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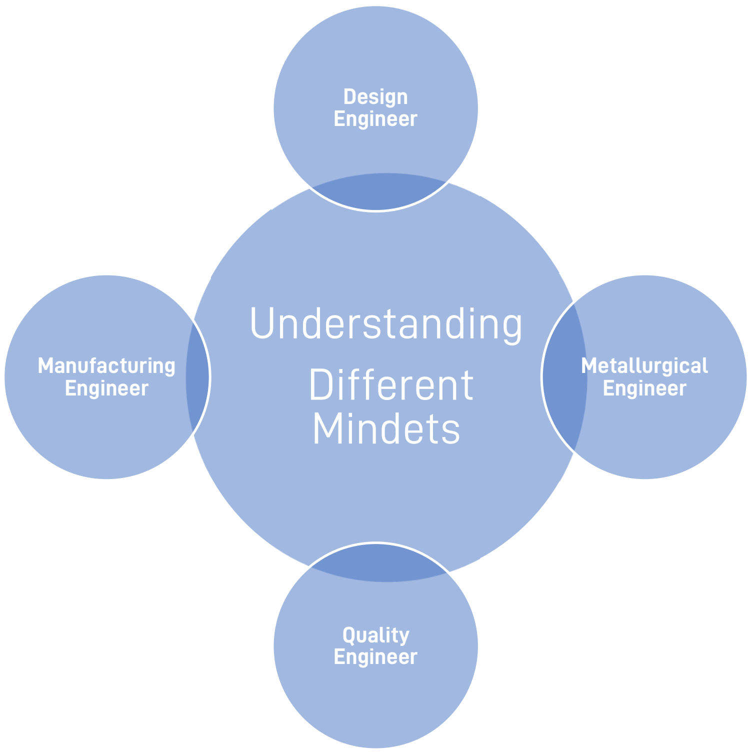
Conceptual Framework For Designing Metal Castings



One of basic principles of the "**system approach**" in engineering design is to define the system boundaries in such a way that conflicting requirements can be recognized and resolved amicably.

We continuously strive towards developing 'optimal' casting and 'component' design for our customers, keeping in perspective customer's-inherent product design, quality benchmarking and economic considerations.

Based on our experience and gained expertise we contribute to developing quality products for our Original Equipment Manufacturers (OEM) and manufacturing – castings proof-machined parts or fully finished precision machined components for wide industrial applications.

Understanding the different mind-sets

Well-designed castings are known to be functional as well as cost efficient. Yet, those directly involved in designing and producing castings know that the principles behind castings are difficult to pin down. "Rules of thumb" abound that attempt to define fillets, radii, changes in casting section, minimum section thickness, tolerance capability, estimating shrinkage for different alloys and unconventional solidification/heat transfer phenomenon undergoing at different shapes/contours of component casting.

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Surprisingly, there are casting designs that regularly seem to violate the "rules" successfully; rather these designs typically have combinations of geometry that should not work, but that do.

On the other hand, design engineers observing this attempt to take latitudes with geometry that seem well founded, only find that their design is either consistently not cast-able or is cast-able at a price too high. This has remained paradox for many years. It has frustrated design engineers, aggravated foundry engineers and metallurgists who attempt to produce troublesome designs, and eventually management or buying team to under-estimating casting processes capabilities. Not to our surprise, it has often led to wrong notion (even belief in some cases) of castings being inferior than other metal forming processes, eventually leading to other forms of metal products to be designed when a casting would be the best product- if properly designed.

First, let us look at the viewpoints of each of the engineers.

Design Engineer

Design engineers typically consider functional mechanical elements, loads, functional environments-temperature, concentration, pressure, atmospheric attack, operating medium, failure-modes, mechanical and physical properties, fabricated shapes, automated secondary operations and aesthetics.

Quality Engineer

Quality and Quality Assurance engineers are concerned about the product, which could consistently comply with quality levels, and yet economical to manufacture. They like to, if not stubborn so to say, prefer adhering to the standards, codes and specifications, or to the different accepted quality systems. Matters on consensus are now developing when more and more companies are working to make products confirming to internationally accepted standards like ISO rather than individual country and proprietary standards.

Each alloy does not necessarily have exactly a matching standard in another country to that of home country. This is also true for different engineering standards prevailing within that nation. For example, AISI and ASTM are both American Standards. Yet, AISI type 304 grade stainless steel composition and physical characteristics are different from the corresponding values of ASTM/ACI 304 grade. Because former is a wrought alloy standard while latter is a casting standard. In addition, codes, standards, procedures and specifications are determined from working with standard specimens, under particular testing conditions and procedures. The resulting values are based on the standard specimen might not be

comparable to the actual values obtained in real application environment and importantly, in the casting that has different part geometries than the standard specification. Standards offer good reference values as far as castings/cast components are concerned. A standard product form is plausible to be procured strictly following the standard specification. Nevertheless, standards should be used as a means to an end rather than the end in itself.

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Metallurgical & Manufacturing Engineer

The metal-casters, patternmakers, and die engineers see fluid flow, heat transfer and solidification patterns in the mould, including hot spots as the metal/alloy changes from the liquid phase to solid phase; they see possibilities for infinite variability in casting shape. They also see foundry tooling (patterns, dies, and/or core boxes) that is critical to dimensional accuracy and consistency. They view surfaces to be machined, and other surfaces that must be consistent dimensionally for machining, fixturing and targeting. They analyse possibilities for specific alloys and heat treatment that is required for the casting's mechanical and physical properties. They see the need for pleasant castings (cast cosmetics or cast aesthetics).

Finally, when the design geometry and the alloy's cast ability are in conflict with each other, the metal caster must consider "thermal trickery", which is the use of chills, insulating, padding, exothermic materials, shifting solidification hot-spots and other heat transfer techniques to set up necessary solidification patterns (called directional solidification) in castings, which are not possibly aided from the casting geometry itself. Modern Finite Element Modelling (FEM) techniques and versatile software's are today available that can successfully simulate- casting solidifications, heat transfer solidification patterns in manufacturing processes, conduct stress and strain analysis, and perform failure analysis that are of great help to designers as well as manufacturers in designing optimal casting, casting - feeding and gating systems that result in final casting product without (or with minimal) metallurgical defects.

Conclusion

Based on these widely differing, yet significant viewpoints; it would be surprising to find good castings design to be obvious and trivial. In fact, cost-effective casting design is technically not a sinecure task for the design and quality engineer to accomplish.

How can we be of help in overcoming conflicting needs and striking truce by developing an agreeable solution?

At AcmeCast® we examine and assess our customer's products/ product related problems from a -design engineer, quality engineer, manufacturing and metallurgical engineer perspective.

Such an approach towards developing solutions gives us the competitive advantage over competition. It enables us to not only come up with solutions but also form basis of making solutions work to the benefit of our customers and, importantly end users. We believe in continuous learning and constantly applying our knowledge, experience and expertise in analysing problems without losing focus of delivering value to customers. One of the basic principles of the "**systems approach**" in engineering design is to define the system boundaries in such a way that conflicting requirements can be recognized and resolved. This is the principle that we are applying here. As our conceptual framework is further dealt with it reveals that geometry holds the key to resolving the design conflict identified within properly defined system boundaries.

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Elements of Conceptual Framework

Physical and Mechanical Characteristics

Four important physical characteristics affect the cast ability and performance of any given casting alloy. These are

- Fluid life
- Solidification shrinkage
- Slag formation
- Pouring temperatures

Each of these characteristics varies widely among alloys and is significantly different among similar alloys. Differences among these four physical characteristics significantly affect the geometry of well-designed castings.

It is also important to understand two important mechanical characteristics affecting the stiffness of any given casting design:

- Modulus of elasticity
- Section modulus

The former is a function of the stiffness of the alloy itself and the latter is a function of stiffness from the casting's geometry. These two mechanical characteristics are also at the heart of well-designed geometry.

Using these physical and mechanical characteristics

Recognize that the above six characteristics affect important variables in designing, producing and using metal castings. These variables include:

- Casting method
- Design of casting sections
- Design of junctions between casting sections Internal integrity required
- Dimensional tolerance and extent of near-net shape requirements Cosmetic/aesthetic appearance

Casting geometry as a tool

Casting geometry is the most powerful tool available to improve the following:

- Cast ability of the alloy
- Mechanical stiffness of the casting

Carefully planned geometry can offset alloy problems in fluid life, solidification shrinkage, pouring temperatures and slag formation tendency. Section modulus from geometry has the power to offset problems with lower modulus of elasticity.

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What to avoid

In developing a sound conceptual framework for casting design, it is important to avoid reliance on some traditional concepts and tools such as:

- Rules of thumb
- General "Do's and Do Not", that are typical of casting design or engineering handbooks
- Simple, orthogonal shape thinking; such as building blocks from mill shapes like plates, bars, tubes, I-beams, other kinds of extrusions of constant cross section etc.

The above shapes limit metal casting's power of infinite shape variability. Casting geometry can be much more free-flowing than orthogonal, extruded, and rotated shapes.

Knowledge and understanding

Just as important as it is in avoiding the above traditional tendencies in design engineering, it vital to know and understand the nature of molten metal and use it to one's advantage

- Embrace the idea of infinitely variable shape
- Use free-hand sketches for a conceptual designing. Move the mass around. Take mass out where it is not required and place it where it is necessary. Use variability of section modulus over length. Use the ability to vary section modulus over section length to design for uniform stress

Systems approach style to design thinking

Develop and make a paradigm shift from the conventional followed approach to "systems approach" in design thinking. Such an approach encompasses a wholesome perspective from initial need for a mechanical or structural element, to molten metal flowing into a shape, to the rough casting right out of the mold or die. It takes into consideration casting finishing requirements, secondary processing in the foundry, secondary processing at a subcontractor and/or the customer's plant, testing, assembly, and final use and abuse of the product, which contains the casting. When successfully applied, "systems approach", results in cost-effective, simple, and elegant metal casting design.

For "Systems Approach" in design thinking to solve your mechanical component design issues or optimizing it, contact:

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