 18-20, 2003
Wolfsburg, Germany

5th Recycling Workshop
November 25-26, 2003
Anthering, Austria

Euroguss 2004
March 2-4, 2004
Nürnberg, Germany

IMA 61st Annual World Magnesium Conference
May 9-11, 2004
New Orleans, USA

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