Semi-solid processing
Semi-solid-route?

Solid feedstock forging

Liquid alloy Pressure die casting

1: pressure die casting
2: thixo-route
3: forging

solid (>%60)-liquid (%40): Semi-solid forging
solid (<%10)-liquid (>%90): Semi-solid casting
characterization

Heating rate: 2.5°C/min

$F_S: 100\%$

$F_L: 100\%$

Heat flow (mW)

Temperature (°C)
Thermal analysis

Semi-solid forming range:

$T_{F_s,70} - T_{F_s,50}$:
- 633.9°C
- 640.6°C

$dF_s/dT$ (°C⁻¹):
- 50% solid: 0.047
- 60% solid: 0.032
- 70% solid: 0.017

T range: 635°C-640°C
Requirements for alloys suitable for semi-solid forming:

- The metal can be brought homogeneously to a liquid fraction between 40 and 60% (no pure metal or eutectic alloy)
- The solid phase is prone to build a fine globular structure.
- The flow behaviour of the alloy is good.

Suspension part
Main process parameters of semi-solid forming and their influence on quality

- **Casting speed** It is important that the metal front stays together during mould filling. A too high speed can lead to turbulences and air entrapment. If the speed is too low mould filling could be incomplete.

- **Geometry of the runner system** Due to the fact that metal is already partly solid, **thicker sections and short runners** are necessary in comparison to die casting. Numerical simulation is a very valuable tool for designing runner systems.

- **Die temperature** To avoid cold shots, $T_{\text{die}}$ has to be high enough. Very often, die temperatures of 200 - 250°C lead to good results.
Squeeze Casting Process

- probable unsoundness is a major limitation of pressure die castings.
- The Squeeze Casting Process was developed to counter unsoundness in pressure die castings.
Squeeze Casting Process

- SC is similar to forging, with a mould made of a hollow lower dye and an upper dye used as a stamp, which are set on a drop forging press.
- Squeeze Casting is of course the potential of the process to produce products which are effectively perfectly sound.
Squeeze Casting

- Liquid metal is introduced into an open die, just as in a closed die forging process.
- The dies are then closed.
- During the final stages of closure, the liquid is displaced into the further parts of the die.
- No great fluidity requirements are demanded of the liquid, since the displacements are small.
- Thus **forging alloys**, which generally have poor fluidities (which normally precludes the casting route) can be cast by this process.
Squeeze Casting or Squeeze Forming

- This technique is especially suited for making fibre-reinforced castings from fibre cake preform.
- Squeeze casting forces liquid aluminium to infiltrate the preform.
- In comparison with non-reinforced aluminium alloy, aluminium alloy matrix composites manufactured by this technique can double the fatigue strength at 300°C.
- Hence, such reinforcements are commonly used at the edges of the piston head of a diesel engine where solicitations are particularly high.
Squeeze casting

Laminate squeeze casting of carbon fiber reinforced aluminum matrix Composites
Hasan Ali Alhashmy, Michel Nganbe
Materials & Design
February 2015, Pages 154-158
Squeeze casting

"squeeze-casting", is now commonly an evolution of pressure die casting, using the same machines, with differences only on the injection speed and on the design of the pouring system.

- the speed of the metal is drastically lowered, so as to avoid any turbulence - typically 0.5 m/s, against 30 to 60 m/s in HPDC.
- the solidification must be progressive from the thinner area of the cast part to the biscuit.
- the channels must be thicker than the cast part, and the gates set so as to feed any area.
Squeeze casting

- The high cooling speed and the pressure applied give the parts excellent mechanical properties, and squeeze casting is therefore particularly suitable for suspension parts.

This method is not widely used due to 2 problems:
- The thickness of the cast part depends on the quantity of metal poured;
- Parts must be of rather uniform thickness. Otherwise, thinner areas, which solidify before thicker ones, will stop pressurizing of areas subject to shrinkage.
Low inclusion Casting Processes

Shortcomings of conventional practice:
- Molten alloy may be held for several hours so that there is some time for oxide films to sink or float.
- However, there is a small density difference between molten aluminium and its oxide, and air is often entrained in folds of the film.
- Thus the separation takes place only slowly.
- A significant proportion of films never sink.
- Degradation of melt quality by turbulent transfer operations is typical of many casting operations.
- This underlines the importance of those processes which are designed to handle the melt without unnecessary disturbance.
Cosworth Casting Process

- designed specifically for the high volume production of high quality automotive castings.
- An electromagnetic pump is used to remove the molten metal which is taken from mid-depth in the furnace to minimize the risk of transferring oxides.
- The large reservoir of liquid metal in the holding furnace allows time for impurities to sink or float, and the electromagnetic pump (no moving parts!) displaces the best quality metal from the mid-depth of the holding furnace up and into the mould, displacing the air ahead of it as it goes.
Cosworth Casting Process

- This approach ensures that the metal rises through the system in a nonturbulent manner, thereby minimizing the formation of excessive oxide films and their incorporation into the casting.
- Firstly, the mould has to remain attached to the pump until the casting solidifies, which results in a slow production rate.
The Cosworth Process
Low pressure sand casting

No melt pouring!
world-wide annual production of casting

ferrous castings are a long way ahead of non-ferrous metals. The majority of non-ferrous castings are made in a wide variety of aluminium alloys and this is followed in importance by zinc alloys. Only relatively limited tonnages of castings are made in magnesium alloys because of their cost.

Aluminium alloy castings are mainly produced using die casting, sand casting and investment casting, with smaller tonnages being cast using squeeze casting and the lost foam process.

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Treatment of hypereutectic Al-Si alloys (> 16% Si)

- These are wear-resistant alloys used for pistons and unlined cylinder blocks;
- they may be sand, chill or pressure cast.
- Grain refinement is necessary to improve castability and machinability.
- Hypereutectic alloys must be refined with P (Al-P).
- Alternatively prerefinned ingot can be used.
- Melting must be under a sodium-free flux, since sodium prevents the refining action of phosphorus.
- Degassing is necessary but modification with sodium or strontium is not used.
Treatment of hypereutectic Al-Si alloys (> 16% Si)

**Melting practice**
- Melt under sodium-free cover flux, adding 0.5% with the charge and a further 0.5% when molten.
- Bring the melt to 780°C and plunge Al-P master alloy, dross-off.
- Degas.
- Skim the metal clean before use.
- The casting temperature for these alloys is high, around 750-760°C.
Treatment of alloys for pressure die casting

- With conventional pressure die casting, castings usually suffer from porosity because air in the die cavity becomes trapped in the casting;
- moreover thick sections are difficult to cast sound because of shrinkage.
- The castings cannot be fully heat treated since the trapped air causes “blistering” of the casting surface when the casting is heated.
- On the other hand, the rapid chilling in the die produces a fine grain structure and good as-cast strength.
Treatment of alloys for pressure die casting

- The commonly used alloys contain 8-10% Si and 2-3% Cu with around 1% Fe.
- The alloys are usually bulk melted and transferred to holding furnaces at each casting machine from which metal is dispensed into the die by an automatic ladle.
- The holding furnaces are topped up from time to time from the melting unit.
- In the past, it was not considered worthwhile to degas the alloy before casting (because some gas porosity was accepted as inevitable).
Treatment of alloys for pressure die casting

- Furthermore, the cooling rate in the die is so fast that grain refinement and modification were also not considered necessary.
- However, with improvements in the practice of pressure die casting, it is found that treatment of the liquid alloy by Rotary Degassing is effective both in degassing and removing non-metallic inclusions, so some die casters degas in the transfer ladle for this reason.
- Strontium modification is also found to be beneficial.
Treatment of alloys for pressure die casting

- Bulk melting is carried out under a covering/drossing flux to ensure minimum metal loss forming a complete cover, adding half early and the rest at final melt down.
- In the holding furnace, a low temperature flux can be used as a cover to reduce metal loss.
- Scatter 0.25-0.5% onto the metal surface and rabble gently until the exotherm develops.
- Push aside or remove before taking ladles.
overview of casting processes and their use in automotive applications
casting processes for automotive components

1) Green sand casting
2) Modified DISAmatic casting
3) Core package casting
4) Gravity die casting
5) Low pressure die casting
6) High pressure die casting
7) Vacuum die casting
8) Squeeze casting
9) Thixocasting
10) Vacuum riserless casting
11) Lost foam casting
### Casting Processes for Automotive Components

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1) Green sand casting  
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8) Squeeze casting  
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11) Lost foam casting
Vacuum Die Casting

- The principle is the same as low-pressure die casting.
- The pressure inside the die is reduced by a vacuum pump and the difference of pressure forces the liquid metal to enter the die.
- This transfer is less turbulent than by other casting techniques so that gas inclusions can be very limited.
- As a consequence, this new technique is specially aimed to components which can subsequently be heat-treated.
- Used when no surface flaws such as blisters etc are forgiven; when high temperature powder coating is an essential step in manufacturing cycle.
Vacuum die casting of precision engineered die cast products
Vacuum die castings

- Aluminium-intensive cars like Audi A2, Audi A8 or Ferrari Modena rely heavily on Vacuum Die Casting (VDC) for the space frame design.
- highly attractive for automotive applications.
- thin walls in large structures: Designs using a minimum wall thickness well below 2 mm.
- joining with standard welding techniques as well as Laser welding and self-piercing rivets.
- crash worthy structures (i.e. A-pillar of Audi A2)
- wide selection of alloys including heat treatable and non-heat treatable alloys.
- high productivity.
VDC Process

**Vacuum Dies:** The principle of vacuum die casting requires the dies to be very tight. Residual pressure is as low as 20-30 hPa. (Normal atmospheric pressure is $10^{13}$ hPa). Therefore tools consist of frames and one or several inserts with air seals in between. Good quality tools loose very little vacuum.

**Melt:** The melt is kept in the dosage furnace below the filling chamber. Melt cleanliness determines heat treatability as well as weldability of castings. If the gas content is too high, heat treatment produces blisters.
VDC Process
Examples of VDC parts

Ferrari Modena Spaceframe: light colored nodes are produced in VDC
Examples of VDC parts

Audi A2 Space Frame: colours indicate different processes

- Red: Die casting parts from ALCAN-BDW, Alloy AURAL-2® - High-Q-Cast®
- Blue: Profiles
- Green: Pannels
Examples of VDC parts

B-Post DC S-Class Coupe

A-Post
Examples of VDC parts

Shock tower Audi A8

A8 Lower A-Post Audi A8
Vacuum riserless castings

- **VRC / PRC** is a combination of **Vacuum Riserless Casting** (VRC) with **Pressure Riserless Casting** (PRC).
- This variant of low pressure die casting has been developed by Alcoa mainly for automotive chassis parts. "Riserless" means no mechanical feeding of melt into the mould.
- In addition, the level of melt in the feeding furnace is kept constant by replacing every shot from a holding furnace.
- Furthermore, the direction of solidification is controlled by active heating and/or cooling.
- Thicker sections can be fed directly in most cases, leading to lean gating systems.
- VRC / PRC castings have a dense, fine grained microstructure with excellent mechanical properties.
Vacuum riserless casting

The VRC process was developed by Alcoa during the 1950s. PRC was added during the 1980s.
Vacuum riserless casting

VRC/PRC Gen III casting machine
VRC/PRC-Processing of chassis parts

- The alloy most commonly used for this process is A356 / AlSi7Mg.
- First, raw material is analysed metallurgically.
- After melting, liquid aluminium is distributed by a channel system feeding furnaces equipped with impellers.
- From there the melt flows to dosage furnaces feeding the casting furnaces after every shot.
- After solidification the chassis parts are removed either manually (small parts) or robotically (large, heavy parts).
- Sawing and deburring is usually automatized. This is followed by X-Ray with automatic image analysis, heat treatment to achieve suitable mechanical properties, crack detection, eventually machining and shipping.
VRC/PRC-Processing of chassis parts

Flow chart of chassis parts production

Process control:

- Metallurgical analysis
- Purity of melt
- Microstructure
- X-Ray
- Mechanical properties
- Dimensional control

Heat Treatment

Quality Control

Shipping
Subframe produced with VRC/PRC: this part is a one piece casting approx. 1200 mm wide
Ultra Large Caster (ULC)

The Ultra Large Caster has been built during a further development effort targeting large castings. Parts produced demonstrates the potential of the process: the tailgate weights 11 kg, replacing 11 stampings and reducing the weight by 25 % (at that time). Wall thickness was between 2.5 mm and 6 mm. The alloy in this case was A356-T5.
Ultra Large Caster (ULC)

Molds for this machine can be as big as 3400 mm x 1700 mm. This allows using a two-out die for parts like the tailgate.

One piece tailgate produced by ULC
Cycle time was 2 minutes: this makes ULC economically attractive
Lost Crucible Process

- means of preventing poor transfer of metal.
- a pre-weighed slug of material is rapidly melted in an induction furnace.
- instead of the normal refractory crucible, a disposable fibre-ceramic crucible is used.
- Once the charge is molten and at the required temperature, the base of the crucible is pushed out by a vertically moving piston.
- As the piston continues to move upwards, the base of the crucible acts as a seal and the molten metal is introduced through the bottom of the mould at a controlled rate.
This new Alcan Lost Crucible Process, if fully developed for production in due course, will conserve the quality of the alloy as produced by the primary producer.

However, for all other processes, where the metal has to be melted in a furnace and then transferred for casting, the problem exists of how to test the quality of the metal.
Lost Crucible Process

Alcan invention / Lost Crucible Process.

```
Melting

Sand or metal mould
Pre-weighed slug
Induction heating for rapid melting

Casting

Base of crucible is pushed out and forms a seal
Controlled fill rate using piston
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chill casting alloys

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## Pressure die casting alloys

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# Investment Casting Alloys

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</table>
Explosions in aluminium foundries

- There is an explosion risk in foundries with a high humidity and when moist tools, dies and equipment is used and when the material charged into the furnace is moist.
- The water entrapped in aluminium vaporizes and bursts the molten aluminium that surrounds it.
- Explosions are classified according to their intensity.
- 3rd level explosion implies bursting of many kilograms of aluminium melt over many meters and can be hazardous. This type of explosion may cause serious injuries.
Explosions in aluminium foundries

Binzhou Weiqiao Aluminum Co.
Effect of alloying elements

- Pure aluminium melts at 660°C.
- It is not suitable for casting and is only used for electrical applications (where high conductivity is essential), and a few other special applications.
- Most casting alloys contain silicon as the major alloying element.
Types of alloying elements

**Primary alloying elements** are added to offer solid solution strengthening, deformation strengthening, age hardening and castability.

**Secondary alloying elements** limited solubility-form intermetallic compounds and affect mechanical properties indirectly by; refining the grain structure increasing the response to heat treatment.
Alloying elements

Special alloying elements to increase strength:
- Zn
- Cu

Alloying elements to increase strength, ductility and toughness:
- Mn
- Mg
- Si (fluidity!)
- Fe (impurity)

Special effects
- Ti, B
- Mn, Zr, Cr, V, Sc
- Bi, Sn
- Ni
Effects of Alloying Elements

Major elements
silicon (Si), copper (Cu) and magnesium (Mg)

Minor elements
nickel (Ni) and tin (Sn) -- found largely in alloys that likely would not be used in high integrity die castings

Microstructure modifying elements
titanium (Ti), boron (B), strontium (Sr), phosphorus (P), beryllium (Be), manganese (Mn) and chromium (Cr)

Impurity elements
iron (Fe), chromium (Cr) and zinc (Zn)
Typical silicon levels of popular casting alloys are:

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Si content (%)</th>
<th>Freezing range(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Si</td>
<td>4-6%</td>
<td>625-525</td>
</tr>
<tr>
<td>Medium Si</td>
<td>7.5-9.5%</td>
<td>615-550</td>
</tr>
<tr>
<td>Eutectic</td>
<td>10-13%</td>
<td>575-565</td>
</tr>
<tr>
<td>Hypereutectic</td>
<td>&gt; 16%</td>
<td>650-505</td>
</tr>
</tbody>
</table>
Al-Si phase diagram

- Pure Al solidifies “isothermally”, at a single temperature.
- Eutectic compositions (Al-12% Si/ 413 alloy) also solidify essentially “isothermally”, that is, within a very narrow temperature window.
Al-Si alloys

- The planar front solidification of very narrow freezing range alloys produces a sound skin extending toward the thermal centre of the casting section.
- They tend to solidify progressively from the die surface toward the thermal centre of the casting’s cross-section.
- There exists a very narrow plane of demarcation between the solidified portion and the remaining liquid.
- That solidification pattern alone provides a minimum tendency to hot tear during casting.
**Al-Si alloys**

- Near Eutectic compositions that solidify within a very narrow temperature window, any liquid to-solid transition shrinkage is confined along the thermal centerline of the casting at the end of solidification.

- Because solidification shrinkage is not connected to the surface of the casting, castings produced from such alloys are usually pressure tight.

- The eutectic alloys have the highest fluidity for a given casting temperature and having a short freezing range, they solidify with primary shrinkage.
Al-Si alloys

- The eutectic alloys are good for thin section castings where fluidity is critical.
- The lower silicon alloys (far away from eutectic) are used where higher strength is needed.
- The hypereutectic alloys are difficult to machine.
- They are used for wear-resistant applications such as pistons.
- As little as 5% Si provides a sufficient degree of isothermal solidification to overcome any major hot shortness issues and, at the same time, improves fluidity.
- In pure AlCu casting alloys (e.g. Al Cu4Ti), silicon is a harmful impurity and leads to hot tearing susceptibility.
Al-Si alloys

Metal casters often label wide freezing range aluminium alloys as being quite “difficult to cast.” It is not, however, their solidification temperature range that makes them difficult to cast, but rather, their characteristic cooling curve shapes (little isothermal solidification) and their lack of fluidity, both brought on by their lack of sufficient Si.

333 and especially B390 alloys also have relatively broad solidification temperature ranges, but those alloys contain significant quantities of Si, to have excellent fluidity and they undergo a substantial degree of relatively isothermal solidification.
Silicon

- Silicon (Si) is the most important alloying ingredient in the vast majority of aluminium casting alloys.
- Si improves casting characteristics by improving fluidity, feeding and hot tear resistance.
- Silicon’s high heat of fusion contributes immensely to an alloy’s “fluidity” or “fluid life”.
- Silicon has limited solid solubility (maximum 1.65%) and yet forms a eutectic with aluminum at a significantly high level (12%) at 577°C.
- Alloys with more than a few percent silicon undergo a relatively large volume fraction of isothermal solidification, thus they gain significant strength while undergoing little or no thermal contraction - very important to avoiding hot tearing or hot cracking issues.
Silicon

Strength

- Silicon alone contributes very little to the strength of Al casting alloys.
- However, when combined with Mg to form Mg$_2$Si, Si provides a very effective strengthening mechanism in Al castings.
- Mg$_2$Si is soluble in the solid alloy to a limit of about 0.7% Mg and provides the precipitation strengthening basis for an entire family of heat-treatable alloys (alloys 356 through 360).
 Silicon

Thermal Expansion Coefficient

Increasing the silicon level in an alloy decreases its thermal expansion coefficient as well as its specific gravity.

Wear Resistance

- Silicon also increases an alloy’s wear resistance, which has often made Al-Si alloy castings attractive substitutes for gray iron in automotive applications.
- The hypereutectic Al-Si alloys, such as B390, are used extensively in premium aluminum bare-bore engine blocks, for example, as well as in numerous pumps, compressors, pistons and automatic transmission components.
Silicon

Cutting Tool Wear

- While Si improves casting characteristics, there exists a downside as well.
- The more Si an alloy contains, especially into the hypereutectic range, the greater the tool wear during machining.
- With the current popularity of polycrystalline diamond cutting tools, tool wear has become less and less of an issue when selecting casting alloys.
- It continues to be an important consideration however where high-speed steel (HSS), carbide or other less wear-resistant tool materials are employed.
Copper

- greatest impact of all alloying elements on the strength and hardness of aluminum casting alloys, both heat-treated and not heat-treated and at both ambient and elevated service temperatures.
- improves the machinability of alloys by increasing matrix hardness, making it easier to generate small cutting chips and fine machined finishes.
- On the downside, copper generally reduces the corrosion resistance of aluminum; and, in certain alloys and tempers, it increases stress corrosion susceptibility.
Copper

- Copper decreases castability and hot tear resistance.
- Aluminum-copper alloys that do not also contain at least moderate amounts of silicon have relatively poor fluidity and low resistance to hot tearing during solidification.
- Although alloys with up to 10% copper were popular in the very early years of the aluminum foundry industry, they have now been replaced by silicon containing alloys, with the exception of the very-high-strength alloy 206.
- Cu improves thermal conductivity.
- Heat treatment is most effective with 4-6% Cu alloys.
Magnesium

- The strength of binary Al-Mg alloys is not generally improved by heat-treating, however, these alloys have excellent strength and ductility in the as-cast and room temperature self-aged condition.
- Al-Mg alloys have marginal castability (they are aggressive toward tools, they lack fluidity because of their low silicon and they tend to be hot-short).
- However, they have excellent corrosion resistance and they tend to be anodized to a natural aluminium colour.
- Mg improves machinability.
- Al-Mg alloys 515 through 518 are designated for die casting.
- Binary AlMg casting alloys are difficult to cast owing to their large solidification range.
Magnesium

- Magnesium’s role is also to strengthen and harden aluminium castings.
- Magnesium’s greatest influence on strength occurs, not in the 5XX alloy series, but rather when it is combined with Si in 3XX alloys to form $\text{Mg}_2\text{Si}$ and/or with Cu in 3XX or 2XX alloys, forming the precipitation-hardening phase, $\text{Al}_2\text{CuMg}$.
- Small additions of 0.25-0.5% Mg allow Al-Si alloys to be hardened by heat treatment, improving mechanical properties through the precipitation of $\text{Mg}_2\text{Si}$ in a finely dispersed form.
- Their proof stress can be almost doubled.
- Mg is used at levels of around 1% in high silicon piston alloys.
magnesium

- Higher levels still, around 3-6%Mg, are used in low silicon alloys to improve the anodising characteristics and give a bright surface finish for decorative components.
- Magnesium content is kept low in pressure diecasting alloys to avoid embrittlement.
- The presence of magnesium increases the oxidation losses of liquid aluminium.
Minor alloying elements

Nickel

- Nickel (Ni) enhances the elevated temperature service strength and hardness of 2XX alloys.
- It is employed for the same purpose in some 3XX alloys, but its effectiveness in the silicon containing alloys is less dramatic.
Minor alloying elements

* **Tin**

- Tin (Sn) in 8XX aluminum casting alloys is for the purpose of reducing friction in bearing and bushing applications.
- The tin phase in those alloys melts at a very low temperature (227.7 °C). Tin exudes under emergency conditions to provide short-term lubrication to rubbing surfaces if such bearings /bushings severely overheat in service.
- The 8XX series alloys are not generally applicable to die casting or its variations and thus are not shown among the alloys suitable for high integrity die casting.
Zinc
- When combined with copper and magnesium, heat treatment and natural ageing characteristics are improved.
- The fluidity is increased but shrinkage problems may occur.
- Increases strength
- Produces (self) age-hardenability in conjunction with magnesium.

Lead
Improves machinability at levels over 0.1%.
Microstructure Modifying Elements

Titanium & Boron

- Titanium (Ti) and boron (B) are used to refine primary aluminum grains.
- Titanium alone, added as a titanium aluminum master alloy, forms TiAl$_3$, which serves to nucleate primary aluminum dendrites.
- More frequent nucleation or initiation of dendrites means a larger number of smaller grains.
Grain refining efficiency is better when titanium and boron are used in combination.

Master alloys of aluminium with 5% titanium and 1% boron are commonly used additives for this purpose.

They form TiB$_2$ and TiAl$_3$, which together are more effective grain refiners than TiAl$_3$ alone.

The most efficient grain refiner for Al-Si alloys has a Ti:B ratio closer to 1.5:1.

That is a special case, applicable to 3XX and 4XX alloys and not to the other alloy systems.
Strontium, Sodium, Calcium and Antimony

- These elements (one or another, and not in combination) are added to eutectic or hypoeutectic Al-Si casting alloys to modify the morphology of the eutectic silicon phase.
- Without the benefit of a modifying treatment, eutectic silicon solidifies in a relatively coarse continuous network of thin platelets.
- That morphology provides abundant stress risers and thus limits the attainment of maximum strength and ductility.
- Modification with one of the above elements changes the eutectic silicon into a fine fibrous/lamellar form.
Microstructure Modifying Elements

Strontium, Sodium, Calcium, and Antimony
Microstructure Modifying Elements

**Strontium**

- Sr accomplishes the same modified eutectic silicon structure as sodium, but strontium’s effect fades at a much slower rate.
- Sr is usually added to somewhat higher retained levels than sodium (0.01 - 0.025%); but Sr can generally be counted on to remain effective for many hours and through numerous re-melts.
- Because of this, Sr has become the preferred modifier in North America.
- Levels of 0.008-0.04% Sr modify the Al-Si eutectic structure.
Phosphorus
Refines the primary Si phase in hypereutectic alloys. In hypoeutectic alloys, low levels of phosphorus coarsen the eutectic structure and reduce the effect of Na and Sr eutectic modifiers.

Sodium
Used to modify the eutectic structure.
Manganese & Chromium

- Alone or in combination, manganese (Mn) and/or chromium (Cr) change the morphology of the iron-rich $\text{Al}_5\text{FeSi}$ phase from its typical platelet/acicular form to a more cubic $\text{Al}_{15}(\text{MnFe})_3\text{Si}_2$ form that is less harmful to ductility.
- If iron exceeds 0.45%, manganese content shall not be less than one-half the iron content.
- As with the platelet/acicular $\text{Al}_5\text{FeSi}$ phase, the volume fraction and size of the cubic $\text{Al}_{15}(\text{MnFe})_3\text{Si}_2$ phase is also a function of concentration levels and solidification rate.
Manganese & Chromium

- Greater concentrations of iron, manganese and/or chromium are tolerable at higher solidification rates.
- While manganese and/or chromium cause a beneficial change to the morphology of iron phases, it is that change in combination with large concentrations of iron, manganese and chromium that leads to “sludge” in traditional secondary die casting alloys.
- Manganese has proven to be a suitable substitute for iron to minimize "soldering« of the cast melt to steel tooling during die casting.
Manganese

- Improves casting soundness at levels over 0.5%.
- Partially offsets iron’s negative effect on ductility when iron content is > 0.15%; controls the intermetallic form of iron in the alloy, leading to improved ductility and shrinkage characteristics.
- Reduces the tendency to stickiness in pressure die casting.
Fe-rich Al$_5$FeSi platelets  Cubic Al$_{15}$(MnFe)$_3$Si$_2$

Mn and/or Cr also tend to stabilize some 2XX and 7XX alloys at elevated temperatures. Cr especially suppresses grain growth. Mn and Cr impart a bronze to gold colour to 7XX alloys that are anodized.
Impurity Elements

Iron

- Iron is present in most traditional die casting alloys as an impurity, yet a very useful impurity.
- Iron in concentrations of 0.8% or more greatly reduces the tendency of an alloy to solder to die casting tooling.
- The Al-Fe-Si ternary eutectic composition occurs at about 0.8% Fe.
- Theoretically, when iron is alloyed to a little above that amount, the supersaturated molten alloy has little tendency to dissolve the relatively unprotected tool steel while the molten alloy and die are in intimate contact.
**Impurity Elements**

**Iron**

- Iron in a moderate range intended to reduce soldering is also credited with improving somewhat the resistance of die casting alloys to hot tearing during solidifications in rigid die cast tooling.

- That characteristic may, however, be overstated as some die casters say iron at the upper end of the typical range actually *increases* hot-tearing issues.
Iron

- Iron combines with aluminum, silicon, and other elements to form a variety of hard, complex insoluble phases.
- The beta Al$_5$FeSi phase forms as very thin platelets, which appear acicular or needle-like in a polished cross section. Such morphologies provide stress risers that significantly reduce the ductility of an alloy.
- Their volume fraction and size are functions of not only the iron concentration but also the solidification conditions (rate).
- The platelets tend to be fewer and smaller at higher solidification rates; thus, die casting is able to tolerate higher iron levels than other casting processes.
Impurity Elements

Iron

- Iron at high concentrations cannot be tolerated in high-integrity die casting variations such as high-vacuum, squeeze and semi solid casting.
- In those cases, a major goal is usually high ductility, and beta Al$_5$FeSi platelets destroy ductility by providing numerous stress risers and points of crack initiation.
- In those cases, primary alloys more traditionally used in sand and permanent mold casting have become the popular choices for high integrity die casting as well.
- Those alloys avoid Al$_5$FeSi platelets by limiting iron to very low limits.
Impurity Elements

Iron

- In some cases, high-integrity die castings have tolerated less pure alloys than required in sand and permanent mold by simply abiding by the rule “if iron exceeds 0.45%, manganese content shall not be less than one-half the iron content.”
- As noted earlier, manganese at concentrations above 0.4% has now been demonstrated to provide adequate protection against soldering, so alloys intended for high integrity vacuum die casting, such as 365 and Alcan's Aural alloys, avoid harmful Al₅FeSi platelets by manganese substitution for iron.
Impurity Elements

Iron

- at a content of approx. 0.2 % and above, has a decidedly negative influence on the ductility (elongation at fracture); this results in a very brittle AlFe(Si) compound in the form of plates which appear in micrographs as “needles”; these plates act like large-scale microstructural separations and lead to fracture when the slightest strain is applied at a content of approx. 0.4 % and above, reduces the tendency to stickiness in pressure die casting.
Iron/manganese

Iron

- Levels of 0.9-1.0% Fe are used in pressure diecasting alloys to prevent die sticking.
- High Fe contents decrease ductility, shock resistance and machinability.
- Castability is decreased by Fe due to the formation of sludge phases with manganese and chromium, so alloys for processes other than pressure diecasting are limited to less than 0.8% Fe.
Impurity Elements

**Zinc**

- The only intentional and controlled additions of zinc (Zn) to aluminum casting alloys are in the 7XX series, and those are not yet suitable for die casting or any of its variations.
- Otherwise, zinc is present merely as an acceptable impurity element in many secondary (scrap-based) die casting alloys.
- As such, zinc is quite neutral; it neither enhances nor detracts from an alloy’s properties.
Impurity Elements

Zinc

- It should be recognized that zinc is a relatively dense (heavy) element, and as such it increases an alloy’s mass density.
- High-zinc secondary alloys usually seem attractive because they cost somewhat less than low-zinc versions.
- However, that attractiveness can be deceiving if the cost differential is too small; it can make little sense to purchase lower cost alloys if doing so means shipping a higher weight of material with each casting.
Lithium
- While lithium up to 3% may be used to improve the properties of wrought aluminium alloys, it has a generally harmful effect on casting properties by reducing the effectiveness of Na or Sr modifiers at levels above 0.5%.
- At even lower levels, above 0.01%, porosity problems are experienced.
- It is recommended that Li levels below 0.003% are used for casting alloys.
Foundry alloys

- Foundry alloys contain substantial amounts of silicon and other alloying elements (Mg, Cu, Zn).
- High alloy content lead to heterogeneous microstructures with a distribution of secondary phases.
- Intermetallic particles promote the initiation and rapid growth of cracks under loading when they are acicular and block with sharp edges.
- Fatigue resistance is particularly sensitive to coarse intermetallic particles.
- The adverse effects of these particles can be limited with sound alloying and casting practices.
## Foundry alloy designations

<table>
<thead>
<tr>
<th>Alloy number</th>
<th>Alloy element</th>
<th>Solid solution</th>
<th>Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1xx.x</td>
<td>Min %99Al</td>
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<td></td>
</tr>
<tr>
<td>4xx.x</td>
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<tr>
<td>5xx.x</td>
<td>Mg</td>
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<tr>
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<td>Cu</td>
<td>✓</td>
<td>✓</td>
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<tr>
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<tr>
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<tr>
<td>9xx.x</td>
<td>Reserved</td>
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</tr>
</tbody>
</table>
Foundry alloy designations

- digit that follows the decimal in each alloy number indicates the product form.
- 0: indicates the cast product-casting itself (die casting, for instance).
- 1: indicates the chemistry limits for ingot used to make the XXX.0 product.
- 2: indicates ingot used to make that XXX.0 product, but ingot of somewhat different (usually tighter) chemistry limits than that of XXX.1.
- While not always the case, XXX.1 often indicates secondary alloy chemistry limits whereas XXX.2 would indicate primary alloy chemistry limits.
- 380.0 could indicate a die cast product likely produced from 380.1 secondary ingot.
Foundry alloy designations

Since melting and melt handling can alter the chemistry of an alloy prepared to make castings, the “XXX.1” or “XXX.2” ingot specifications are always somewhat tighter than the “XXX.0” specifications for the cast part.

And according to convention, “XXX.2” ingot always has tighter chemistry limits than “XXX.1” ingot.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Form</th>
<th>Si</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Mg</th>
<th>Zn</th>
<th>Ti</th>
<th>Each</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>360.0</td>
<td>die casting</td>
<td>9.0</td>
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<td>0.05</td>
<td></td>
<td>0.15</td>
</tr>
</tbody>
</table>
Foundry alloy designations

- Letters can also precede an alloy’s designation number.
- Letters denote some variation on the original designated alloy, perhaps a lower-impurity version, or a version that has an additional controlled element, or one that has a modified range for one of the controlled elements.
- Not all alloys have both a “XXX.1” and “XXX.2” ingot forms.
- Many of the more traditional die casting alloys will have only a “XXX.1” secondary-alloy ingot call-out and many “premium castings” alloys will have only a “XXX.2” primary ingot call-out.
Distinctive property of 1XX alloy is high electrical conductivity.

They are used commercially to cast electric motor rotors.

Rotors are usually cast on vertical high-pressure die casting type machines especially designed for the purpose. The high electrical conductivity of relatively pure aluminium is useful in collector rings and conductor bars, which are cast integrally with steel laminations that are stacked in the die prior to casting.

These alloys might occasionally also be used to cast connectors for joining transmission cables,

but 1XX alloys are not candidates for high integrity die castings.
applications
2xx / Al-Cu alloys

- The highest strength aluminium foundry alloys
- Ultimate tensile strength ~130-450 MPa
- Retain strength and hardness at elevated temperatures.
- However, limited ductility and toughness!
- Low corrosion resistance!
- Suitable for sand and permanent mould casting!
- Limited fluidity: high risk of porosity and hot tearing!
- Hence more suitable for investment casting!
- Can be heat treated!
- Most popular alloys: 201.0, 203.0
2xx / Al-Cu alloys

- When casting 2XX alloys in rigid molds or die casting dies, special methods are required to minimize solidification stresses; two effective techniques are 1) cast in hotter than usual tooling and 2) eject cast parts from tooling at the highest practical temperature.

- Special techniques are also necessary to chill critical strength/ductility areas of castings, simultaneously promoting directional solidification from colder remote casting extremes back to ingates or other sources of shrinkage feeding and promoting finer solidified structures.
2xx / Al-Cu alloys

- A201.2 offers high mechanical properties but is expensive and is thus in limited use.
- 206 and A206 offer nearly as high mechanical properties, are much less expensive and are considered viable candidates for future applications.
- Suitable for die cast versions like semi solid processing, employing new processing tools like Continuous Rheoconversion Processing (CRP™) and/or Controlled Diffusion Solidification (CDS™).
2xx / Al-Cu alloys

- Applications for alloys 206 and A206 include military and aerospace hardware where the highest tensile and impact properties are required.
- They are also used for a variety of structural castings on trucks and trailers, in gear and pump housings, and increasingly in automotive structural hardware.
- 2XX alloys are not good candidates for HPDC because of their poor fluidity and tendency toward hot-shortness.
- lower casting temperature, higher tool temperature, pressure filling and viscous, stable-front flow of semi solid metal processing offer significant promise for high-integrity die cast products from alloys like 206.
242.0 / A242.0 alloys

- Used when high strength and hardness are required at elevated temperatures
- Moderate fluidity; limited hot tearing and porosity
- Reasonable Leak tightness!
- Good machinability
- High anodised surface quality
- Good arc and resistance weldability
- Resistance to corrosion not too bad! (can be improved with coating!)
- Used in pistons and air cooled cylinder heads
2xx alloys

Aerospace structural parts

Fuel transfer components in jet engines

Body parts in jet engines
2xx alloys

Jet engine fan components in civil and military airplanes
2xx alloys

Tactical Tomahawk missile body parts

Electronic and optical surveillance components mounted on light vehicles-single piece casting
Al-Si alloys

- **Wear resistant alloys**: 390 and 392
- **Pressure die casting alloys**: 336, 339, and 413
- **Sand/permanent mould alloys**: 355, 356, 319, and 320

Temperature (°C)

- %5-8 Si
- %8-10 Si
- %10-13 Si
- %16-20 Si

%Si

α + liquid

Si + liquid

α + Si
Popular alloys in Al-Si system
Commercial cast Al-Si alloys

(a) Al-Si equilibrium diagram.
(b) Microstructure of hypoeutectic alloy (1.65-12.6 wt% Si).
(c) Microstructure of eutectic alloy (12.6% Si).
(d) Microstructure of hypereutectic alloy (>12.6% Si)
Microstructures in Al-Si system

Hypo eutectic

Hyper eutectic

Primary phase:

\( \alpha \)-Al

Silicon
3xx / Al-Si-Mg alloys

- The 3XX alloys are the true workhorse of the aluminium casting industry because of their superior casting characteristics and good strength.
- Al-Si-Cu alloys are the most prevalent and the higher-copper versions are fully heat treatable.
- When full heat treatment is desired, the Al-Si-Cu-Mg alloys provide the highest strength and hardness, at both ambient and elevated temperatures.
3xx alloys / Al-Si-Mg (Cu)

- Excellent fluidity
- Heat treatable
- High strength
- Ultimate tensile strength: 130-275 MPa
- High elongation, ductility and toughness in some alloys
- Good wear resistance
- Good machinability but poor corrosion resistance in Cu-bearing alloys
- Suitable for a variety of casting processes (sand, permanent mold and pressure die casting)!
3xx alloys/Al-Si-Mg (Cu)

- ideal for large complex castings!
- Very precise castings with very fine intricate details
- cylinder blocks
- cylinder heads
- wheel
- Aerospace
- components
- Compressor and
- pump parts
3xx alloys/Al-Si-Mg (Cu)

- An attractive balance between cast strength (without heat treatment), castability and cost!
- Mg concentration is controlled at very low levels in order to avoid the formation of oxides that result from turbulent mold filling!
- However, even this much Mg (~0.3%) contributes to strength and machinability.
- Recycled alloys are not good enough for critical-safety components.
3xx alloys/Al-Si-Mg (Cu)

The most popular alloys

- for sand casting: 356.0 and 319.0
- for permanent mold casting, A356.0
- For pressure die casting 360.0, 380.0/A380.0 and 390.0
- Squeeze, forge-casting and many other casting methods 357.0/A357.0
- Alloy 332.0 is one of the most widely used foundry alloy as it is produced entirely from recycled metal
A356 is currently the workhorse of aluminium structural castings.

- Excellent castability
- No risk of hot tearing and solidification contraction!
- Machinability is good in the heat treated state (T6). Savings can be obtained with carbide based tools due to high Si.
- Good surface quality. Good surface look as polished. Looks good and grey coloured as anodised.
- Good weldability.
- Cannot be soldered.
356.0

- A356 has long been the material of choice for cast aluminium automobile wheels and has become the standard for most automotive chassis and suspension castings as well.
- Cast in sand for gear boxes, oil pans, rear axle housings, water-cooled cylinder heads, pump cases.
- 356/A356 alloys are preffered in electrical components, marine vessel components, pump housings.
- Preferred for Permanent mold castings, engine components, valve housings, airplane wing couplings, fuel tanks of airplane and missiles
This is an ideal alloy in T6 temper for marine vessel applications where leak tightness and corrosion resistance are two very critical properties.

Alloy 357 is similar to A356 but has higher strength. It, too, is used to make “premium quality” castings.

A356 is the most popular alloy used in squeeze casting and semi solid metal processing.
Alloys 360 and A360 have been developed specially for pressure die casting. Hence, they contain higher Si and Fe and the impurity content of this alloy is higher.

Alloys 360 and A360 are in the same family as A356, but were designed specifically for die casting and, as such, contain more silicon and higher iron and allow more impurities than A356.
A380.0/B380.0

- General purpose pressure die casting alloys. Designed specifically for pressure die casting.
- Castability, leak tightness, hot tearing resistance of these alloys are good.
- Good mechanical properties.
- Good Machinability. However, carbide based tools are recommended because of their high erosive capacity.
- Electrocoating produces excellent results. Polishing and anodising quality are also good.
- Moderate weldability; cannot be soldered.
- Moderate corrosion resistance.
The 380 family of alloys have long been the workhorses of the die casting industry, probably accounting for 85% or more of all die cast aluminum. These are secondary (scrap-based) alloys that also evolved specifically for die casting, and thus contain more silicon and iron, and allow more impurities than alloys intended for other casting processes. These alloys provide a good balance between low material cost, moderate strength without need for heat treatment and castability. They are used in mowers, gear housings, air cooled cylinder heads.
Mg in these alloys is usually controlled to very low levels to minimize formation of oxides during very turbulent cavity fill,

but small amounts of Mg (~0.3%) can markedly improve hardness and machining characteristics (tight chip curl, short chips, minimum BUE on tools and improved surface finishes),

thus specifications often require some Mg in Al-Si-Cu die casting alloys;

through NADCA’s efforts, the Aluminum Association and ASTM specs have recently changed to allow Mg up to 0.3% in the US too.

The traditional 380-type alloys, being scrap based, are not suitable candidates for high integrity die casting.
319.0, A310.0, B319.0 ve 320.0

- Castability and weldability of 319.0 and A319.0 alloys are good with a reasonable level of strength. Leak tightness of these alloys is exceptional.
- Hot tearing and solidification contraction are limited.
- Casting properties and mechanical properties are not too much affected by impurity levels.
- Machinability is good.
- Carbide tools are recommended to resist wear and counteract the adverse effects of inclusions.
The strength of B319.0 and 320.0 alloys is higher with respect to 319 and A319. They are generally produced with permanent mold casting. Other properties are similar.

Sand castings of these alloys are used for crank cases of internal combustion and diesel engines, gas and oil tanks and oil boxes.

Permanent mold castings are used for water-cooled cylinder heads, arka dingil gömleği and engine components.
Alloys 319 and B319 are used in numerous commercial casting applications and have been extensively used in recent years for automotive engine crankcases, intake manifolds and cylinder heads.

Alloys 319 and B319 are also used to cast oil pans for autos and trucks.

Neither version is considered a die casting alloy, due mostly to their moderate silicon levels, however, their solidification modes have already made them very attractive choices for semi solid processing.

Pistons for automobiles are also cast from the 3XX alloys.
Alloy 332 is the traditional car engine piston material; but 339 and B390 alloys, which are better able to withstand the stresses of modern high specific output engines, are increasingly replacing 332.

Another general-purpose alloy is 333, more-or-less the permanent mold version of the 380-type die casting alloy.

Alloy 333 has traditionally been used to cast sole plates for irons, a variety of meter and regulator parts and also automotive cylinder heads.
355

- The 355 type alloy, especially C355, is one of a small group of select alloys used to make military and aerospace parts for “premium strength/quality” castings (the 206 alloys are also in this group, as are A356 and 357).
- They are used in aircraft crankcases, gearboxes, housings and supports, as well as in impellers for superchargers.
- This alloy has already been used for semi solid processing and to a limited extent for squeeze casting as well.
A390.0/B390.0

- Hyper-eutectic alloys
- Very high wear resistance owing to primary silicon particles dispersed in a eutectic matrix.
- Suitable for pressure die casting
- Can be cast as thin sections and complex parts.
- Leak tightness and hot tear resistance are both high.
- Limited die soldering!
- Permanent mold casting good!
- Slow cooling in sand molds have an adverse effect on as-cast structure.
A390.0/B390.0

- Does not require heat treatment!
- Hence, fatigue performance (that is impaired by residual stresses from heat treatment) is good.
- Thermal expansion coefficient is low.
- An attractive material for internal combustion engine pistons, cylinder blocks and heads, compressor and pump housings and brake components since it has low thermal expansion, high wear resistance and hardness
A390.0/B390.0

- 390, B390, 393 are used primarily in wear applications (engine blocks, compressors, pistons, pumps, pulleys, brake systems, etc.)
- but they are also popular for very thin parts, since they have exceptional fluidity.
- because of low ductility associated with the presence of primary silicon crystals, are not candidates for high integrity die casting, even though they are heat treatable and capable of high strength and hardness.
390, B390, 393 are generally preferred for applications such as engine block, compressor, pump and brake systems that require high wear resistance.

They are also preferred for the casting of thin sections owing to their very high fluidity-castability.

Hyper-eutectic alloys are not suitable for safety-critical parts as they contain primary silicon particles and have limited ductility.

They can be hardened with heat treatment and can be produced at high strength and hardness levels.
3xx alloys / Al-Si-Mg (Cu)

356.0 alloy turbo part for a Mercedes truck

380.0 alloy sand casting rear axle sleeve

357.0 and A357.0 alloy sand and permanent mold castings

Automotive suspension components
3xx alloys / Al-Si-Mg (Cu)

Die cast gear box
380.0 alloy

Low pressure die cast
automotive wheel
A356.0 alloy
3xx alloys / Al-Si-Mg (Cu)

Renault Safran cylinder head

7 kg A380 gear box
Pressure die casting
3xx alloys / Al-Si-Mg (Cu)

A380 sand casting

investment cast 3XX alloy parts

319 sand casting
4xx/Al-Si alloys

- The 4XX alloys are used where good castability is required in conjunction with better corrosion resistance than is generally afforded by copper containing 3XX alloys.
- Suitable for sand, permanent and pressure die casting
- Major alloys in this group: 413.0, 443.0
- Applications include marine castings, office equipment frames, and equipment for food handling and components for the chemical industry.
- Alloy A444 is essentially A356 alloy, but without the magnesium.
413.0/AlSi12

- popular because of high castability owing to its eutectic composition and low melting point (570°C) and excellent weldability
- Can be cast as thin sections
- Tensile strength: 120-175 MPa
- Moderate ductility
- Good wear resistance
- Printer and typewriter housings/cooking utensils; popular in marine and architectural applications owing to its high corrosion resistance
Alloy 413 is the Al-Si eutectic alloy and solidifies over the narrowest range of all casting alloys except perhaps the 1XX rotor alloys.

As previously mentioned, eutectic alloys solidify progressively from the die surface toward the thermal center of a die casting’s cross-section.

That planar-front solidification produces a sound skin extending to nearly the thermal center of the casting section.

At the end of solidification, any liquid-to-solid transition shrinkage is confined along the thermal centerline of the casting.
Because solidification shrinkage is not connected to the surface of the casting, castings produced from these alloys are usually pressure tight.

413 is also a secondary based alloy and like the 380 alloys, is not considered a suitable candidate for high integrity die castings.
The 443 alloys have broad casting process applicability, and are suitable for use in processes ranging from sand to high-pressure die casting.

4XX alloys are even used to cast electric motor rotors that require high electrical-resistivity (motors with high starting torque); in such cases, more highly alloyed die casting compositions like 443.2 are commonly used.

Alloys such as 443.1 provide conductivities in the range of 30 to 35% IACS.
A444 has outstanding ductility combined with moderate strength and is used extensively to cast lamp pole bases, bridge rail supports and for highways, where impact absorbing capabilities without failure are important.

While the 4XX alloys are not heat treatable, A444 for highway applications is often given a T4 treatment (exposed to typical solution heat treating temperature for an hour or so) so as to spherodize eutectic silicon and thus provide maximum ductility and energy absorbing capability in the event of vehicle impact.
Silicon in 3XX and 4XX alloys

- All 3XX and 4XX alloys undergo a significant degree of relatively isothermal solidification at their major Al-Si eutectic arrest.
- By the time cooling resumes below that arrest temperature, the bulk of the solid has already formed and only the lowest melting temperature phases remain liquid (generally, Cu and/or Mg bearing eutectics).
- The 3XX and 4XX alloys already have, at that point, sufficient structure and strength to overcome whatever cooling-contraction restrictions the mold might impose as the casting continues to solidify from the Al-Si eutectic arrest to the solidus temperature.
- 3XX and 4XX alloys have almost no tendency to hot tear or hot crack, except where some form of imposed “hot spot” might exist in the die during late stages of solidification.
5xx.x/Al-Mg alloys

- Long solidification range due to high Mg; castability difficult; prone to hot tearing; they are not selected for pressure die casting.
- Generally sand/occasionally permanent mold cast!
- Very high surface quality; anodising quality!
- Excellent corrosion resistance!
- Good machinability
- Ultimate tensile strength range: 120-175 MPa
- Typical alloys: 512.0, 514.0, 518.0, 535.0
- 512.0 and 514.0 alloys exhibit medium strength and high elongation.
- They are not heat treatable!
5xx.x/Al-Mg alloys

- The 5XX alloys have the best corrosion resistance of the aluminium casting alloys.
- They also polish to bright finishes and they tend to anodize with a pleasing natural aluminum appearance.
- Therefore, they are popular for decorative castings as well as castings used in dairy and food-handling equipment, for pipe-fittings in marine and chemical systems, marine hardware and architectural /ornamental applications.
- The 5XX alloys require more care in preparation and casting than lower-magnesium content alloys because they are more reactive in the presence of oxygen, moisture in the atmosphere, lubricants and the like.
Similar to the 2XX alloys, 5XX alloys lack fluidity and have hot-shortness tendencies, thus they are not often selected for die casting.

However, pressure during die casting minimizes fluidity issues and semi solid processing can minimize hot shortness issues.

Alloys 515 through 518 are actually designated for die casting, and might be specified when maximum resistance to corrosion is required, and/or when a combination of strength and ductility higher than is generally achievable using common 3XX or 4XX die casting alloys in the as-cast (F temper) is desired.
5xx.x/Al-Mg alloys

- Relatively new entries into the 5XX family of alloys are “Magsimal-59” developed by Rheinfelden Aluminium in Germany, Maxx alloy 59 developed by Salzberger Aluminium GmbH (SAG) in Austria and the Aural 11 alloy from Alcan.
- These alloys were designed especially for high vacuum die casting of crashworthy automotive components requiring high ductility.
- To avoid the ill effects of Fe phases on ductility, these alloys employing Mn to reduce die-soldering tendencies.
5xx.x/Al-Mg alloys

- The strength is not improved by heat treating;
- however, they have good strength and good ductility in the as-cast (F temper) and room temperature naturally-aged condition
- they are now receiving well-deserved attention for large structural die castings that would be difficult to heat treat without developing residual stresses and distortion.
- They show potential for increased use for die casting large, thin-walled automotive body, chassis and suspension components that must have both strength and ductility without the stress and distortion that would surely be imposed when heat treated.
5xx.x / Al-Mg alloys

- Interestingly, they show great promise for processing by rheocasting in the semi solid temperature range.
- A major issue when die casting the 5XX alloys, including the Mn-containing alloys designed for high vacuum die casting, is reduced tool life.
- The presence of Mn might overcome soldering issues, but reactive Mg still increases aggressiveness to tool steel, and die life is shorter than when casting lower-Mg Al-Si alloys.
7xx.x / Al-Zn alloys

- Heat treatable
- More difficult to cast than Al-Si alloys
- Used only when machinability is required and surface quality and appearance is critical because of poor castability.
- Sand and permanent mold castings (pressure die casting is out of question!)
- Excellent machinability
- Good dimensional stability
- Good corrosion resistance
- High surface quality
- Typical alloys: 705.0, 712.0
- Tensile strength: 205-380 MPa
7xx.x / Al-Zn alloys

- 7XX alloys have good impact properties
- they develop reasonably high strength without a need for heat treatment.
- The 7XX alloys continuously age at room temperature but develop nearly-peak properties within 20-30 days after casting.
- They are therefore popular for large machine tool parts, furniture, garden tools, textile and office machine castings, trailer parts and mining equipment parts
7xx.x / Al-Zn alloys

- Ideal for huge parts that could be troublesome to heat treat and quench without issues of stress and distortion.
- The 7XX alloys have the highest solidus temperatures of all aluminium casting alloys (other than pure aluminium/rotor metal), which renders them suitable for use in assemblies that are joined by brazing.
- The 7XX alloys are not intended for die casting, but like some 2XX and 5XX alloys, might benefit from semi solid processing and thus become candidates for high integrity die casting.
8xx.x/Al-Sn alloys

- Heat treatable
- Limited strength
- High wear resistance
- More difficult to cast than Al-Si alloys
- Suitable for sand and permanent mold casting (not for pressure die casting!)
- Perfect machinability
- Typical alloys: 850.0, 851.0
- Tensile strength: 105-205 MPa
- Difficult to cast like the 7XX alloys. Preferred only when machinability is required.
8xx.x/Al-Sn alloys

- used exclusively to cast bushings and journal bearings.
- excellent compressive properties
- unique lubricating properties under over-heat conditions.
- The unique ingredient in 8XX alloys is Sn which resides in the solidified casting largely as small globules of the essentially-pure element. If normal lubrication fails and causes overheating of a bushing/bearing, the tin phase melts at 231°C (its normal low melting temperature) and exudes from the over-heated surface to provide emergency liquid-tin lubrication and thus it prevents catastrophic failure of the system.
etial alloys

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<tr>
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<th>RENK KODU</th>
<th>Fe</th>
<th>Si</th>
<th>Cu</th>
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<th>Mg</th>
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<th>Ni</th>
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