



# Improving performance & reducing weight with *T-Mag* magnesium castings

Geoffrey de Looze

CSIRO Process Science and Engineering

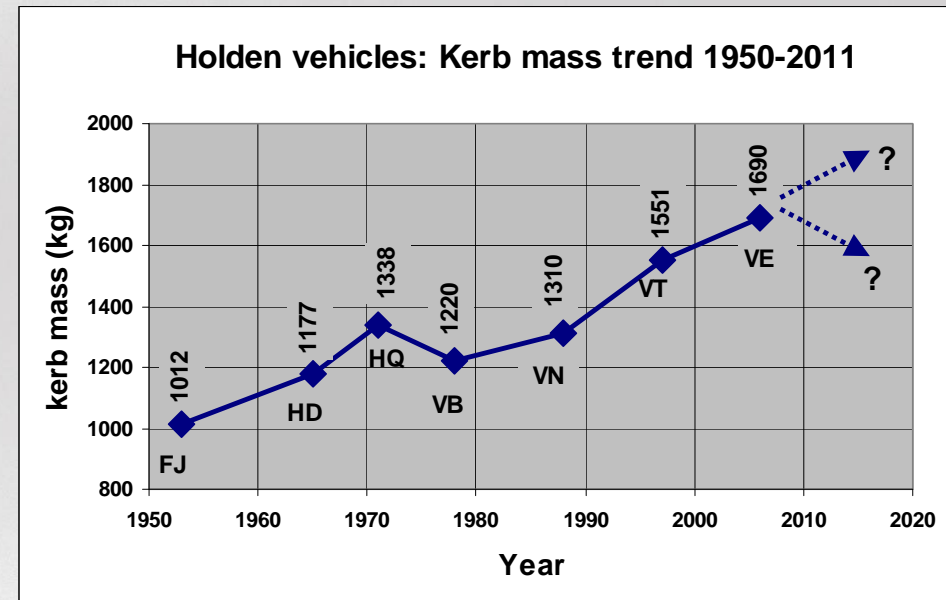
Clayton, Victoria





# *The need for lighter materials*

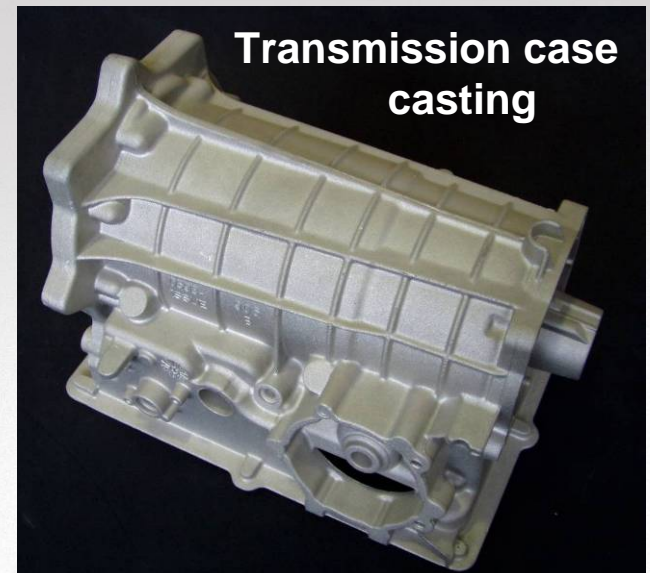
- Aluminium has displaced steels & irons in engines, transmission cases, suspension components & structural items saving weight
- These weight savings have been allocated to vehicle comfort features and safety performance: -kerb mass has not reduced
- A progression to magnesium - the lightest structural metal - is a (logical?) tool to arrest this trend.





## *Why castings?*

- Casting is often the most economical method
- It is often the only economically viable process e.g. engine cylinder heads, engine blocks, transmission cases.
- ‘Semi-permanent mould’ casting processes – combine the economy of re-useable dies, with the ‘hollow part’ shape-flexibility of sand cores



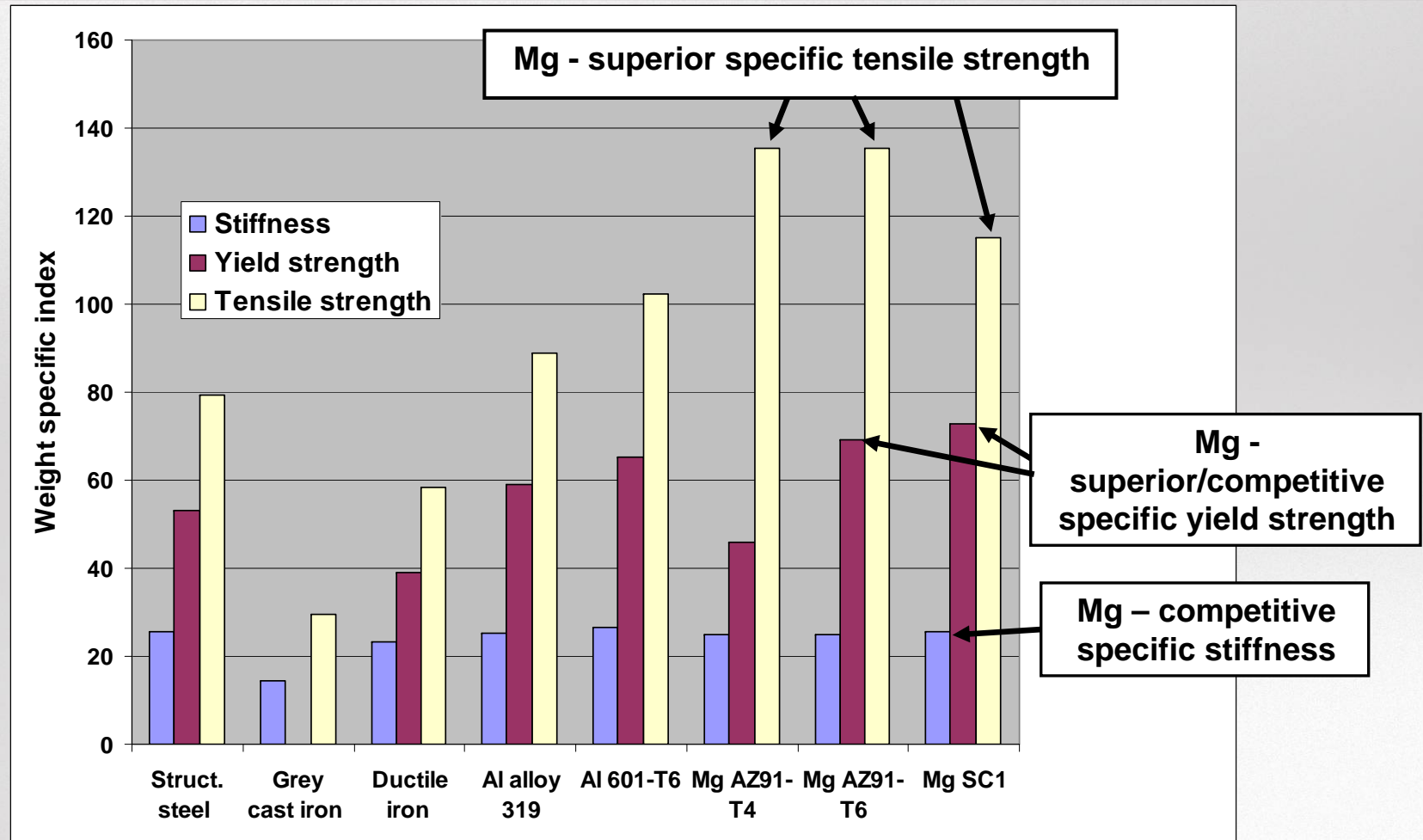


# Cast magnesium vs. other materials

Cast material	Density (kg/m <sup>3</sup> )	Typ. Elongation (%)	Hardness (HB)	Stiffness (GPa)	Yield strength (MPa)	Tensile strength (MPa)
Structural carbon steel	7800	20	220	200	415	620
Grey cast iron	7000	0.6	210	100	-	207
Ductile iron	7100	18	170	165	276	414
Al alloy 319	2790	2	95	71	165	248
Al alloy 601-T6	2690	7	80	71	175	275
Magnesium alloy AZ91-T4	1810	13	55	45	83	245
Magnesium alloy AZ91 T6	1810	5	66	45	125	245
Magnesium alloy SC-1	1789	3.7	-	46	130	206



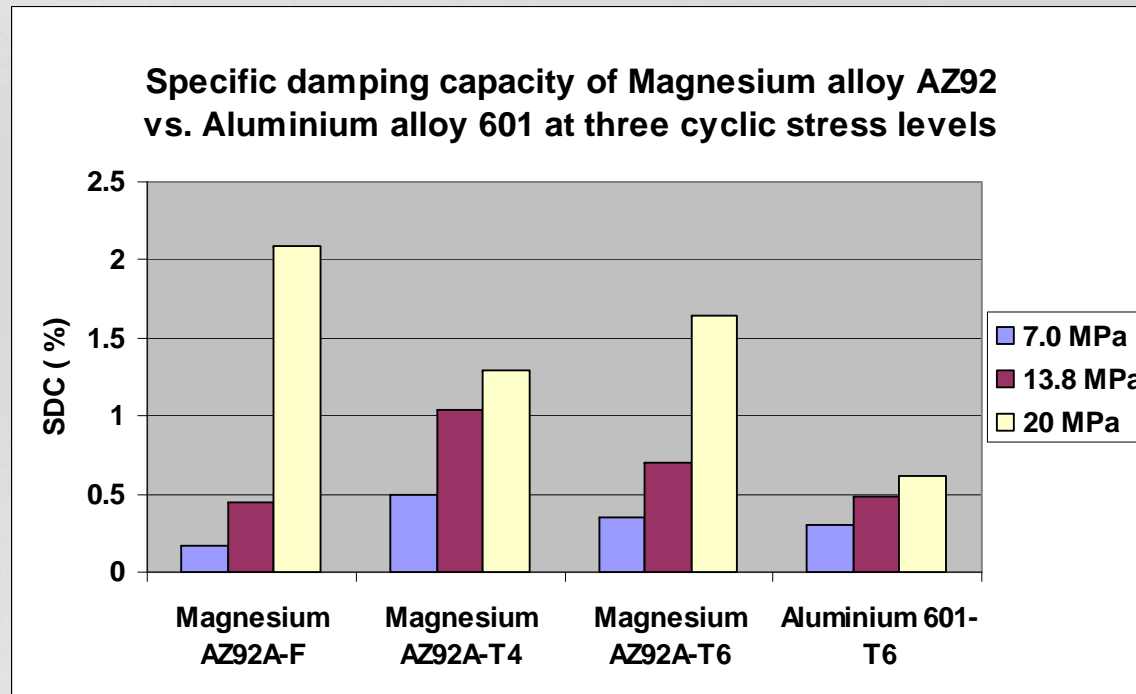
# Comparisons of weight specific properties





# Damping properties

- **Specific Damping Capacity (SDC)** describes the ratio of energy absorbed during a stress cycle to the strain energy stored in the material
- A high SDC is desirable for vibration reduction e.g. steering wheels and NVH management e.g. engine mounts
- Magnesium alloys have a higher SDC than aluminium alloys





# Why use the T-Mag\* casting process?

*Economically* eliminates problems with existing processes when casting magnesium

## **Gravity die casting:**

Metal oxidation, poor temperature control, low poured yield

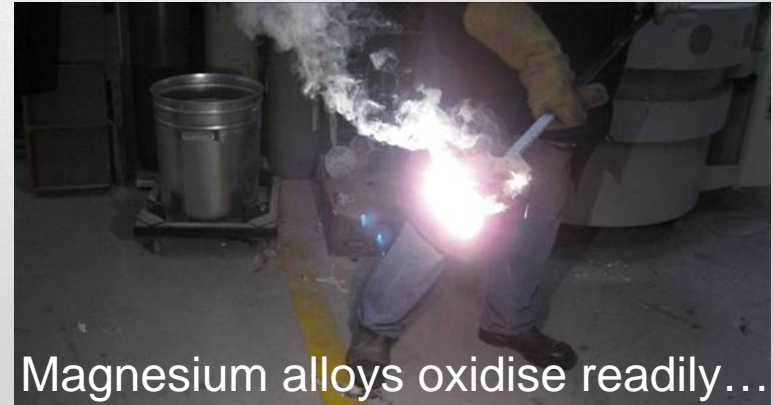
## **Low Pressure Die Casting:**

Difficult cover gas application

## **High pressure die casting:**

Castings not heat-treatable, no hollow castings, capital intensive - needs high production volumes

\*Patent pending



Magnesium alloys oxidise readily...

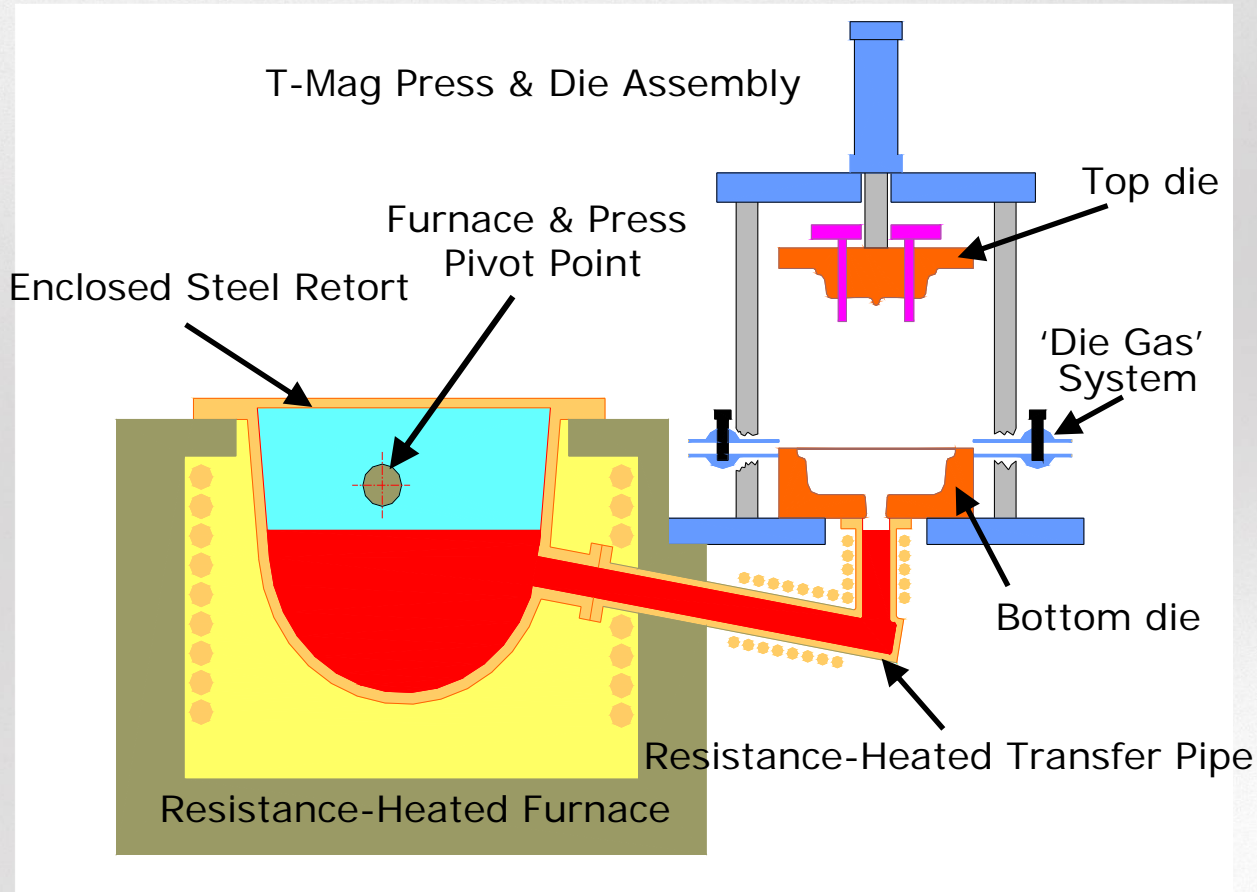
... these oxide particles give the casting poor properties...



...or even black castings!



# *T-Mag equipment layout*



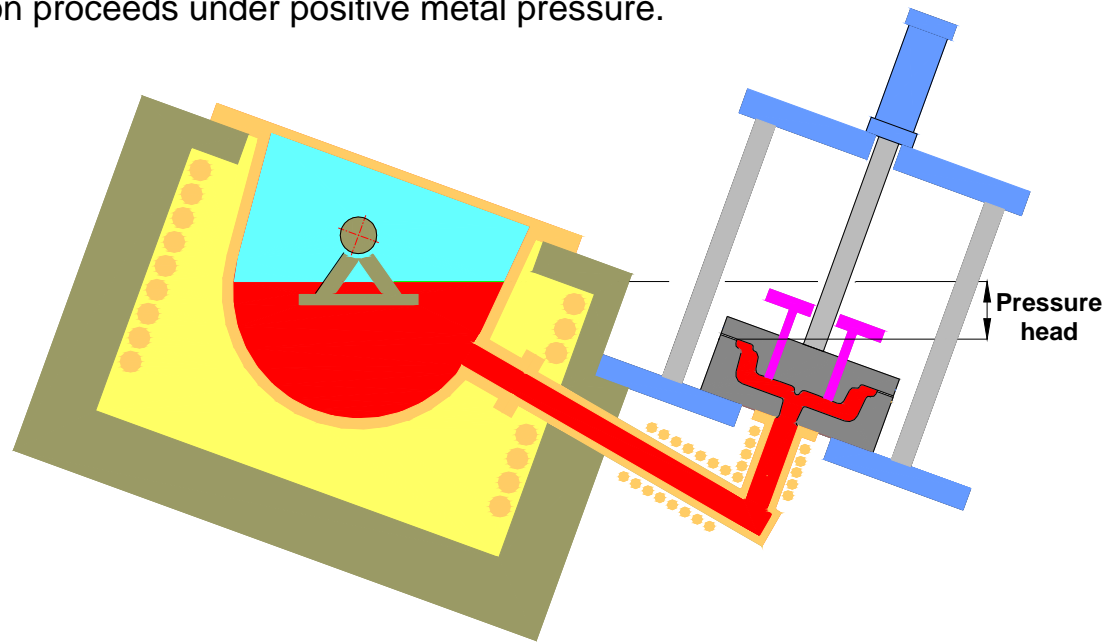


# *T-Mag Pouring method*

## **Casting Position**

Die & furnace tilts until cavity is full and pressure head is established.

Solidification proceeds under positive metal pressure.





# T-Mag castings, a casting cycle

**Movie:**  
**One cycle of racing kart rear wheel production**



**10" wheel casting & wheels,  
Tensile test piece**



**Motorcycle engine block**



**Front and rear racing kart  
wheels and castings**



**Light truck suspension arm castings**



## *Case Study: A new T-Mag magnesium engine mount*

Starting point is the existing aluminium alloy high pressure die cast (HPDC) engine mount.



A new design must satisfy:

- The geometric constraints of engine & chassis, plus clearances needed during assembly.
- 29 specified loading cases.
- Minimum 1<sup>st</sup> mode natural resonance frequency of 1000 Hz.

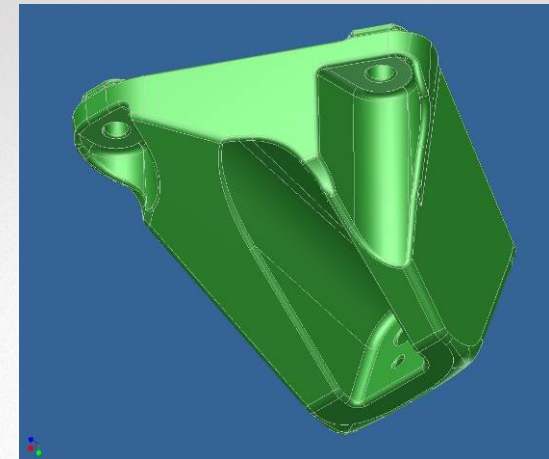
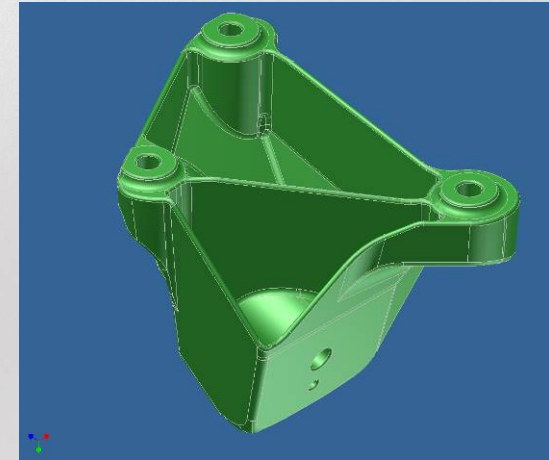




# *Engine mount design for the T-Mag process*

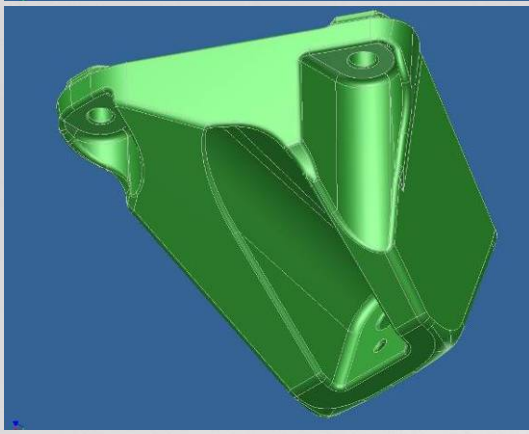
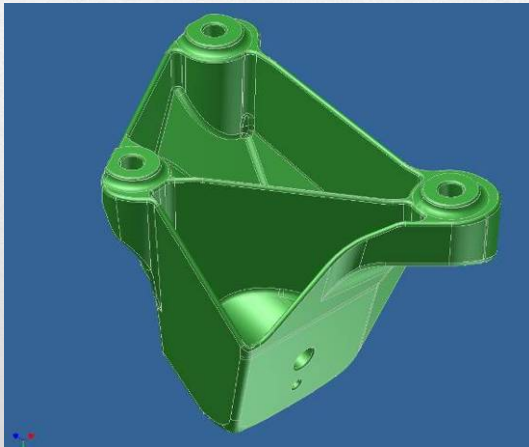
Parallel and iterative strands of analysis

- Component *mechanical design* via finite element analysis (FEA)
- Component *castability* analysis via MAGMAsoft
- *Tooling design* to suit the T-Mag process accommodating the other requirements.





# The T-Mag magnesium vs. HPDC Al designs

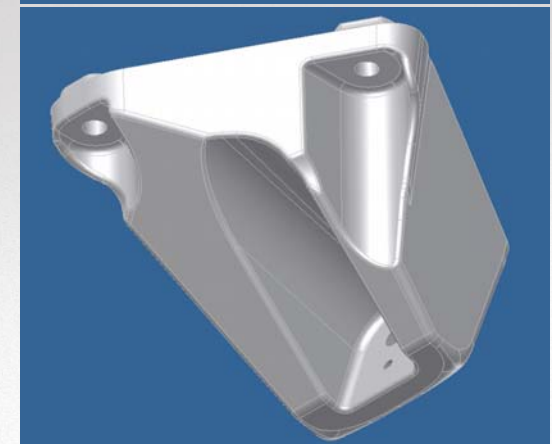
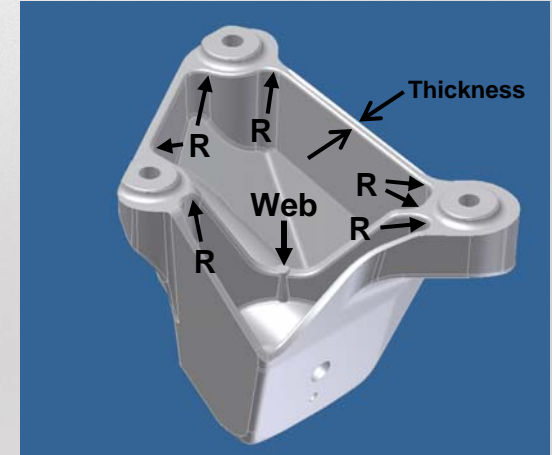


Current HPDC aluminium.

Weight = 725 g

The design changes made accommodated both the material and the process

- *Minimum necessary change* approach was adopted
- General wall thickness increased 1.45 times
- Lowered transverse rib
- Fillet radii increased



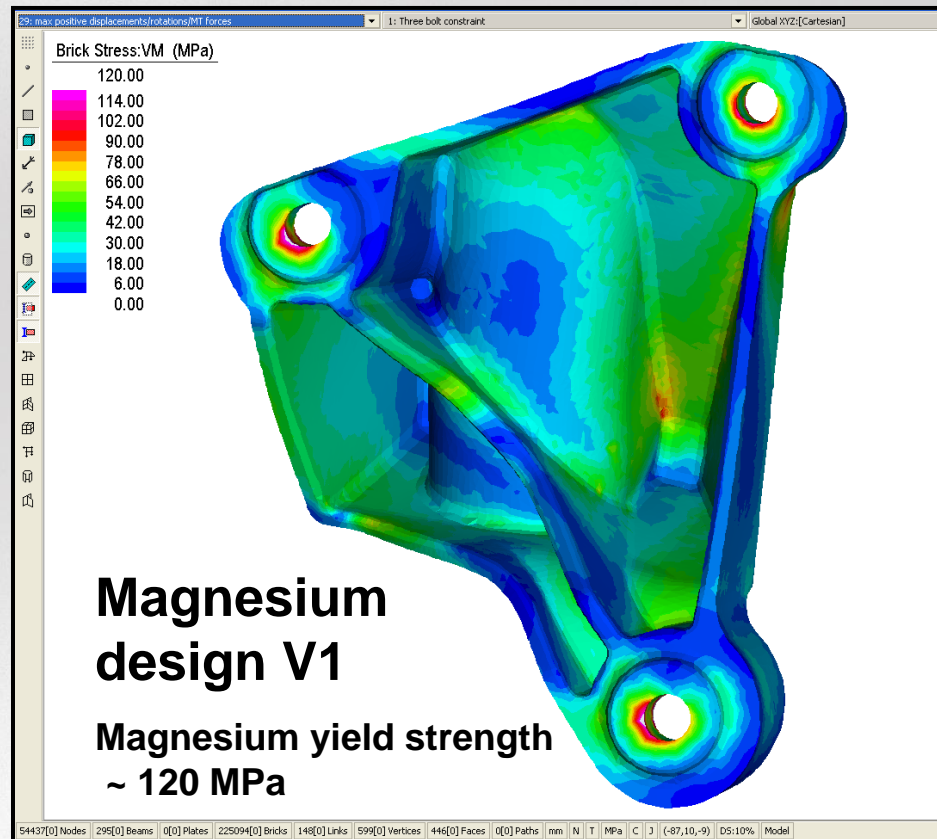
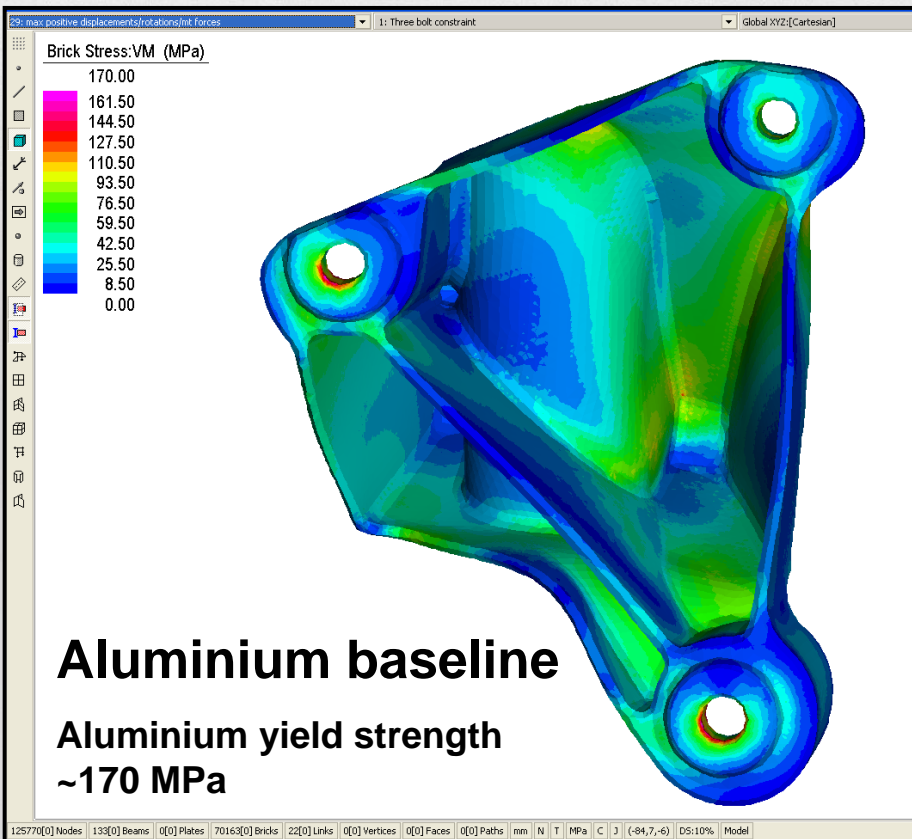
Proposed T-Mag Mg Design.

Weight = 611 g



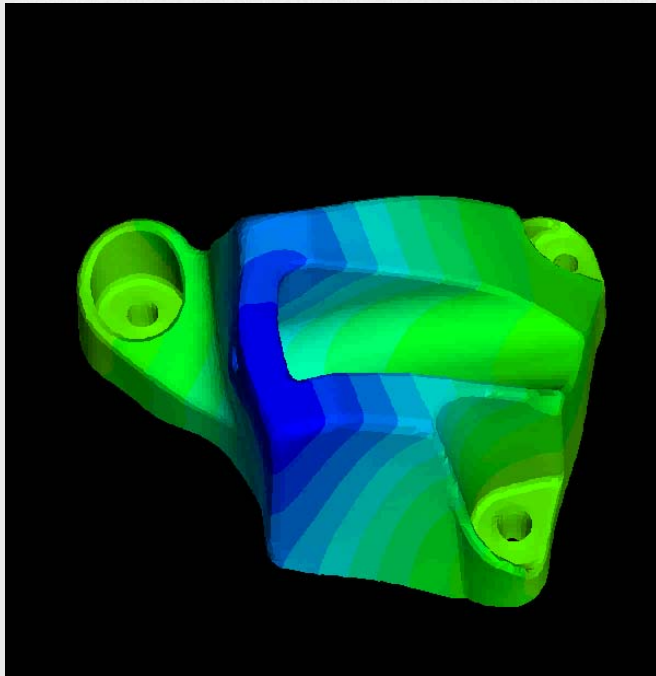
# FEA analysis example - a severe load case

**Load case no. 29: 'Maximum Positive/Rotations/MT Forces'**  
[Fx = -14.744kN Fy = -4.179 kN Fz = -7.603Kn]





# *FEA analysis - 1<sup>st</sup> mode resonance analysis*

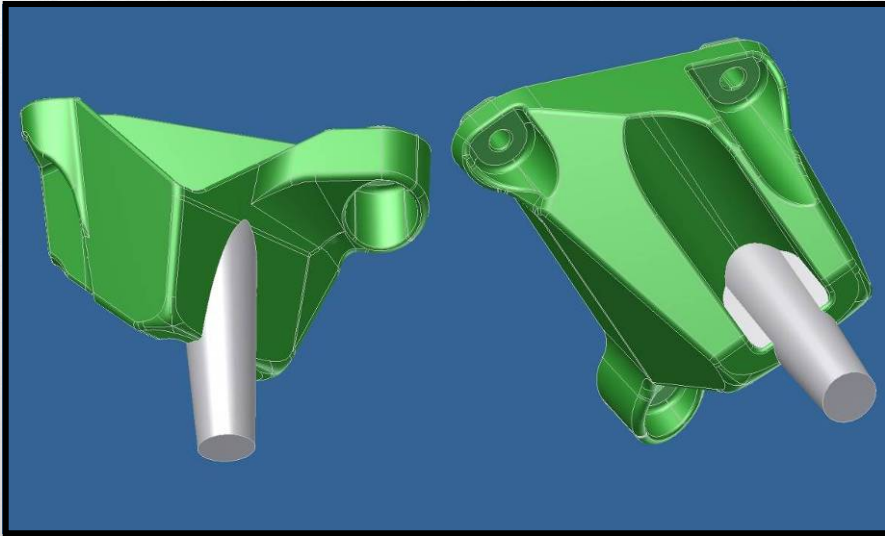


Animation illustrating  
mode 1 resonance  
(displacements exaggerated)

- **Objective is to significantly improve on the performance of the baseline aluminium component (~1240 Hz)**
- **Magnesium design Version 3 has matched, but not exceeded, this figure.**
- **Development of the magnesium design continues with a targeted 1<sup>st</sup> mode frequency of 1300 Hz.**

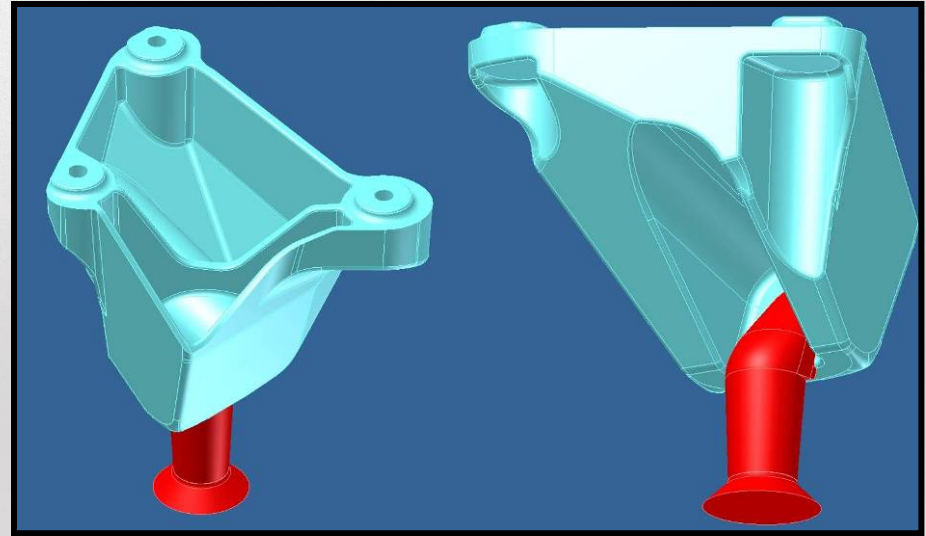


# *Use of casting simulation - runner design*



## Option A – with natural ‘draw’

- Simple 2-piece die (no sliding core needed)
- More extensive fettling
- Possible solidification difficulties

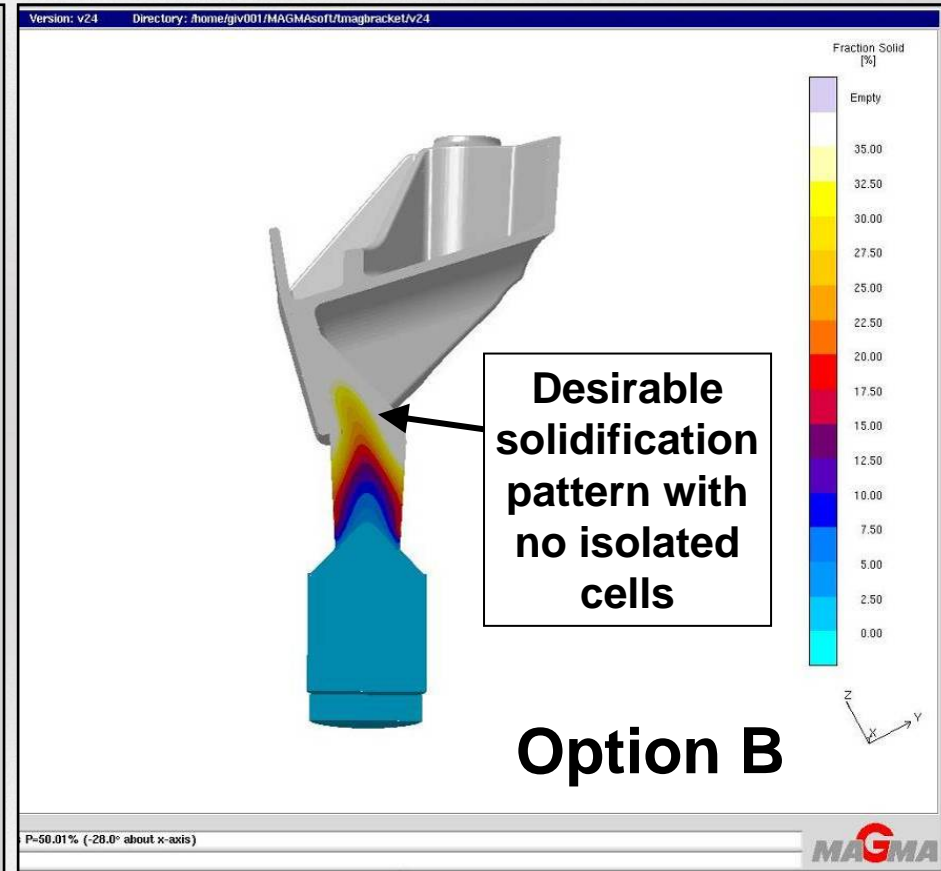
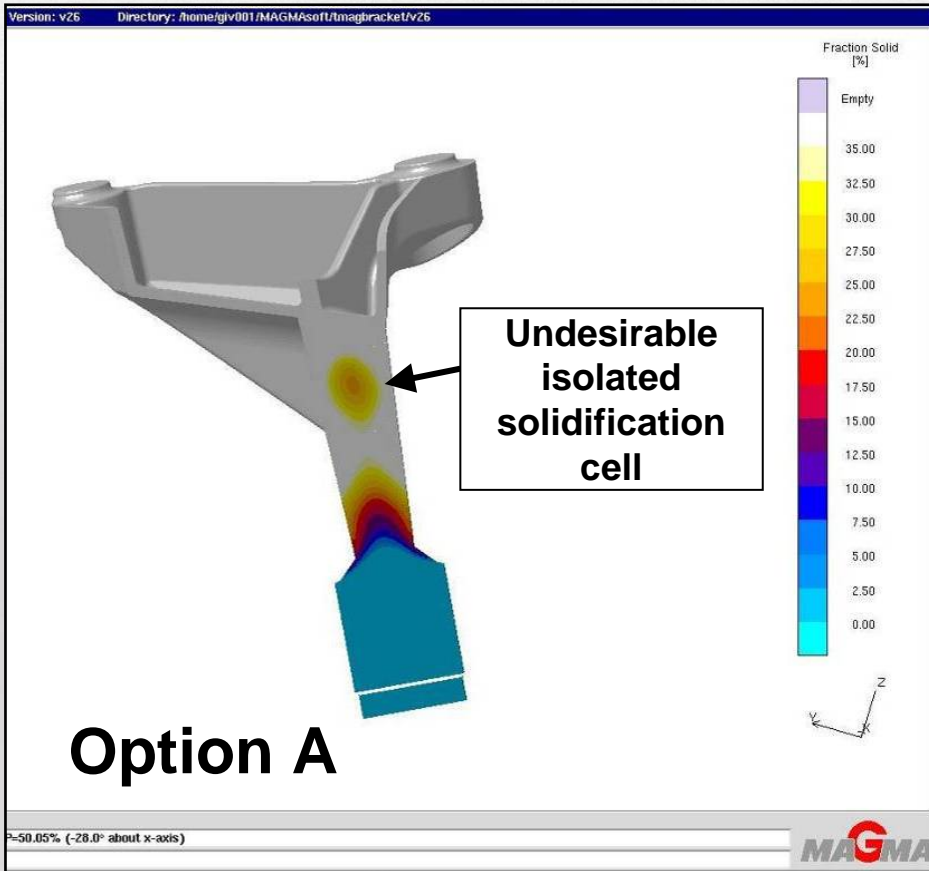


## Option B – no natural ‘draw’

- Requires 3-piece die with sliding core and core actuation
- Easier fettling
- Freedom to design for optimal solidification



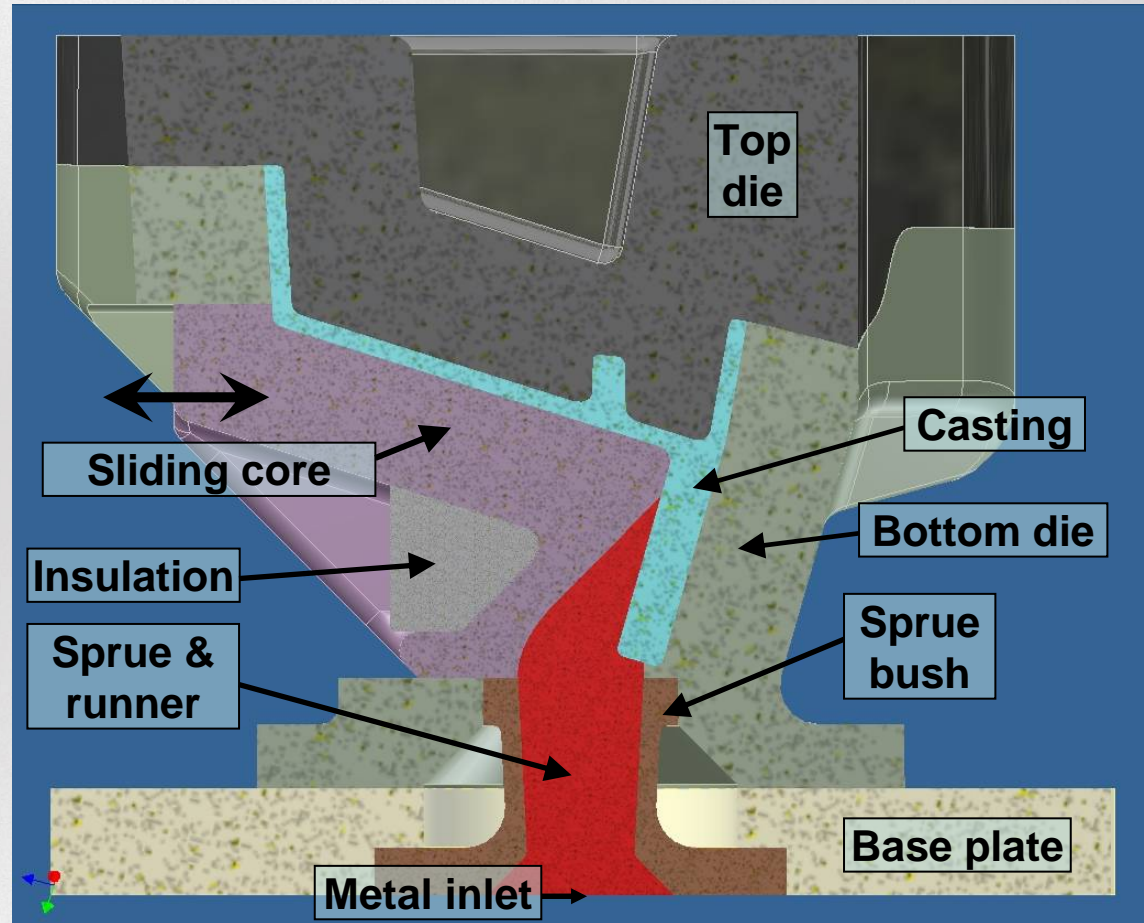
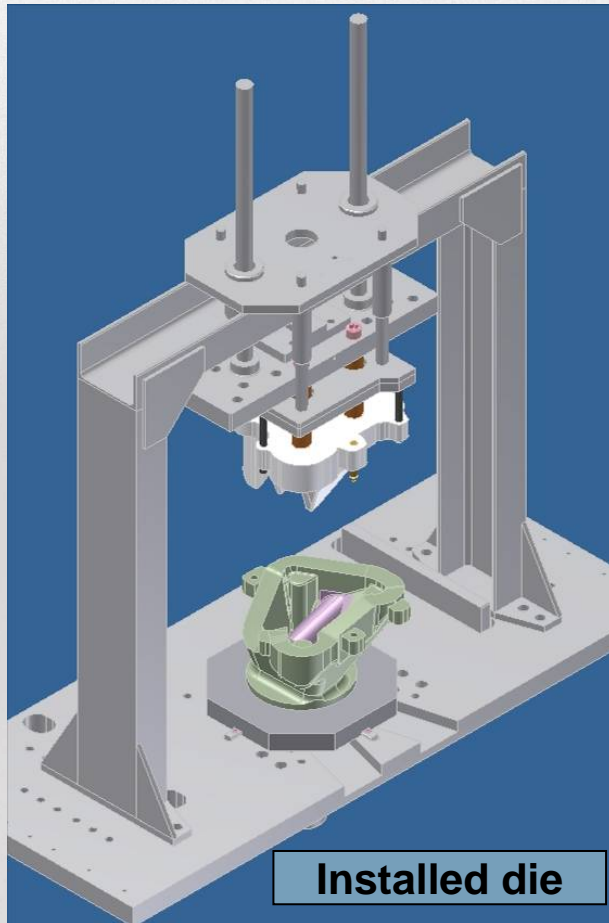
# Fraction Solid results, options A & B



**Decision: Use option B, and accept a more complicated die**



# Layout - Final die design





## *New magnesium engine mount by the T-Mag process*

### **FEA analysis of proposed Mg design indicates**

- Acceptable working stresses against specified loadings
- 114g (~ 16%) weight reduction
- 1st mode resonance frequency currently matches the baseline aluminium design, development is ongoing to achieve significant improvement.

### **Casting die design**

- Three-piece die with sliding core required
- Sound casting solidification predicted with minimal porosity defects.

### **Current Status**

- Die under construction; scheduled for delivery July 2011
- Manufacture of prototype castings to commence
- On-vehicle testing planned later in 2011.



# Contacts

**Geoff de Looze**

**CSIRO Process Science & Engineering,  
Clayton, Victoria**

**Telephone +61 3 9545 8436**

**Mobile 0407 557020**

**[geoff.delooze@csiro.au](mailto:geoff.delooze@csiro.au)**

**Steve Groat**

**T-Mag Pty Ltd**

**Telephone +61 8 8262 7666**

**Mobile +61 419 816 707**

**[steve.groat@t-magcasting.com](mailto:steve.groat@t-magcasting.com)**

**Foundry**

**29-31 Johannson Road**

**Wingfield SA 5013**





## Casting processes vs. application: Example – Engine Block

	Permanent Mould	Precision Sand	HPDC	Lost Foam
Mould material	<b>Steel</b>	<b>Sand</b>	<b>Steel</b>	<b>Sand</b>
Core material	<b>Sand/Steel</b>	<b>Sand</b>	<b>Steel</b>	<b>Sand/EPS</b>
Mechanical properties	<b>Good</b>	<b>Good</b>	<b>Good</b>	<b>Medium</b>
Porosity level	<b>Low</b>	<b>Low</b>	<b>Medium</b>	<b>Medium</b>
Block geometry	<b>Closed Deck</b>	<b>Closed Deck</b>	<b>Open Deck</b>	<b>Closed Deck</b>
Shape complexity	<b>Good</b>	<b>Good</b>	<b>Low</b>	<b>High</b>
Volume required	<b>Low</b>	<b>High</b>	<b>High</b>	<b>High</b>
Capital Cost	<b>Low</b>	<b>High</b>	<b>High</b>	<b>High</b>
Production rate (parts/hr)	<b>4-6</b>	<b>50</b>	<b>25-30</b>	<b>50</b>
Liners inserted	<b>Yes</b>	<b>Yes</b>	<b>Yes</b>	<b>No</b>
Liners pre-heating	<b>Yes</b>	<b>No</b>	<b>Yes</b>	<b>No</b>
Heat Treatment	<b>T6</b>	<b>T6</b>	<b>T5</b>	<b>T6</b>
Average Wall Thickness (mm)	<b>5.5</b>	<b>5</b>	<b>4</b>	<b>5</b>
Major advantage	<b>Best for low to medium volume</b>	<b>Draft reduction and no warm-ups</b>	<b>Thin walls with good mechanical properties</b>	<b>Freedom of design and reduced machining.</b>