Steel, Stainless Steel, High & Super Alloy-
Heat, Wear, Abrasion, Pressure & Corrosion Resistant
Castings, Spares, Replacement Parts, Custom-Made Components
Manufacturer-Supplier to OEM's, Plants, & Process Industry
Machined, Proof-Machined, CNC/VMC Precision Machined Components
Conversion to Castings from Fabrications, Forgings & Welded Assemblies
Engineering, Materials & Metallurgical Consulting

WH-76, Mayapuri Industrial Area
Phase-I, New Delhi 110 064, India

T: +91-(0)11-2811-5021
F: +91-(0)11-2811-5021
E: acmecast@acmealloys.com
W: www.acmealloys.com

Alloy Characteristics
Affect Casting Design

Sarju Prasad, Chief Metallurgist
BSc Honours (Physics) BSc (Metallurgical Engineering) REC, Rourkela (NIT-RKL), India, MAFS (USA)

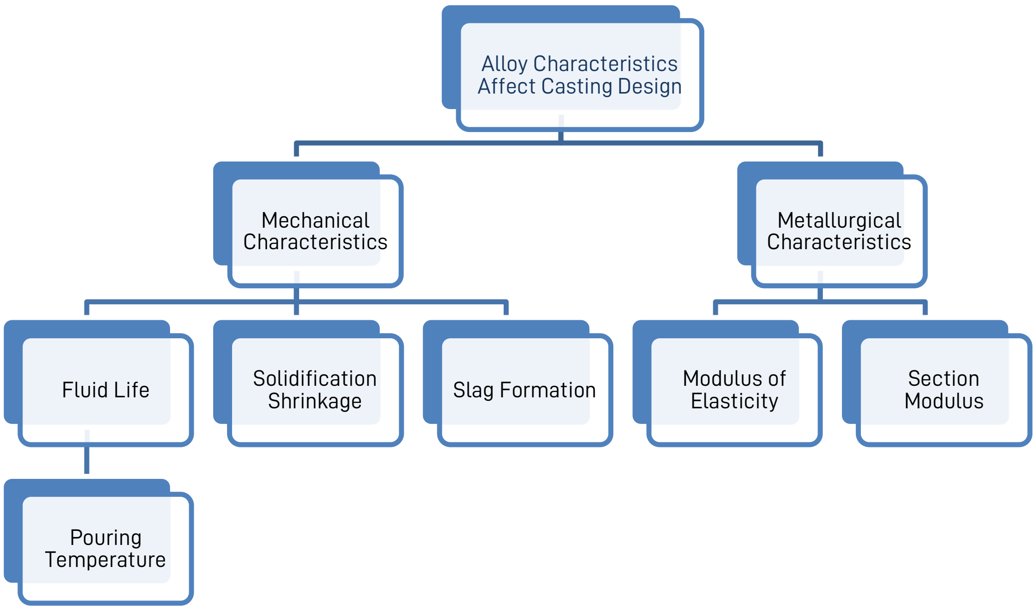
AcmeCast® makes a strong commitment to its customers in recommending and manufacturing best possible alloys for their industry specific end-application needs.

Besides manufacturing alloys conforming to alloy standards, one of our core competences lies in casting close-to-final geometry, combined with developing and manufacturing 'hybrid or custom made' alloys. Such alloys are at slight gyrations from the alloy standards that meet or exceed customers or client's line of industry specific-end applications, performance and duty requirements.

With more than 40 years of experience and expertise in high alloy metallurgy, our customers and end users have benefited from our collaborative efforts in finding solutions to some of the most vexing problems encountered by them.

Our products have been influential in achieving significant cost savings up to 25% (and even more in some cases) by just making right alloy choices, good casting designs, optimal precision machined components and use of appropriate alloy for a particular application. The increased cost-to-benefit have come in different tangible as well as intangible ways ranging from- lower rejects, lower life cycle costs, reduced tooling/tooling costs, less frequent demand for replacement, shorter times to transform casting into a finished part, lower process/plant downtimes, improved productivity, 'in time' components supplies, lower inventories, lesser inspection costs, savings in lost man-hours following up of sourcing materials; to building core competence with the help of our pragmatic materials and metallurgical consulting services.

Recognizing the impact of physical alloy characteristics and mechanical characteristics at the outset will enable the design engineer(s) avoid many of the pitfalls in "assuming" that one alloy could be treated like any other alloy(s).



Fluid Life

A molten metals fluid life is more than its ability to fill the mold cavity. The fluid life also determines how long the metal flows through narrow channels to form thin sections, and how readily it proudly solidifies and confirms to fine geometry details.

The temperature of the molten metal is not the **only** factor that affects the alloys' fluid life. For a given alloy, fluid life does not increase with superheat (excess temperature above the alloy's liquidus temperature). However, fluid life of every alloy does not necessarily increase equally with temperature. In other words, fluid life of a molten metal alloy is also dependent on chemical composition, metallurgical and surface factors.

Fluid life will affect the design characteristics of a casting. By understanding the nature of individual metal behaviour of an alloying element in conjunction with its behaviour in the alloy, its fluid life can be closely predicted. Thus, by having the knowledge of fluid life of a particular alloy, the designer will recognize several important design criteria.

Some of these are:

- Minimum section thickness that can be attained
- The maximum length of a thin section
- The fineness of cosmetic/aesthetic detail that is possible

It is also vital to understand that moderate or even poor fluid life does not limit the cost effectiveness of design.

Knowing that an alloy has limited fluid life, cautions the designer that the casting should feature:

- Softer shapes
- Finer details in the bottom portion of the mold
- More taper leading to thin sections
- Larger lettering (on the surface part)
- And other details which depend upon the type and intricacy of the job

Some casting processes feature molds that are very dry and hot. These molding process minimize the effects of convection, a mode of heat transfer, which reduces fluid life.

Solidification Shrinkage

There are three distinct stages of shrinkage as molten metal alloy solidify:

- **Liquid shrinkage**
- **Liquid-to-solid shrinkage**
- **Solid shrinkage**

Liquid Shrinkage is the contraction of the liquid before solidification begins. While paramount to metal casters, it is not an important design consideration but it significantly affects the cast ability of the part or component.

Liquid-to-Solid Shrinkage is the shrinkage of the metal as it goes from the liquid's disconnected atoms and molecules to the formation of crystals of atoms and chemical compounds the building blocks of solid metal. The amount of solidification shrinkage varies a great deal from one alloy to another, but it can vary from very little to high shrinkage volumes.

Steel, Stainless Steel, High & Super Alloy-
Heat, Wear, Abrasion, Pressure & Corrosion Resistant
Castings, Spares, Replacement Parts, Custom-Made Components
Manufacturer-Supplier to OEM's, Plants, & Process Industry
Machined, Proof-Machined, CNC/VMC Precision Machined Components
Conversion to Castings from Fabrications, Forgings & Welded Assemblies
Engineering, Materials & Metallurgical Consulting

WH-76, Mayapuri Industrial Area
Phase-I, New Delhi 110 064, India

T: +91-(0)11-2811-5021
F: +91-(0)11-2811-5021
E: acmecast@acmealloys.com
W: www.acmealloys.com

Alloys can be classified into three groups based on their solidification range:

- **Directional**
- **Eutectic**
- **Equiaxed**

Based on our experience over various product development and replacement parts manufacturing projects, we are of opinion that failure to recognize the impact of liquid-to-solid (solidification) shrinkage is one of the worst errors that "rule of thumb" design handbooks make.

Liquid-to-Solid shrinkage is an extremely important consideration for the design engineer. In some alloys, disregard for this type of shrinkage results in voids in the casting and cast components. Both the design and foundry engineer have the tools to overcome this problem, but the design engineer has the most effective tool. Part geometry!

Geometry could be found that meets structural needs and solidification shrinkage needs. For some alloys determining that particular geometry could be very simple. For other alloys, finding that geometry is the real essence of a good casting design. Should that geometry not be found for difficult alloys, the foundry engineer and the metallurgist; then must resort to "**thermal trickery**" to create fluid flow and heat transfer patterns which the part geometry fails to provide. Here comes into perspective the technique of 'directional solidification' and techniques such as "single crystal casting" used for manufacturing Nickel and Cobalt base super alloy parts for turbine blades, aircraft, aerospace, defence and nuclear applications.

"Thermal trickery" is creative technique, a major weapon in the expert metallurgical engineer's arsenal. However, it is expensive. When required, AcmeCast can get thermal trickery 'right' for the benefit of its customers. Eliminating thermal trickery with good design makes castings that cost less to produce and cost far less to process and assemble.

Solid Shrinkage, often-called pattern maker's shrinkage, occurs after all the metal has completely solidified and is cooling to ambient temperature. Solid shrinkage changes dimension of the casting from those in the mold to those dictated by the rate of solid shrinkage of the alloy. In other words, as the solid-casting shrinks away from the mold walls it assumes final dimensions that must be predicted by the pattern/die maker. This variability of pattern maker's shrink is very important design consideration in all the prevailing casting processes.

This uncertainty about pattern/die maker's shrink is why we normally recommend producing a first article (sometimes called a **sample casting** or **first article run**) to establish what dimensions really are prior to going into commercial production. The pattern is called a **master pattern**, which contains all the necessary allowances required to cast the desired part to requirement. There is a high risk in assuming, that the final solid shrinkage predictions built into patterns/dies and core boxes will result in final dimensions that are "close" enough to prediction to fit within allowable tolerance.

Despite all good planning, the nature of pattern maker's shrink is unpredictable enough and important enough that adjustments will be necessary on the pattern to achieve the final product dimensions and tolerances.

Slag Formation

Amongst metallurgical and foundry engineers, slag is usually associated with the higher melting point metals (ferrous metals) and is composed of liquid non-metallic compounds (usually refractory), products of alloying and products of oxidation in air. Moreover, no one wants slag inclusions in the castings and cast components.

Some molten metal alloys are much more sensitive to slag formation than the others are. Castings made from these alloys are much more prone to contain non-metallic inclusions. There are casting processes, quality control techniques and design considerations that can dramatically reduce the probability of non-metallic inclusions on casting. Design geometry to minimize the possibility of non-metallic inclusions affecting the surface quality of the castings.

Pouring Temperature

Metal castings are formed in molds that withstand the extremely high temperature of liquid metals. Interestingly, there are not many choices of refractors to do the job. As a result, high molten temperatures are very important to casting geometry and to the casting process that should be used.

For practical purpose, sand and ceramic materials with refractory limits (1650°C–1820°C) are most common mold materials used today worldwide. As the temperature of the molten metal alloy increases, design considerations must be given to heat transfer problems and thermal abuse of the mold itself; one reason why stainless steel and high alloy castings are difficult.

WH-76, Mayapuri Industrial Area
Phase-I, New Delhi 110 064, India

T: +91-(0)11-2811-5021
F: +91-(0)11-2811-5021
E: acmecast@acmealloys.com
W: www.acmealloys.com

Modulus of Elasticity

The measure of stiffness of a metal itself (regardless of material shape) is known as Modulus of Elasticity or the Young's Modulus. In the case of metals, it is a function of metallurgy and it is a mechanical property of the metal alloy. Although this is a parameter discussed at length in engineering books on material science, it is a common measurement in foundries. In most foundries, the modulus of elastic (straight line) is the portion of the stress/strain diagram created whenever a test bar is pulled on a universal testing machine.

Section Modulus

Another measure of stiffness is section modulus, which is stiffness from shape or geometry; unlike modulus of elasticity, it has no correlation with the material. Actually, section modulus is an aspect of moment of inertia, which is a function of a shape's cross-sectional area in combination with its height. Stiffness from geometry of section modulus is a very powerful tool. Ever wondered, why hollow bricks are stronger than the solid bricks used in construction industry. Why hollow pipes can vertically withstand more applied (static and dynamic) load than solid pipes? Section modulus holds the answer. The knowledge of section modulus enables engineers to create metal shapes that are much stiffer than the material itself could ever be.

The most significant observation that could be made about stiffness from geometry is that there is no other reason besides metal casting that can offer so much geometry in the design and manufacturing of component shapes.

Another important observation is that design stresses in a structural part, are attributed directly to its section modulus. In fact, increasing section modulus decreases stress in a direct, an inverse relationship.

We now see an important synergy between modulus of elasticity and section modulus. Modulus of elasticity determines how much stress a metal can safely carry before it begins to deform permanently and section modulus enables design engineer to use geometry to keep the stress within safety limits. As we have learned, creative use of section modulus enables relatively weaker metals to do the work of the stronger ones.

For custom-made end application solutions in heat, wear, abrasion, pressure and corrosion resistant alloys, contact us.

Vishal Kumar
T: +91-98-111-15423
E: vishal@acmealloys.com