Advanced Casting Technology
Literature study

Topics

1. **Use of standards in casting design**

   Standards are key tools in a design process and ensure soundness in many areas like geometry, purchasing contracts, materials and properties.

   What does a casting designer need to know about standards?
   Main casting related standards and why they are important?
   How do standards affect a design process?
   ISO 8062 – 3? Others?

2. **CAD programs and casting design**

   Computer Aided Design (CAD) or Computer Aided Manufacturing (CAM) has become the backbone of production engineering in many ways. Modern CAD programs have lots of good separate tools for a more automated process of mold/part design (e.g. CREO mold/cast).

   How do these affect the design process from the viewpoint of a casting designer?
   What is a good Computer Assisted Design process?

3. **Purchasing process of cast components**

   Casting components is often a multi-step process necessitating large investments, which makes it somewhat rare for companies to have in-house foundries. This in turn necessitates finding good suppliers and imposes lots of responsibilities on purchasing departments and purchasers themselves.

   What main steps does a purchasing process of cast components have?
   What are some of the possible pitfalls when sourcing critical parts?
   How do these steps affect the work of design engineer?
   Cooperation with a foundry, and the necessity of cooperation of design/purchase/production departments in-company?
   Conflicting requirements, e.g. can a purchaser screw themselves over by requiring wrong things?

4. **Casting simulation and casting design**

   Casting simulation tools have been a great addition in ensuring good quality mould designs and castings. Gating and feeding systems are one of the most critical areas of casting design and play a large role whether a component is usable or not in the end.

   What are the main commercially available simulation programs regarding casting simulation?
   What is casting simulation normally used for and what can they be used for generally?
   How can simulation be used to improve the design process and properties of castings?
What advanced features do these kind of software have?
Virtual prototyping and automated optimization possibilities with simulation tools (e.g. MAGMA5.3 optimization modules)?

5. Selection of casting quality level and its effect on construction

Castings, like components made with almost any other production method, are not 100% perfect/sound. This simple fact complicates design processes in general and puts responsibility of knowing what is possible to achieve with select casting methods and materials cost effectively on designers. Quality levels are used to define the normal attainable ranges of accuracy and properties.

What needs to be taken into account when assigning a required quality level of castings?
What effects does quality level have on construction/design of a cast part?
Importance of "optimal quality level"? E.g what is passable and what is too strict?
Can a purchaser screw themselves over by choosing a wrong quality level?

6. Additive manufacturing in casting design (and manufacturing)

Additive manufacturing can be said to be on the peak of hype at the moment. It’s not far-fetched to say that using additive manufacturing as a main production method is currently not a good way to mass produce parts. However, coupling different kinds of additive manufacturing technologies with established methods, like casting, might be a huge leap forward.

How can additive manufacturing (AM) benefit a casting designer and the production/prototyping process of castings?
Full AM (e.g. metal printing) vs traditional casting vs a hybrid process (e.g. pattern printing for sand or investment casting)?
What pros/cons does AM have regarding freedom of shape versus a traditional casting process?
In which part of production is AM best used when producing castings?

7. Patternless casting

Patternless production methods, like sand mould machining (or robotic moulding) and sand mould printing, are mainly used in fast prototyping processes of cast components. These kinds of processes lend themselves to flexible production ideologies and “zero batch” production of castings. Foundries need to be ready to make decreasingly smaller series and more complex geometries in the current global market climate. Patternless methods are one of the ways this can be achieved cost-effectively compared to established traditional ways.

What type of patternless casting methods are there?
What advantages/disadvantages do these have, e.g. regarding small series or prototyping vs traditional methods and bigger production series?
Possibilities of robotics and automation?
8. Comparison between casting and forging

Comparison of casting versus forging comes up often even with laymen, enthusiasts and hobbyists. The view is often skewed with feelings of superiority of one over the other and is further strengthened when marketing and money comes into play. The only ultimate fact is, that all production methods have their strengths and weaknesses.

What are the main benefits and disadvantages of cast and forged parts?
Is there a difference in the possible shapes/geometries that can be produced with these manufacturing processes?
Do casting and forging have same kind of main design principles, e.g. parting planes and drafts?

9. Near net shape casting methods

Near net shape production methods are often used when part dimensional accuracy, great surface quality and least amount of finishing/machining is wanted. Tightening of these requirements is not possible with all casting methods. However, some methods are designed to achieve those tight tolerances.

What are the main near net shape casting methods, e.g. investment casting?
What benefits/disadvantages do these have over more traditional methods?
Do these have any differences in design principles compared to other casting methods?
Are these methods geared for big or small batch sizes?

10. Filtration of castings

Lots of things contribute to final quality levels of cast components. Filtration, reduction of turbulence and good gating design are key aspects in keeping metallurgical quality high.

What purposes do filters have?
What type of filters can be used for which cast materials?

11. Feeding and solidification characteristics of cast materials

Design of proper feeding systems ensure sound castings without shrinkage defects and the like. Some cast materials are better than others in self-feeding, e.g. ductile cast iron vs. cast steels.

12. Exothermic feeders, their use and yield

Basic feeders are reservoirs of molten metal to replace shrunken material inside mold cavities. Natural feeders have relatively low yields (feed ratio) due to thermal losses and create larger foundry returns inside casting processes. Exothermic feeders are one solution to this challenge.

What is the exothermic effect based on and how big improvement does it make?
How are they used compared to natural (moulded) feeders?
Are there environmental factors regarding their use?

13. Environmental aspects and circular economy of foundries

Foundry industry is sometimes falsely seen as a particularly dirty and polluting business. Current regulations are in fact quite strict on what can and can’t be done. Many byproducts are usable materials in other industries and some can be reclaimed to be used again in foundry process.

Moulding sand reclamation techniques?
Use of foundry sands ...

14. Foundry sands and binder systems

Sand casting is one of the most used types of casting methods, and there are multiple ways to harden sand mixtures in moulding processes. There are also many different sand types that can be used in addition to binders. Some binder systems work best with particular processes. E.g. rammed sands vs resin binders.

What are the main types of foundry sands (base sands) and their pros and cons, health and safety, economic factors? Global availability of certain sand types?
What are the main types of binder systems and what are they best used for?
Are there differences in reclamation possibilities?

15. Fettling of raw castings

Fettling is the process where raw castings are removed from gating systems and all unwanted irregularities are removed before steps like machining etc. Processes like cutting and grinding are used manually and nowadays more automatically than ever before. Fettling is often forgotten compared to other processing steps and can incur large costs in the long run.

What types of operations can be used to make fettling easier or more consistent?
Are there mould/part design choices that reduce unwanted features, like casting flash?
Possibilities of robotization/automation?

16. Effect of series sizes on choice of casting methods

All casting methods, from more manual to automatic types, have certain ranges where they are most cost-effective. Tooling and moulding, for example, have very different costs between permanent and lost-mould methods. Some cast products are optimal for a certain process, but may be done differently due to tooling costs vs. batch/series size.

What kind of series are specific casting methods best for (select a few most important ones)?
Manual vs. automatic moulding?
Permanent vs. lost moulds?
Other factors?

Hint: software like CES Edupack is free for Aalto students.
17. Patternmaking and sand moulding

Before any moulds can be made, tooling is needed (lost-mould methods). The art of making these toolings is called patternmaking. Naturally, any raw casting can be as good as the pattern used. Tooling materials have different properties regarding dimensional stability, mouldability and other factors.

What kind of materials are normally used in patterns?
What types of patterns are there? (hint: match plate etc.)
Are there any design choices in part, pattern or core design that are extremely important in ensuring casting quality or dimensional stability?

18. Welding of cast materials

Welding, same as casting, is best used in conjunction with other production methods to achieve optimal efficiency. Some cast materials have better weldability than others, and welding is often done to some castings and almost never on others.

What cast materials are readily weldable, which are not, why?
What special factors are there in production or repair welding of castings?
Ferrous vs. non-ferrous?

19. Mould coatings

To ensure high surface quality and reduce surface defects, expendable and permanent moulds are nowadays coated with various (often refractory) coatings. Some coatings are water based and others made with other solvents for different purposes.

In what processes are coatings normally used and why? Why not?
What type of coatings are there?
Steels vs. cast irons? Non-ferrous castings?
Environmental factors with water based vs. others?

20. Aluminium and its' alloys as cast materials

Aluminium is one of the most used engineering materials with multiple good properties, like strength/weight ratio and easily used in permanent molding techniques. Pure aluminum is almost unusable in most engineering applications and thus gets most beneficial properties through different alloying elements (standardized alloying system designations).

What are the main alloy types of cast aluminium?
Why are these different alloying systems used and what beneficial properties do they give?
Heat treatments? Castability? Melt processing?
What are the most used casting methods?
21. Cast irons, the versatile iron-carbon composite materials

Ferrous cast materials are undoubtedly one of the most used and known engineering materials to exist. Cast irons have lots of great properties that arise out of carbon alloying and manipulation of graphite in melt. Multiple variations of cast irons exist, each with their own specialty uses.

What are the main cast iron types and what are they normally best used for?
What is special about carbon and iron?
Melt processing? Heat treatment? Castability?
What are the most used casting methods?

22. Cast steels, strength through heat treatment

Casting steels is not as easy as it is for cast irons, which contain fluidity enhancing alloying elements. One of the main advantages of cast steels is huge variety of possible properties through alloying and heat treatments. Essentially all steel castings are heat treated to homogenize microstructure and improve mechanical properties. Stainless and heat resistant steels are some examples of special cast steels.

What different types of cast steels are there?
What are the main alloying elements?
Why are most steels heat treated?
Castability?
What are the most used casting methods?

23. Copper based casting alloys, corrosion resistance and sliding properties

Copper based alloys are often used in special applications due to their properties. Different variations of bronzes and brasses are widely in cast form in applications like sliding bearings and marine propellers.

What different types of cast copper alloys are there and what’s special about them?
What are the main alloying elements?
Castability?
What are the most used casting methods?

24. Magnesium casting alloys, light weight and complex processing

Magnesium alloys are in the least dense range of usable engineering cast metals. Aluminium alloys are regarded as light metals, but magnesium alloys take this specialty even further while still retaining enough mechanical properties. Processing and casting of magnesium is not as easy, though.
What different types of cast magnesium alloys are there and what’s special about them?
What are main alloying elements used?
Castability? Melt reactivity?
What are the most used casting methods?

25. Reactive cast materials

Some cast materials, like magnesium and titanium, are rather reactive in normal atmosphere at melting temperatures and they need special attention process wise. Flammability and oxidization tendency are some of the things that need to be thought about when processing these reactive materials.

What cast materials need special care in molten state? ("more than normal")
What can be done to make casting of these materials possible?

26. Zinc cast alloys

Zinc alloys have some special characteristics, like very low melting temperatures compared to many other non-ferrous cast materials. Thus, they have many good uses where other materials might not be economical.

What different types of cast zinc alloys are there and what’s special about them?
What casting methods are normally used? Why?
Castability?

27. Cast composites

Cast composites (or cast metal matrix composites) are combinations of metal and different reinforcements to fill a specific niche. The choice of reinforcement often dictates what properties are wanted, like hardness or wear resistance etc.

What are the main metal matrix types used? Why?
What casting methods make the use of these possible?
Reinforcement/addition types?
Examples of applications?

28. Cast superalloys, high tech materials for extreme environments

Superalloys are, as their name suggests, alloys that have superb properties in highly stressed applications where other types of materials are insufficient. The term “superalloys” cover many alloying systems based on different elements.

What different types of cast superalloys are there and what’s special about them?
What are main base and alloying elements used?
Need for special processing steps?
What are the most used casting methods?

29. Sand casting, from small to massively huge parts

Sand casting is one of the most versatile methods in the field of casting and has little limitations regarding size and materials, but at the same time is not optimal for every situation. Especially parts that need intricate cored/hollow features are suitable for sand moulding.

What types of sand moulding methods are there?
What cast materials are suitable with sand casting?
How accurate parts can be made?
Normal batch sizes? Small or big production runs?

30. Investment casting, high precision – limited size

Investments made with lost pattern-methods are one of the oldest metal production styles in existence. One of the main advantages of investment castings are superb surface qualities and dimensional accuracy.

What moulding methods can be used?
What cast materials are suitable?
How accurate these methods are?
Normal batch sizes? Small or big production runs?

31. Die casting, the route to high production runs

Die casting, in gravity, low pressure or high pressure variants are widely used permanent mold methods. Permanent mold methods are much more material specific than with sand moulding, for example. Permanent vs. lost mould methods have different advantages and disadvantages and naturally are optimal for different things.

What types of die casting methods are there?
What types of cast materials are they suitable for? Why?
How accurate these methods are?
Small or big production runs? Mould cost?

32. Compound casting

Compound casting methods combine materials (similar or dissimilar) together to form a composite casting in some sense. There are cases that require very specific material properties in certain locations. Compound casting can potentially achieve these, especially in lightweight applications.

What is this method based on?
What materials can be cast in this style?
Application examples?

33. Centrifugal casting

Centrifugal casting is a method to economically produce cylindrical parts that might not be easy to consistently produce with other methods.

What materials are best suited for this?
Special applications?

34. Shell molding

Shell molding as a process is somewhere between sand molding and investment casting. As such, when normal sand casting is not enough, this method is a good alternative. In shell molding, as the name suggests, a thin hardened shell is used rather than a bulky mold.

What is the process like?
What advantages compared to other methods like sand casting?
What materials can be used?

35. Squeeze casting

Squeeze casting is a method where the basic principles of casting and forging are brought together. This method is somewhat similar to die casting in the sense that thin wall components are possible.

What is the process like?
A way to produce cast composites?
What materials are optimal for this method?

36. Semi-solid casting methods

Semi-solid casting (SSM) is a method where the semi-solid slurry nature of some cast materials are used to circumvent method and material specific challenges in more established processes. High-pressure die-castings, for example, have many disadvantages in material properties and processibility compared to other methods.

What different SSM casting methods are there? What is special about them?
What materials can be used in these?
What advantages compared to normal ‘fully molten type’ -methods?

37. Non-destructive testing (NDT) of castings

The engineer that says it’s possible to manufacture flawless parts is a liar. Non-destructive testing is used to check quality levels of castings and are normal elements of production processes. NDT
methods are often used in conjunction with destructive ones, but often in such way that minimizes the need to scrap parts. Optimal way to test is a key point especially when it comes to extra-large castings.

What are the NDT methods that can be used to check castings?
What types of defects can be found?
What cast materials are they usable on?

38. Fluid dynamics of castings

Pouring/Filling is one of the most important elements in making a good casting. Badly designed running systems and turbulent flows are some of the main reasons for the undeserved reputation that casting as a production method is low quality compared to others. How melt flows into mold cavities is hard to design properly for the uninitiated, and so needs to be thought as a critical step in production of castings.

What problems does bad filling system create?
What are key elements in a good filling system?
Do different cast materials change the situation in any way? E.g. are some materials more prone to fluid based defects compared to others?

39. Mould dynamics

Good moulds make good castings. Ease of moulding is not the only thing to think about when designing tooling. Moulds are as dynamic as the materials poured in to them and need proper process control to work as intended.

What type of mould defects are there?
What kind of reactions may happen in-mould?
Do different cast materials change the situation? E.g. casting temperature?

40. Melt reactions

Molten metals are often very reactive and bad process control can create unwanted defects in cast parts. Gases, surface films, inclusions and etc. have material specific effects that need to be taken into consideration.

What are the main gaseous interactions?
Oxides, surface films and others can be entrained in melts. How, why and what effects do these have?
How can melt reactions be lessened?
41. Casting accuracy

Accuracy of final cast products are combinations of many processing steps. For example, tooling, moulds, assemblies and their design dictate how accurate final components truly are.

What contributes to accuracy and error of cast parts?
Material and moulding method specifics?
Does dimensioning (design and drawings) and measurement techniques contribute to total accuracy?

42. Topology optimization and casting

Topology optimization is a mathematical geometry optimization methodology, which aims to maximize part performance vs. objectives like weight saving. New supporting technologies, like additive manufacturing, used in conjunction with more established production methods can enable production of shapes not normally possible.

What is this optimization based on?
What additive manufacturing methods might be possible to use in conjunction with casting?
Feasibility?

43. History of casting as a production method

Casting is one of the oldest mass scale production methods in existence. Quality of historic castings might not be comparable to modern metallurgy, but compared to other metal technologies at the time, casting was and still is a great choice for many applications.

What casting methods were used in historic times?
What alloys were invented when and where?

44. Castings in arts

Castings are also used in many non-engineering applications. From sculptures to other quite massive installations, casting can be a great way to enable production of the shapes that an artist wants. The processes in artistic castings are quite similar to the ones used in engineering fields.

What type of moulding or casting processes are often used?
What materials?
What special techniques might there be?

45. Examples of replacing other production methods with castings

A more free-form topic. The key idea here is to show what advantages castings can have compared to other manufacturing methods. Case studies or other types can be used here to show examples.

46. Choose your own topic

If your own special interest cannot be found here, suggest one to the course staff.