

Kick-starting new engineers

At EDS Casting & Forging B.V.



EDS

Mathijs ter Kuile





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ABSTRACT

EDS Casting and Forging B.V. (EDS) is an Amsterdam-based design agency, specialised in redesigning welded assemblies into castings. As EDS is growing rapidly, and plan to keep on growing, they expressed a need of centralising their in-house design knowledge. From this need, the following problem statement was formulated:

“New engineers at EDS have a lack of easily accessible sources, to learn how to design an economical casting or forging”

To approach this problem, the following research questions were formulated:

1. What does a new engineer need to learn in order to design an economical casting or forging at EDS?
2. What kind of learning source could fit within EDS?

To find answers to those research questions an analysis phase was executed considering the following topics:

- EDS Casting and Forging
- Designing at EDS
- An economical casting or forging
- New engineers at EDS
- Learning sources
- Estimating cost

As can be observed, these topics cover all crucial elements of the research questions, enabling the analysis phase to answers them. The insights from this analysis were used to create concepts, and define design criteria to evaluate those concepts.

The concept that was chosen to develop further was the EDS kick-start, a program specially designed to optimise the learning curve for new engineers at EDS.

The EDS kick-start is divided in 3 phases:

- The 1st phase takes 1 week. In this week, the new engineer should obtain as much knowledge about casting and forging as possible. For this phase the EDS traineeship was developed.
- The 2nd phase takes 3 months. During this period the new engineer needs to be productive for EDS, while still learning new skills and knowledge. For this phase a recommendation was made for an EDS learning sources overview.
- The 3rd phase takes as long as the engineer is working for EDS. During this phase the engineer should be fully enabled to learn from the projects he is doing. For this phase a recommendation was made for an EDS quotation book.

The product of phase 1, the EDS traineeship is the main focus of this project. This traineeship was developed using the principle of constructive alignment (Biggs, 2011). The assignments of the traineeship were inspired by the ‘7 principles of good teaching’ (Chickering, 1987) and build upon learning goals that were shaped, making use of Blooms taxonomy (Bloom, 1956).

An early version of the traineeship was tested with a new engineer and found to be very valuable for both the trainee, the mentor, and therefore, also for EDS. With the testing insights the traineeship was developed further to an final version, and presented to EDS, ready to be used for the foreseeable future.

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1. INTRODUCTION



This chapter describes what this graduation project is about. It introduces the context that formed the problem statement, and the approach that was used to come to a solution (a design proposal) that would tackle this problem.

1 INTRODUCTION

Throughout the ages, shaping metals by casting and forging has proven its value to human development. A large variety of casting and forging methods have been developed, enabling humans to manufacture metal parts into many different shapes and sizes, in both very small, and in very large quantities.

Considering casting (Figure 1), the process itself is easy enough to understand: A quantity of metal is heated to just over its melting point, after which it is poured into a preformed cavity to solidify. However, designing a casting for minimal costs while meeting strict quality requirements to perform its function, that is where the challenges of casting (and the same counts for forging) come to practice.

Designers nowadays need to know a lot about the many different manufacturing processes and materials in order to design an economical product that fulfils its requirements. The higher the requirements, and the more the possibilities of the process are exploited, the more knowledge is required.

Preliminary problem statement

EDS Casting and Forging B.V. (EDS) is a medium sized design company in Amsterdam that is specialized in developing castings and forgings. They started in 2015 with only a limited amount of casting and forging knowledge, but in only a few years they have grown to a 13-people strong design company with substantial in-house engineering knowledge about casting and forging.

As EDS is still growing at a high pace, the need appeared for drafting a casting/forging design guide. This book, full of design guidelines and tips and tricks, would bundle all the in-house knowledge about designing castings and forgings. This way, all engineers could get their information from one central document, and new engineers could quickly be up to date to all the manufacturing insights. Based on this need, the following problem definition was stated:

'Engineers at EDS, both starting and experienced, have a lack of easily accessible sources to create and evaluate concepts on manufacturability and price'



Figure 1 Casting metal

Final problem statement

The problem that arises with guidelines is that they are not strict testable rules, but rather a suggestion on what is the norm. For instance, a casting shape in which the metal solidifies before it is completely filled (cold-running), can still be filled when a more extensive gating system is applied. In other words, these guidelines do not indicate what is possible, they just indicate what normally can be manufactured without extra measurements or high rejection percentages (leading to additional costs).

Although it is possible to define casting and forging methods in a series of guidelines, it might be more useful to create an understanding about the process variables that form the basis for these guidelines. In other words: to design effectively one should not just apply casting and forging guidelines, but rather learn to understand what they are build upon, and learn to apply them effectively to a design. Therefore, the problem statement that is addressed in this graduation project is:

'New engineers at EDS have a lack of easily accessible sources to learn how to design an economical casting or forging'

Research questions

From this problem statement, two research questions were formulated:

1: What does a new engineer need to learn in order to design an economical casting or forging at EDS?

2: What kind of learning source could fit within EDS?



2. ANALYSIS



This chapter describes the topics that were researched to find answers to the research questions that were formulated in the introduction.

2.1 COMPANY PROFILE AND AMBITION

EDS Casting and Forging B.V. (EDS) is a design agency based in Amsterdam. EDS stands for Engineering, Design, and Supply, which means they are not only able to do the design and engineering of castings and forgings, but are also able to supply the parts, making use of their worldwide network of foundries and forgers.

Company activity

The slogan of EDS is: "Together, we reduce costs". For most projects, this is done by making a cast redesign of a formerly welded assembly. Figure 3 shows an example project where EDS has managed to reduce cost (and weight) significantly.

Although the main business of EDS is in sand and investment castings, they are aiming to be oriented towards manufacturing in general.

Clients and projects

EDS does many different projects for companies in many different countries. They develop both very simple parts and more complex parts as for example the rear axle of Big-M (Krone's biggest truck).

Future vision

As illustrated in Figure 2 EDS is growing fast, and plans to keep growing in each turnover, number of employees and in organisational-structure. One big step in this growth, is getting ISO-9001 certification in which all company processes are defined.

Conclusion

EDS is a fast growing company, specialised in redesigning welded assemblies into castings, this way reducing costs for the customer. Most clients are original equipment manufacturers for agricultural vehicles or other metal work.

EDS Casting & Forging

Employees:

12



Men-Women:

92%-8%



Annual turnover: €1.300.000



Client sample:



2.1 COMPANY PROFILE AND AMBITION

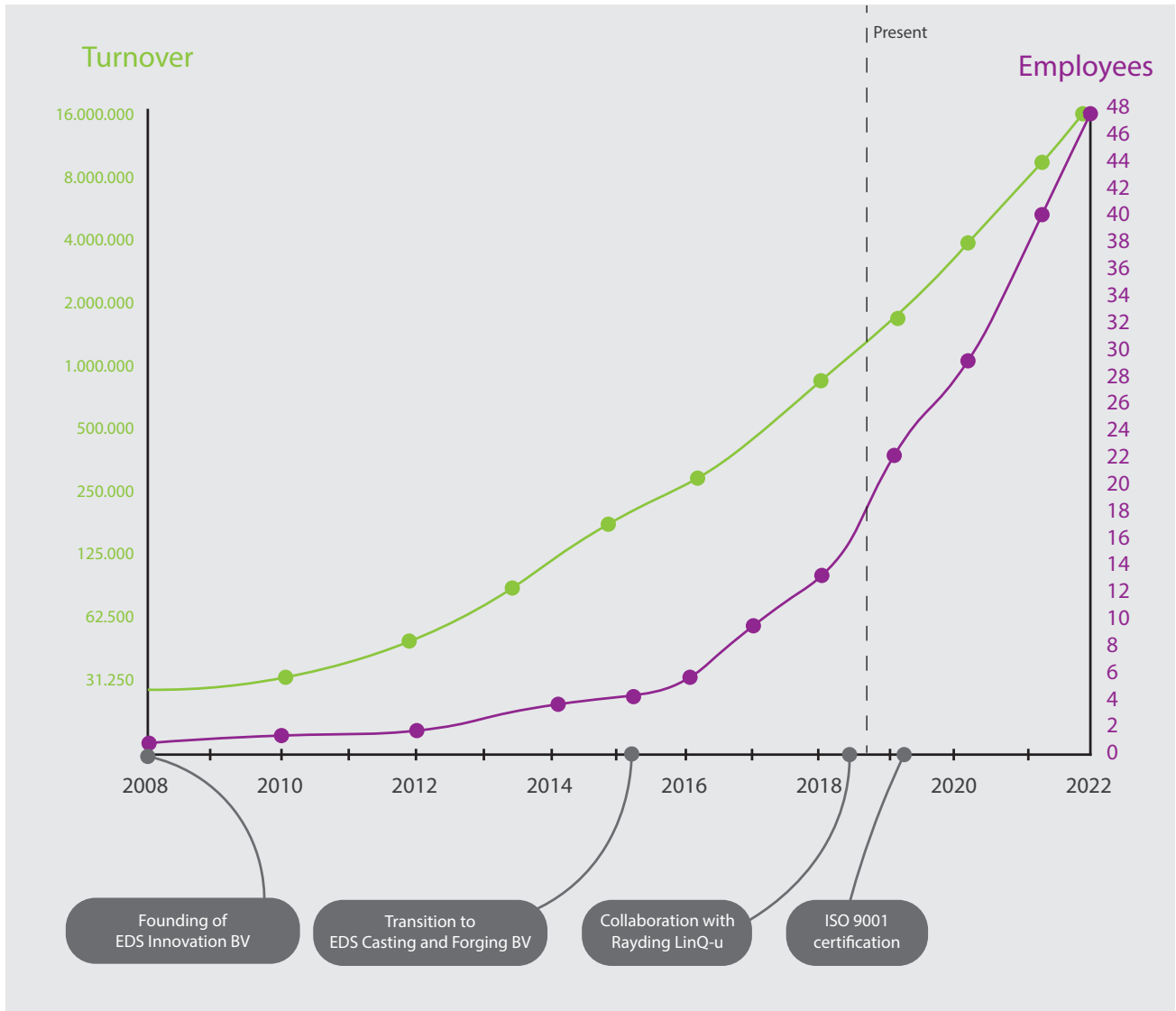


Figure 2 EDS history and goals

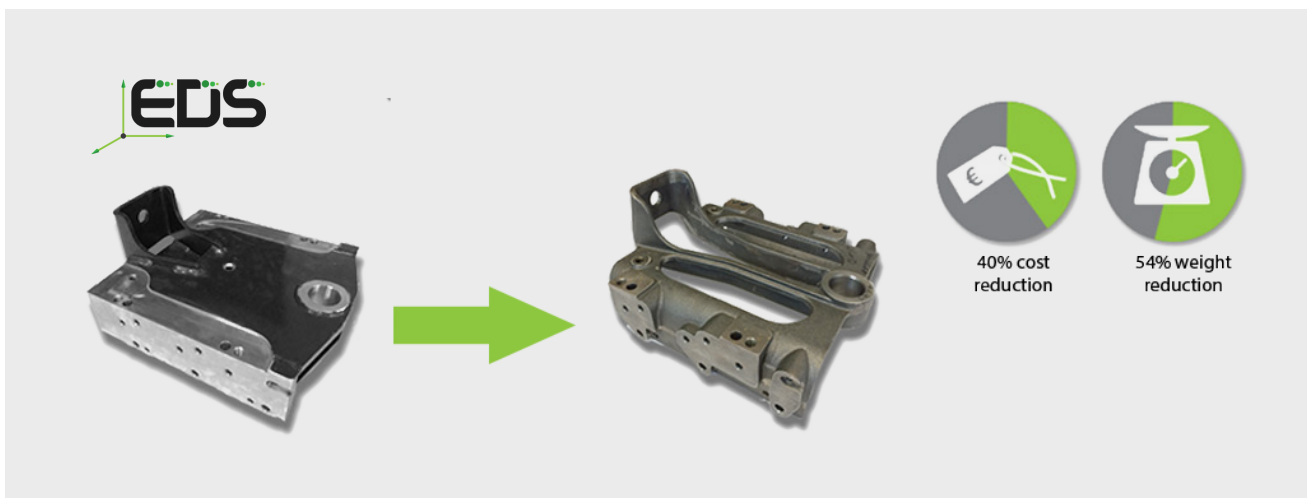


Figure 3 "Together, we reduce costs"

2.2 SKILLS FOR DESIGNING AT EDS

To find out what it is necessary to design at EDS, the EDS design phases and the required skills for designing at EDS are analysed. After this analysis, the two topics are combined in a matrix to map all skills that are required throughout the design process. The information of this analysis is obtained by reading casting and forging literature, by visiting multiple foundries and by performing multiple EDS design projects.

EDS design phases

The EDS design phase is initiated when the sales department has indicated a promising casting or forging project and has communicated this part to the engineering department. The EDS design phase consist of an analysis phase, a concept phase and an engineering phase. After the engineering phase the project is passed on to purchase.

Analysis phase

At the start of the analysis phase, the engineering department is provided with the 2D and 3D of the original design, and a 'Funnel document', that shows the business case of the part. With this information the context of the product is analysed using the Product Analysis Document (PAD). This document contains all the topics (such as current price, load-case, coating, etc.) on which the engineers should be fully informed before the project can go to the concept phase .

Concept phase

In the concept phase, the designing starts and concepts are generated. Concepts differ often in manufacturing process, parting line, use of cores/slides, or in the degree of similarity between the concept and the original part (1:1 design vs new

architecture). The concepts are modelled in CAD, sometimes 3D printed and communicated to the client. Together with the client one concept is chosen to be further developed.

Engineering phase

In this phase the product is optimized for manufacturability, weight and strength. Almost always a Finite Element Method (FEM) study is done. After the design is finished, technical drawings are made so that quotations can be requested.

Skills for designing at EDS

When designing for EDS the engineer should know the in-house established EDS methods, should have general design skills, and should have a good manufacturing knowledge. The more developed the designer is in these skills, the faster and better will be the outcome of the project.

Knowing EDS methods

EDS makes use of fixed templates and methods in the design phase. To design for EDS it is required to know these methods and documents by heart.

General design skills

As EDS is a design company, design skills are required. This means the engineer has the ability to understand the context of the project and to come to a new solution that creates value.

Manufacturing knowledge

To come to a fruitful design that can be manufactured the designer should have knowledge about the main manufacturing processes.

2.2 SKILLS FOR DESIGNING AT EDS

Skill matrix

When the three phases of the EDS design phases are combined with the three skills for designing at EDS, an overview is created for what skills are required in what phase while designing at EDS.

Conclusion

The skill matrix (Figure 4) provides insight in what is required from the designer when designing at EDS. As can be seen EDS works a lot with templates (Funnel document, PAD, report template). Therefore, it can be assumed that templates would fit EDS well for teaching new engineers.

Skills for designing at EDS

	EDS method	General design skills	Manufacturing knowledge
Analysis phase	Funnel document Kick-off meeting PAD document	Structural working Analytical skills Mechanical skills (load case etc.)	Weldings Tolerances Standard components
Concept phase	SolidWorks buildup 3D printing	Creativity Design methods Iterative design circle Visual skills	Casting principles (physics) Parting line and draft Manufacturing processes Costs
Engineering phase	Technical drawing template FEM setup EDS report template	CAD skills Supporting decisions well	Material characteristics Design guidelines

Figure 4 Skill matrix

2.3 AN ECONOMICAL CASTING OR FORGING

The phrase 'an economical casting or forging' can be interpreted in different ways. Therefore, this chapter defines what is actually meant with these terms.

Casting and forging processes

When talking about casting and forging there are many casting and forging processes that could be considered.

To narrow down the focus of this graduation assignment it was chosen to make a selection of these processes based on their relevance for EDS and their relevance for the casting/forging industry.

- Sand casting was chosen as this process is by far worlds most used casting process and often used by EDS.
- Investment casting was chosen as most EDS products are manufactured with this method.
- Hot closed die forging was chosen since this is an interesting alternative when the material requirements can not be reached by any of the casting processes.
- Gravity die casting was chosen because it is an important process in the casting industry.
- High pressure die casting was chosen as it is an important process in the casting industry, and allows for radical other product geometry than all other casting processes.

Economical design

By doing design projects and researching costs (see chapter 2.6), the elements of an economical design became clear.

In an economical design

- A process is chosen that fits the shape, tolerance requirements and quantity of the design
- The use of cores and slides is minimised
- The tooling is kept simple
- The material of the part is chosen wisely, and the amount minimised
- The parts is designed conform the casting design guidelines of the given process so no extensive gating is required, and the percentage of rejected parts is kept low.

These definitions approach an 'economical design' in a very restrictive way. Through interviews with experts in the field, it became clear that there was a second layer of an 'economical design', which yielded a definition that is a bit more opportunistic:

"A economical design is a design that fully utilises the possibilities of the used manufacturing process"

Figure 5 shows two investment cast redesigns (right and middle) of a machined original design (left). In this example the choice of having an expensive process with an expensive design (many slides required) is justified by the added value it creates (no more machining/assembly costs).

2.3 AN ECONOMICAL CASTING OR FORGING

Process choice

A process choice can be a difficult choice as many variables should be taken into account when making it. Often the choice is between a cheaper process with extra (machining) costs, or a more expensive (qualitative) process that needs less secondary processing. At EDS, in many cases both versions are developed, and only after that, the quotations determine which process is chosen.

Design guidelines

Every process allows for a different product geometry (like minimal wall thickness). Designers should know what geometry is possible with which process, what could be defined in design guidelines. However, as many variables have an influence on them, it is very difficult to establish design guidelines.

At EDS there is no in-house source for these design guidelines. As a result most engineers design with verbal guidelines developed by the lead engineer, or they use guidelines found online.

Conclusions:

At EDS, when talking about casting and forging, in most cases the following processes are meant:

- Sand casting
- Investment casting
- Hot closed die forging
- Gravity die casting
- High pressure die casting

When these castings and forgings are economically designed, it means that the design fully utilises the possibilities offered by the process. Those possibilities could be defined in design guidelines. Nevertheless, this is not easy, as these design guidelines are also dependent on many variables. This is also the reason why EDS has no in-house design guidelines.



Figure 5 *Fully utilisation of process possibilities*

2.4 NEW ENGINEERS AT EDS

EDS has been growing significantly over the last years and aims to keep on growing. In order to keep on growing, their engineering capacity should grow as well. Therefore, EDS is hiring new engineers at a high pace. As these engineers are the potential users of the design proposal that will result from this project, it was analysed who they are, and what design experience and manufacturing knowledge they have.

In researching these questions, multiple semi structured interviews have been conducted with EDS employees and the target group itself.

Target group

To keep up with its growth, EDS is planning to hire on average 5 employees (out of which 3 should be engineers) on an annual basis.

Currently, EDS recruits these students by offering internships and graduation projects to students. Most of the students like the company so much that after their project/study, they decide to stay at EDS.

EDS finds these (sometimes foreign) students by giving lectures at design schools, pushing graduation assignments to the graduation wall, or by personal relations. The students are mostly a 3rd year or higher in their WO or HBO studies.

The students are selected based on the EDS-DNA and skill-set displayed in Figure 6.

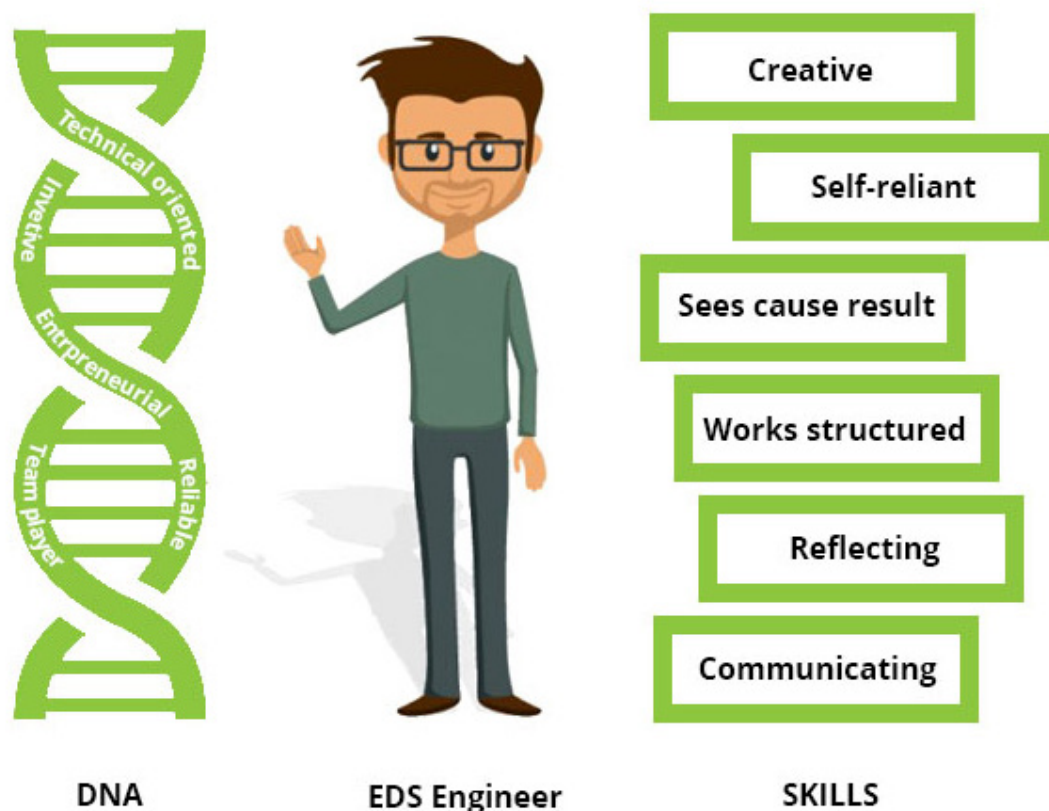


Figure 6 EDS DNA and skill-set

Design experience

As all starting engineers have a background in design schools, they are all familiar with the basics of designing. They know about design methods, have experience with a variety of design projects, and know the iterative design circle (if not literally, they do know by feeling). They know to draw 'free body diagrams', analyse functionalities, and have basic visualization and CAD (SolidWorks) skills, to give shape to their ideas.

Knowledge about manufacturing

In the Netherlands both WO and HBO design studies teach their students the basics of manufacturing. A research was conducted to indicate how much manufacturing knowledge was possessed by these students (see appendix 18).

Almost all interviewees showed to have a basic understanding about casting and forging. Almost all of them knew about draft and parting line, material properties, use of slides and cores, and also about shrinkage and filling the mould.

What they were not familiar with were how the different processes were executed in practice, the unique selling points of the different casting processes, casting guidelines, costs of castings and how to use tolerances.

Starting at EDS

New engineers are supplied with an 'engineering introduction training' sheet (see appendix 19). This sheet lists 5 points that the trainee should perform when starting at EDS. Point 1 is reading old project reports, point 2 is reading casting literature and standards, point 3 is traveling to as much clients/suppliers as possible, point 4 is looking over the shoulder of an other employee, and point 5 is performing design projects.

Although this approach is proven to be successful, it was observed from personal experience that this might not be the most efficient way to start designing at EDS Casting and Forging. Point 1 and 2 provided not as much manufacturing knowledge as required for point 5, point 3 did barely happen, point 4 was found to be slightly awkward, and point 5 was effective, but was time consuming for the mentor, as not yet enough casting knowledge was obtained to be able to design independently.

Conclusion

The engineers that start at EDS are mostly Dutch students, selected on the basis of their fit with the required 'EDS DNA' and 'EDS skills'. Varying per individual, they have a vague, or a basic understanding of the main manufacturing processes, but none of them would be able to design an economical casting. The introduction training helps to learn this, but has most likely not the most efficient approach.

2.5 CURRENT LEARNING SOURCES

To define what kind of knowledge sources can be used for this project, an overview was made of the current learning sources that can be used to obtain casting and forging knowledge.

Matrix variables

To get a overview of the diversity of the learning sources it was chosen to map them in a matrix (Figure 7). To create the matrix the following two variables were identified:

General versus specific sources

There is a big difference in how specific sources can be. Some learning sources teach very general insights, like how the shaping process happens, while others are very specific about for instance process variables, or material properties.

Approachable versus hard to comprehend sources

There is also a large difference in the comprehensibility of the learning sources. While some sources are really approachable and easy to get insights from, are other sources way less easy to understand.

Identified sources

The following sources were identified as being effective for learning about casting and forging:

Literature

There is an abundance of literature sources dealing with casting and forging. Some of them explain just the basic principles behind a method, for example 'Manufacturing and Design' (Tempelman, 2014), and 'Making it' (Lefteri, 2012). They provide a good starting point to design, but when more specific or in-depth knowledge is required more advanced literature like

the 'casting iron' (Davis J, 1994) should be considered. Also there are many great informative papers like for instance 'Casting design for performance' (Lampman, 2009).

Online sources

A great amount of information can be found online on websites of foundries, forgers, universities, or even Wikipedia, which was observed to be a valuable source for casting and forging information. Especially when having specific questions, online sources are an effective tool to come to quick answers with a reasonable trustworthiness.

Photo's and video's

Although there does not seem to exist a good video that explains casting or forging from a designers perspective, there are many interesting (DIY) video's to be found online. EDS also has a media library with very informative photos and videos about the processes in practice.

Foundry visits

Foundry visits were found to be a highly effective learning source to understand the process, to see what shapes are easily produced, and to see what shapes are harder to create.

Analyse everyday products

This learning source, or better framed: this mind-set is very effective to learn about casting and forging. By analysing existing parts, a lot of insights can be obtained about design choices and design possibilities.

Showcase shapes

For injection moulding there are various showcase shapes that show the possibilities and the consequences of for instance various wall thicknesses or rib designs.

2.5 CURRENT LEARNING SOURCES

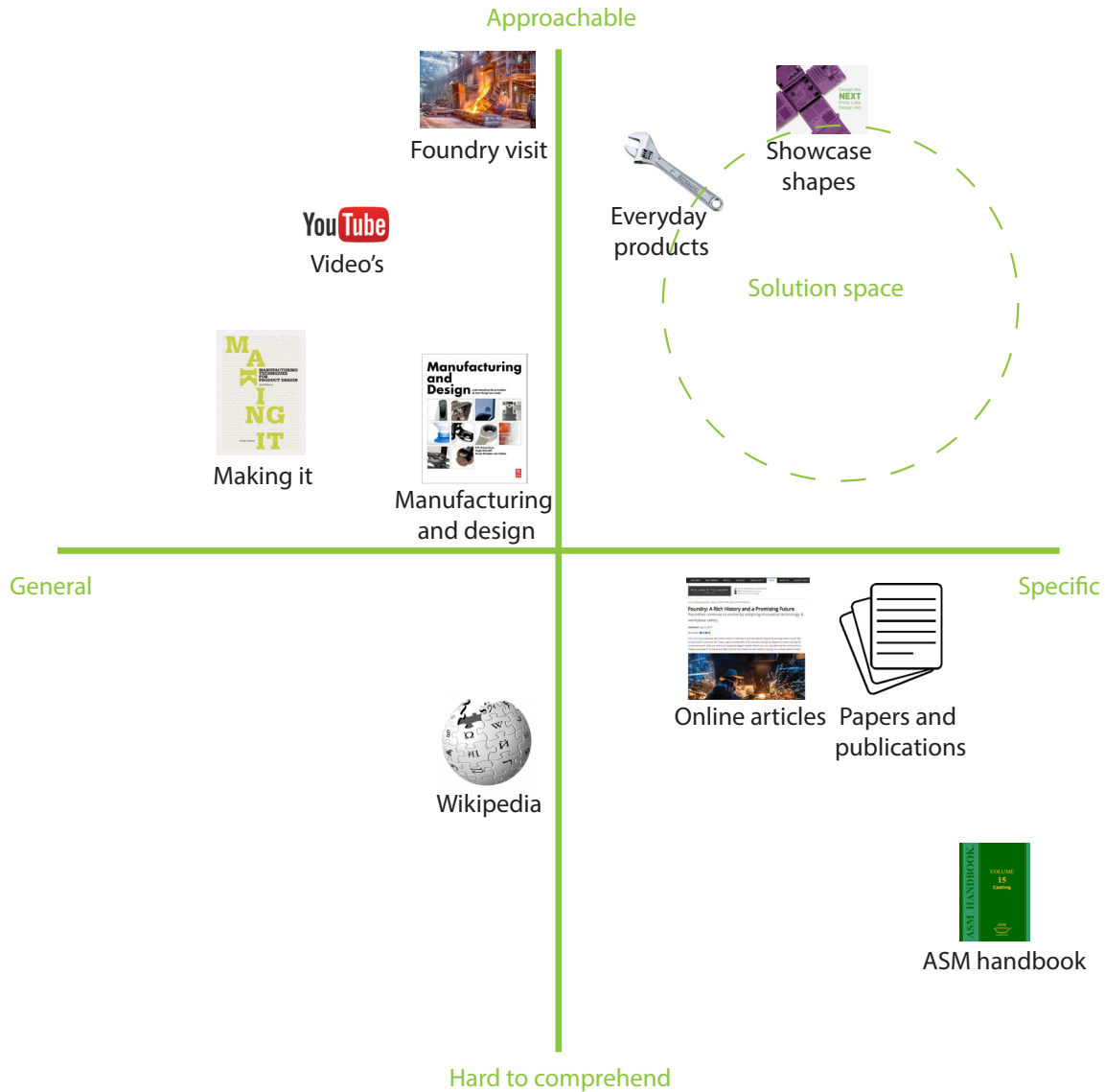


Figure 7 Learning sources overview

These showcases are very interesting for designers as they display what is possible, but also show the consequences of suboptimal designs.

Documenting sources within EDS

EDS stores many sources and documents in their literature and media folder on Dropbox. Unfortunately, there are so many sources that it is hard to know the value of the individual sources and good sources easily get lost.

Conclusion

As new engineers at EDS need to know specific knowledge, but do not have the time to learn from sources that are hard to comprehend, it is desired to have a solution that is approachable, while still being specific. Identified opportunities for such a source are:

- Approachable yet specific literature
- Online sources register (where to find good sources)
- Manufacturing video from the designers' point of view
- Analysing existing parts
- Showcase casting (like already exist for injection moulding)

2.6 ESTIMATING COSTS

In the conceptual design phase, the architecture of the product is formed, determining over 70% of the total development costs. As the project gets to the detailed design phase (engineering phase), the ability to impact costs reduces, while the costs of design changes increases dramatically (Figure 8). Therefore, in order to design effectively there is a great benefit for designers in knowing the financial consequences of their design decisions in an early stage of the conceptual design phase.

Cost price estimation methods

The problem of not knowing the costs of a part is well known. Therefore, many attempts have been made in developing a tool to estimate the cost price of castings and forgings.

Estimating by formula

In 'Designing castings for performance', (Lampman, 2009) the costs of a casting are expressed in a formula (Figure 9). Such a formula, however, is not valuable for designers, as it is impossible for a designer to make a good estimation about for instance the 'equipment and labour costs', or the 'process lead time'.

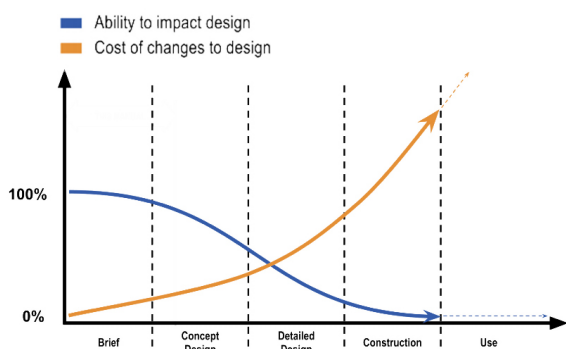


Figure 8 Impacting cost

Estimating by cost price tool

Online tools have also been developed to estimate costs. Custompartnet.com offers a series of tools to estimate the costs of various casting and machining processes. Although these tools give a price rather quickly (after one has converted all dimensions into inches and counted the number of 'design features'), the accuracy of these price estimations is questionable as this tool does not take into account important factors like the country of production, or the risk/percentage of rejected parts. Therefore, also this kind of tool is not useful for designers.

Insight in cost price separating costs

CPM-industries (CPM-industries, 2014) provides insight into the costs of castings by explaining the cost price division of a typical sand casting:

- Material costs (for grey iron): 10-25%
- Material costs (for aluminium): 40-60%
- Moulding costs: (5-10%)
- Pouring costs: (15-20%)
- Core costs: (10-20%)

An approach like this is useful, as it can help the designer in making design choices (e.g. a designer can save costs with 10-20% by eliminating cores).

$$Cost = \frac{C_T}{N} + C_c + V C_m + \frac{C_0 t_{cycle}}{Y} + C_s$$

Where:

- C_T = total tooling cost (€)
- N = lifetime number of castings
- C_c = cost of coring (€/unit)
- V = total casting volume (L)
- C_m = alloy cost (€/dm³)
- C_0 = casting equipment and labor cost (€/hr)
- t_{cycle} = total casting lead time (hr)
- Y = yield (usable castings/N)
- C_s = cost of secondary processing (€/unit)

Figure 9 Cost price formula

2.6 ESTIMATING COSTS

EDS cost price estimation method

Within EDS, costs are roughly estimated by multiplying the weight with an (in-house) €/kg value of a process-material combination. This price, however, does not include secondary processing, packaging or transport.

EDS Quotation research

In an attempt to validate the accuracy of the EDS cost price estimation method, and to research the influence of quantity and weight on the costs/kg price and the tooling costs, all EDS quotation of 2017 have been analysed in a quantitative study. Figure 10 shows the normal-distributions of the costs retrieved from the quotations. Between the brackets is the expected costs per kg price. Due to confidentiality reasons, the units of this figure, and the correlation figures are not shared in this section of the report.

As can be observed, the costs estimation of forging and sand casting was relatively accurate, while the costs of both water glass and silica sol investment casting were way higher than expected. This difference is for a large part caused by the fact that many investment casting quotations

included prices for machining. Therefore, no conclusions can be made for any of the investment casting processes.

The full EDS quotation research can be found in appendix 20.

Conclusion

Current cost price calculation methods do not enable designers to foresee the financial consequences of their design decisions. With the EDS quotation research the EDS cost price estimation method was analysed, and insights about the influence of quantity and weight on the costs per kg and tooling costs were obtained.

Although no substantial conclusions could be drawn from this research, a research with a bigger dataset, or one that analyses the part geometry as well, could still result in meaningful insights.

Until such a research is performed, the best way to understand cost price is to have a lot of experience with quotations, like for instance the employees in the EDS purchase department have.

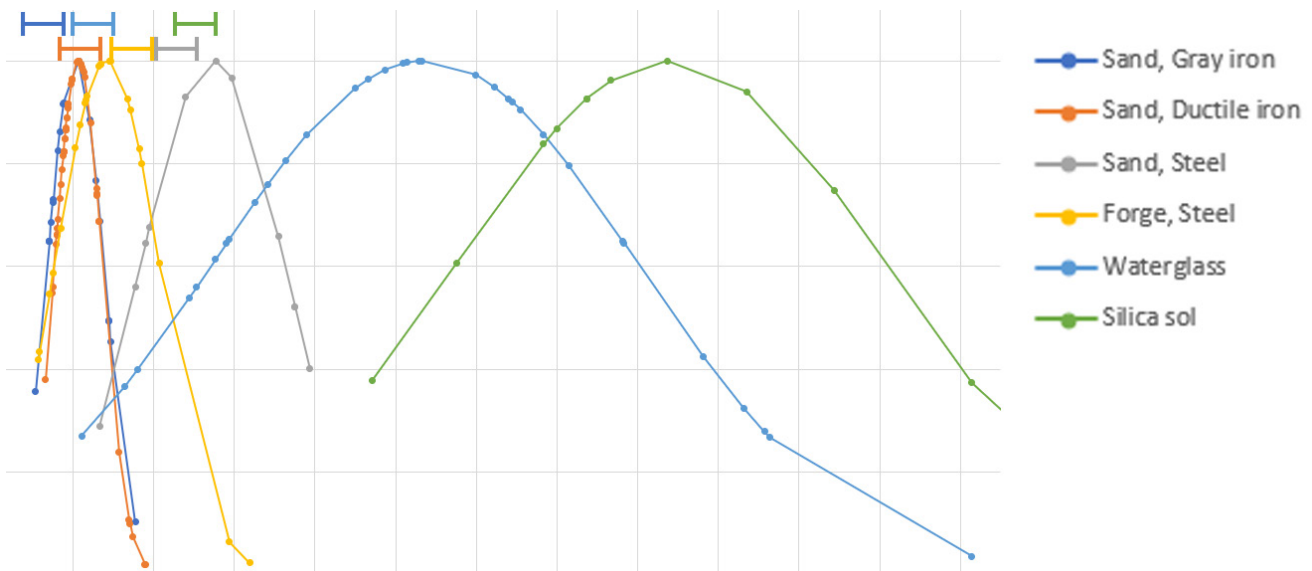


Figure 10 Normal distribution of process-material combinations

2.7 ANALYSIS PHASE CONCLUSIONS

Company profile and ambition

- EDS is growing at a high pace and expects to keep on growing
- EDS structures and methods are documented within EDS ISO-9001

Designing at EDS

- EDS has 3 design phases: analysis phase, conceptualization phase, and engineering phase
- A wide variety of required skills and knowledge is indicated
- Standard files and templates are widely adapted within EDS

An economical casting or forging

- With casting and forging the following processes are meant
 - Sand casting
 - Investment casting
 - Hot closed die forging
 - Gravity die casting
 - High pressure die casting
- Design guidelines are useful when designing an economical part
- EDS has no in-house design guidelines
- An economical casting fully utilises the possibilities of the chosen process

Starting at EDS

- New engineers at EDS are mostly engineering students from HBO or WO in year 3 or higher of their studies.
- These students have a vague understanding about manufacturing principles
- These students have no knowledge about design guidelines for processes
- The 'trainee introduction document' offers room for improvement

Manufacturing and design resources

- The learning source to be designed should be approachable yet specific
- Identified opportunities are:
 - Approachable yet specific guide
 - Online sources register (where to find good sources)
 - Manufacturing video from designer's point of view
 - Analysing existing parts
 - Showcase casting (like already exist for injection moulding)

Estimating costs

- Estimating cost price is indicated to be an important yet difficult topic
- There is no such thing as a reliable user-friendly cost price estimation tool
- The EDS cost price estimation method, is confirmed to be suitable for sand casting and forging
- The EDS quotation database is a valuable database from which many insights can be obtained



3. DESIGN CRITERIA



In this chapter the two research questions stated in the introduction are answered and design criteria are defined. The answers to the research questions will help in creating concepts, and the design criteria will be used to evaluate these concepts.

3 DESIGN CRITERIA

In the introduction, following research questions were stated:

*Research question 1:
What does a new engineer need to learn in order to design an economical casting or forging for EDS?*

*Research question 2:
What kind of learning source could fit within EDS?*

Answers to research questions

Based on the research of the analysis phase these two research questions are answered as follows:

What does the new engineer need to learn in order to design an economical casting or forging for EDS

The new engineers at EDS are mostly HBO or WO students in their 3rd year or further. They have a basic understanding about manufacturing but do not know the different manufacturing processes by heart. When starting at EDS they need to learn a lot about manufacturing, about the EDS working structure, and general design skills as indicated in chapter 2.2. Learning the EDS working structure however, is already covered by the EDS ISO-9001 document. To design an economical casting or forging at EDS, an engineer should know the design guidelines of the 5 main processes indicated in chapter 2.3, know how design decisions influence the cost price, and know how to fully use of the design possibilities that are offered by these 5 main manufacturing processes.

What kind of learning source could fit within EDS?

The information should be transmitted in a learning source that is clear and approachable. Opportunities might be to use video, physical products, or a guide that explains casting and forging in a specific yet approachable way. Also templates can be used as they are likely to be adapted by EDS. The proposed shape could use or trigger the 6 skills of the engineer as defined in chapter 2.4. In any way, as EDS is a growing company, the final product should be able to evolve and grow along with the company.

Design criteria

To be able to evaluate the concepts that will be developed, design criteria were established (Figure 11). As not all stated criteria are equally important, a weight is assigned to every design criteria.

Design criteria	Weight
Valuable teaching material	5
Feasible within the time frame of graduation	5
Approachable content	3
Distinctive from existing sources	3
Encourages later adjustments/growth	2
Fit with EDS company structure	2

Figure 11 *Design criteria*

Valuable teaching material

As teaching is the main goal of this project it is also the most important criterion. It makes sure that concepts that teach more effectively are rated higher.

Feasible within the time frame of graduation

Is it important that a fruitful result can be obtained during the graduation project. Therefore, this is also a very important criterion. This criterion eliminated concepts that are too ambitious, or concepts that require intensive cooperation with other parties (foundries have normally a delivery time of at least 3 months).

Approachable content

As defined in chapter 2.5 there is a need for specific, yet approachable learning sources. Therefore, approachability is a relatively important criterion. This criterion makes sure that solutions that are visual, interactive or physical are preferred above concepts that are more static, or harder for the engineer to comprehend.

Distinctive from existing sources

As it is not useful to create what is already established, it is an important criterion that the concept is distinctive from the existing sources.

Encouraging later adjustment/growth

EDS is a growing company, and so is their knowledge and their experience in handling things. Therefore, a concept that can be altered, updated, or extended has a slight preference above fixed concepts that are produced once but are hard to update.

Fit with EDS company structure

EDS has an established way of working in which the concept should operate. A concept that requires a change in this way of working is therefore less preferred, as such a concept has a lower chance on being adapted successfully.



4. CONCEPTUALIZATION



This chapter describes the concepts that were developed and explains what these concepts are about. This chapter concludes with an evaluation and selection of the established concepts using the in chapter 3 defined design criteria.

4.1 CONCEPT 1: EDS DESIGN GUIDE

The EDS design guide is a concept for an in-house document that teaches new engineers the basics about casting and forging, and functions as a reference book while designing. The design guide consists of multiple chapters, and addresses several relevant topics. Presented here are 3 topics that an EDS design guide could contain:

Cost price distribution overview

As described in chapter 2.6 knowing the financial consequences of design decisions is crucial when designing a product. From the EDS quotation research, a lot of insights can be extracted about costs.

The cost price distribution overview visualises the data of this research (Figure 12). It shows for various process-material combinations the cost per kg distribution, and indicates 2 or 3 products that are chosen to be representable for the shape complexity in relation to the indicated cost price. From these overviews an engineer can better estimate the expected cost price of his design.

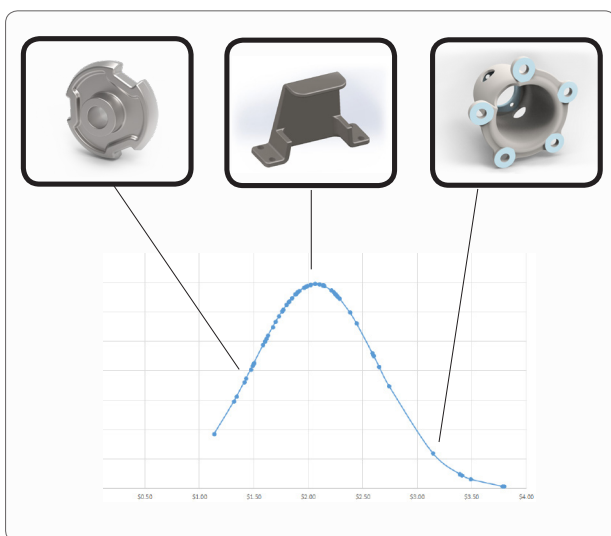


Figure 12 Cost price distribution

EDS design guidelines

Design guidelines describe how a product should be dimensioned in order to be manufacturable. By establishing these EDS guidelines engineers at EDS are better able to fully utilise the possibilities of the chosen manufacturing process.

In the established concept for design guidelines, the values that plead for a manufacturing method are made green, and the values that are the downside of a process are indicated in red. Due to confidentiality reasons the established concept for design guidelines is placed in appendix 9.

Processes overview

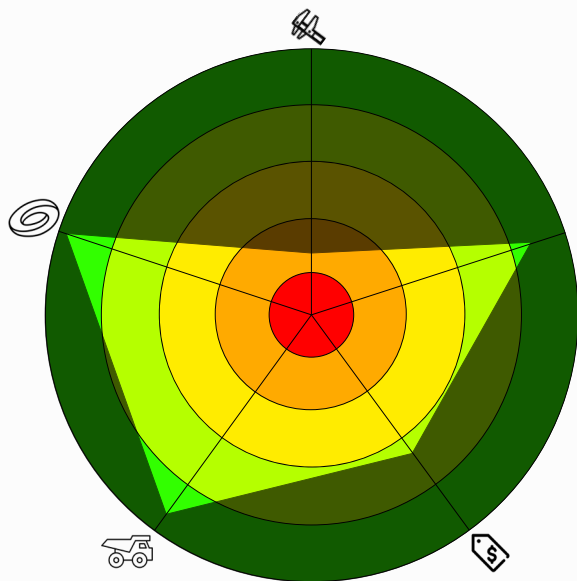
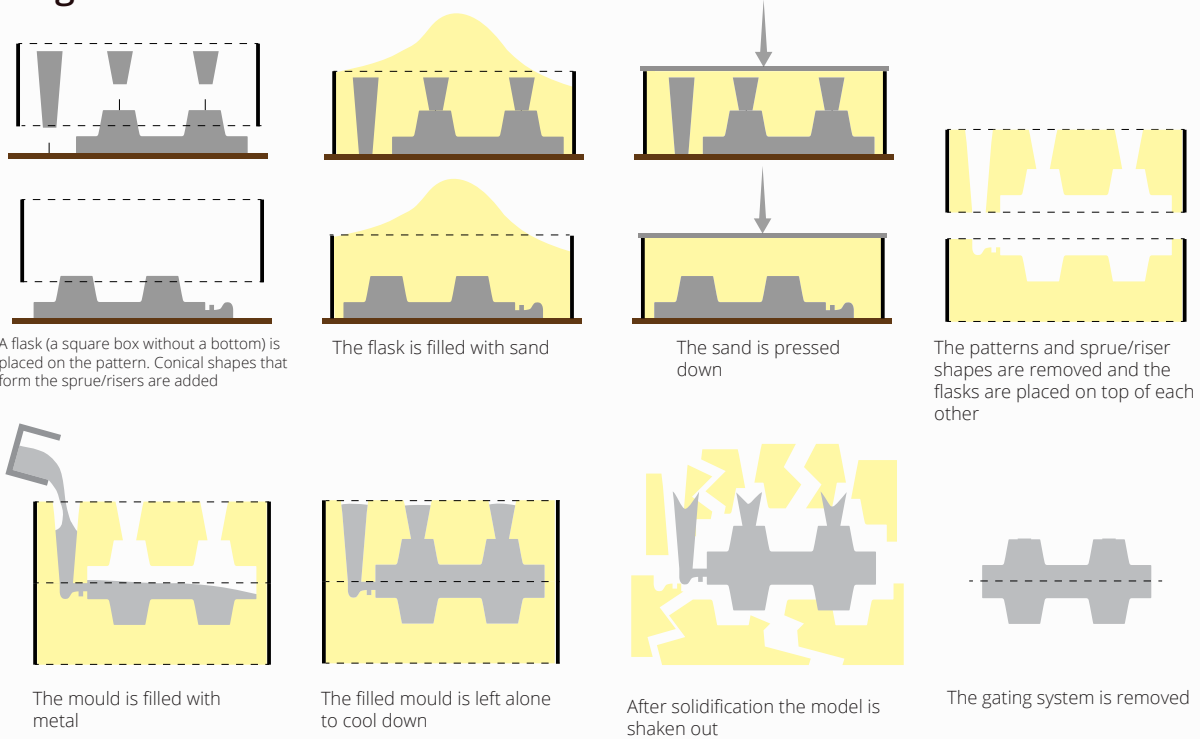
Understanding the main casting and forging processes is crucial when designing at EDS. The EDS processes overview explains the basics of every of the in chapter 2.3 defined casting and forging processes. For every of these processes the shaping sequence is visualised and the qualities of the process are evaluated (Figure 13).

Having such an in-house process overview would also be beneficial for EDS as this could be used as a promotional tool.

The process overviews for the other casting and forging processes can be found in appendix 16.

Sand casting

Sand-casting is used to cast almost all metals in both very low and high quantities. The use of sand cores allows gives sand-casting a large form freedom.



-  **Quality**
Sand casting has in general the lowest dimensional tolerances of all casting processes. The texture of the sand also results in a high surface roughness.
-  **Investment costs**
Sand cast patterns can be significantly cheaper than the dies used for other casting processes.
-  **Part price**
Sand casting is a relatively time intensive process which results in a slightly higher part price than other casting processes.
-  **Materials**
Sand casting can be done with almost all materials. Only the high melting point materials will melt/fuse with the sand, resulting in a bad surface finish.
-  **Form freedom**
Sand casting is suitable for a range of products from small to very large. The use of cores allows sand casts to take complex shapes.

Figure 13 Process overview sand casting

4.2 CONCEPT 2: EDS KICK-START

The EDS kick-start is a concept for a program that is specially designed to kick-start new engineers at EDS. During this kick-start the new engineer will learn about all topics that are indicated in Figure 14. This is done by letting the trainee perform learning activities like reading relevant literature, analysing real parts, answering questions, looking up information, etc.

This kick-start program has not only as function to train the new engineer, it also helps EDS in reviewing the qualities of a new engineer in a very early stage, and could potentially function as a tool to attract new talent to EDS.

Casting knowledge	Design skills	Practical skills	EDS skills
<p>Basic understanding of castings</p> <ul style="list-style-type: none"> Basic understanding about draft Some knowledge about shrinkage Familiar with some materials Familiar with some processes Understanding about difficulty of thin section 	<p>Skilled in designing</p> <ul style="list-style-type: none"> Design methods Doing research Creative problem solving Iterative design circle 	<p>Good practical skills</p> <ul style="list-style-type: none"> Above average CAD skills Basic FEM Understanding Basic to good visualisation skills Understanding of technical drawings 	<p>Starting level</p> <p>In possession of the EDS DNA</p> <ul style="list-style-type: none"> Undertaking Teamwork Inventive Technology
<p>Repeating the casting basics</p> <ul style="list-style-type: none"> Shrinkage/feeding Casting processes Casting defects Casting vocabulary 	<p>Design based exercises</p>		<p>During first week</p> <p>Testing of EDS skills</p> <ul style="list-style-type: none"> Understanding Self-reliant Reflective Structured working Creative Problem solving
<p>Understanding process variables</p> <ul style="list-style-type: none"> Draft Materials Parting line Surface roughness Wall thickness Weight and quantity Tolerances 	<p>Design assignment</p>	<p>Visualisation and modeling</p> <ul style="list-style-type: none"> 3D printing Modelling Sketching FEM 	<p>Evaluation</p>
<p>Wrap up</p> <ul style="list-style-type: none"> Costs of castings Finalise own casting design guide 	<p>Analysis and conceptualisation</p> <ul style="list-style-type: none"> Casting analysis Idiation for castings 		<p>During test period</p> <p>Understanding what EDS is about</p> <ul style="list-style-type: none"> EDS Sales EDS Purchase Funnel document
	<p>Working on funnel projects</p> <ul style="list-style-type: none"> Conceptualisation 	<p>Structural working</p> <ul style="list-style-type: none"> EDS CAD setup Technical drawing 	
<p>Casting in practice</p> <ul style="list-style-type: none"> Foundry work 	<p>Working on simple projects</p> <ul style="list-style-type: none"> Performing full analysis Engineering 	<p>Design communication</p> <ul style="list-style-type: none"> PAD Document 	
<p>In depth literature</p> <ul style="list-style-type: none"> Gating and shrinkage Materials 	<p>Working on normal projects</p> <ul style="list-style-type: none"> Engineering 		

Figure 14 EDS learning topics

Presented here are three learning activities that the EDS kick-start program could contain:

Allocate designs to the right process

When designing a casting or forging it is important to know the different possibilities and limitations of the manufacturing processes. In this assignment a trainee first needs to allocate given products to the certain manufacturing processes (Figure 15). Thereafter, by use of this example, he needs to design himself one product for multiple processes.

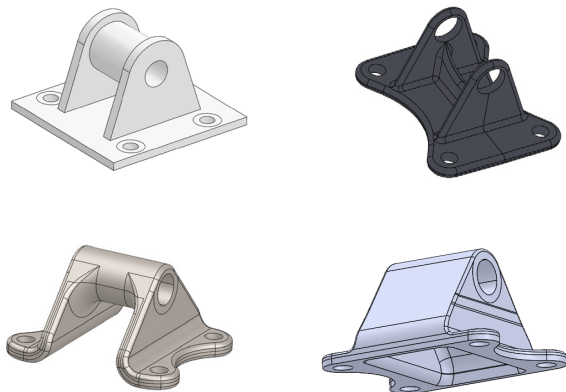


Figure 15 *Designing for multiple processes*

Learning about tolerances

Understanding and applying tolerances is an important skill to learn when designing at EDS. During this assignment the trainee learns to use ISO 8063-3 (standard about tolerances) from his mentor. The trainee uses this knowledge to determine the allowed minimal and maximal dimensions of a given part. Thereafter the trainee measures the (physical) part himself (Figure 17), analyses the official measurement report and evaluate if the part is indeed made within the indicated tolerance grade.

Redesign sub-optimal designed parts

When designing a casting it is important to know how to make an affordable cast that can be produced without casting defects. In this assignment the trainee first learns theory of designing economical castings without casting defects. After learning this theory he needs to apply this knowledge to an existing sub-optimal designed part as illustrated in Figure 17

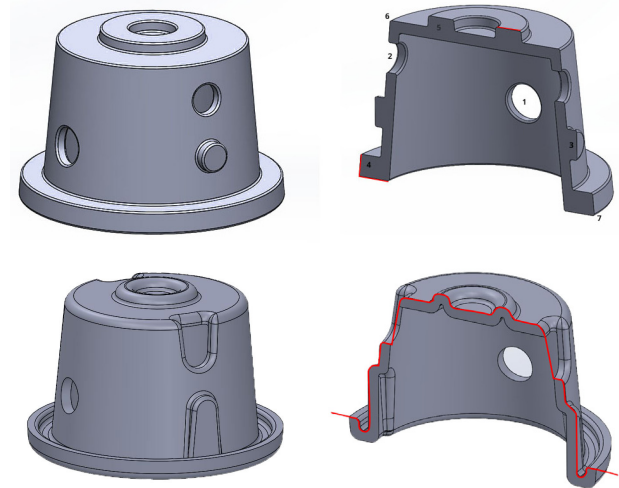


Figure 16 *Improving design*



Figure 17 *Measuring critical dimension*

4.3 CONCEPT 3: EDS DESIGN TOOLS

EDS design tools are concepts for tools that help, or give insight in the casting or forging design process. Three design tools have been developed. Each of these tools is actually a concept direction in itself, however, to keep this report concise they are here presented as one concept. In the concept selection (chapter 4.4) the concepts will be evaluated individually.

Showcase casting

Guidelines on paper as described in concept 1 are very valuable, yet very relative. A thin wall thickness, for instance, that cannot be achieved at a first try, can still be achieved when using a more extensive gating system or by choosing another alloy.

A showcase casting is a cast designed to show where the boundaries lie of what is possible. The showcase casting in Figure 18 shows the result of: various thickness/length ratio's, various draft angles, various cored hole diameters, various junction designs, unfed material volume and holes that are perpendicular to the parting directions but are shaped without cores.

When such a casting would be produced in the most common steel, grey iron, and aluminium alloy, it would be a very interesting learning object that could also be used for promotional purposes.

EDS quotation book

As described in chapter 2.6 the skill of estimating cost price can be obtained when having a lot of experience with quotations. EDS as a company has much experience with cost price as they receive five to ten quotations every week. This knowledge, however, stays in the heads of the purchase employees and in a database, in which variables as material, process, and kg are not separated. This makes it impossible for designers at EDS to learn from it.

The EDS quotation book would store all relevant quotations in a approachable, visual way, enabling designers to learn from it. For the EDS quotation book to come into existence a template would be made. For every received representable quotation a one pager should be made, summarising the design characteristics,

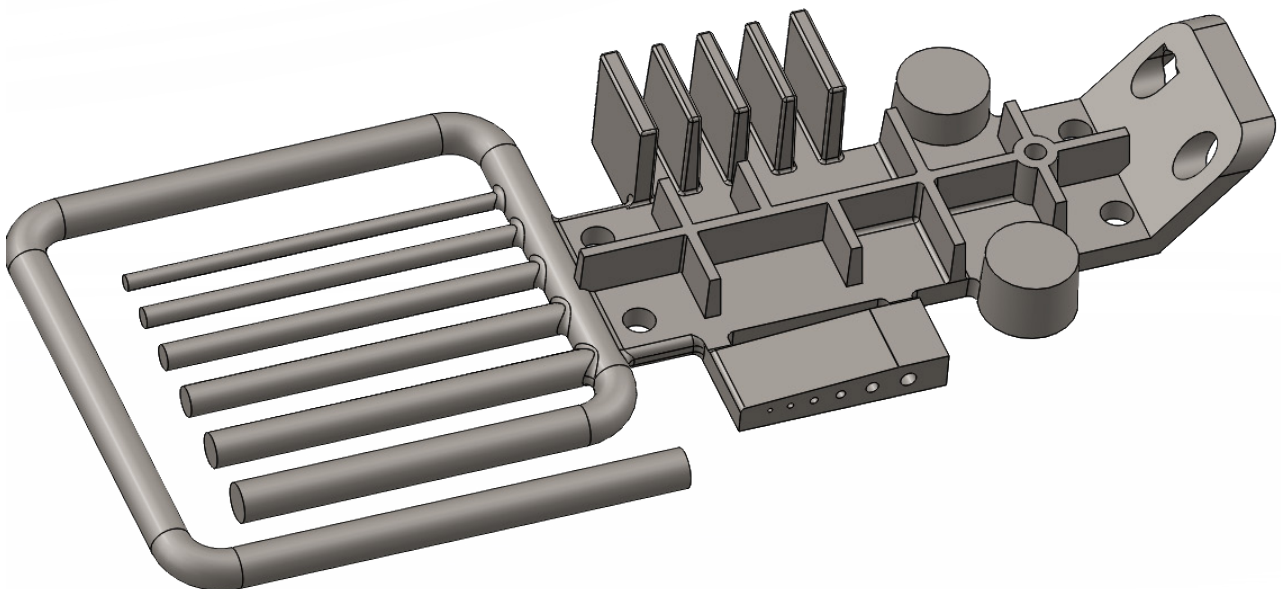


Figure 18 Sand casting showcase

4.3 CONCEPT 3: EDS DESIGN TOOLS



Figure 19 Process selection tool concept

process information, and the cost price build-up. Over the weeks, when the content of this book increases, it will become a very valuable learning source for understanding cost price.

Process selector

Choosing the right manufacturing process is a difficult action in which many factors have to be taken into account. Especially for new engineers it can be difficult to choose the right process.

This process selector calculates a score for every process based on 9 criteria. When using this process selector the user fills in an 'x' at the relevant value of the criteria. This assigns a score to every process, and also indicates if it is hardly possible (orange) or not possible (red).

To choose the right process the user analyses the scores for all processes, and checks which processes are possible. When the process with the highest score is a process that is possible, that process should be chosen. When the process with the highest score is not possible, the user should evaluate if he can change the design to make it fit that process, or choose the best, yet possible process.

In the example of Figure 19 (user test within EDS), high pressure die casting has the highest score, but is not suitable as ferrous material, and a very small draft <1, was required. In this situation the user should evaluate if the design could be adjusted to be from aluminium and have a larger draft, or decide that lost wax (second highest score) is the best manufacturing method.

4.4 CONCEPT SELECTION

To select the most promising concept, the established concepts were evaluated with the weighted design criteria of chapter 3. An average score was calculated for every concept as shown in Figure 20.

Design criteria	Weight	EDS design guide	EDS kick-start	EDS showcase casting	EDS quotation book	EDS process selector
Valuable teaching material	5	4	5	4	4	2
Feasible within the time frame of graduation	5	5	5	3	4	4
Approachable content	3	2	4	5	5	4
Distinctive from existing sources	3	2	4	4	4	3
Encourages later adjustments/growth	2	5	5	2	4	5
Fit with EDS company structure	2	5	3	3	3	1
Weighted average		3.9	4.5	3.6	4.1	3.2

Figure 20 Weighted choice table

Evaluation

To better understand the strengths and the weaknesses of the proposed concepts, they are evaluated shortly.

EDS Design guide

This concept scores high on its fit with EDS, as the company explicitly communicated their interest in such a guide. Also it scores high on valuable teaching material, as it is possible to put a lot of valuable teaching material in such a guide. Since the guide would be a static document it scores low on approachability, and the distinctiveness with other sources scored low as well, as much content of such a guide can already be found in other sources.

EDS kick-start

This concept scores high on almost all the criteria. It is very approachable, teaches a lot, and allows very well for later adjustments. Only its fit with the company structure scores a bit lower, as it requires substantial time commitment from the new engineers, where they would normally be already productive, fixing things, or performing simple assignments.

EDS showcase casting

This concept scores high on approachability, as it would be a very interesting physical object, and it scores high on teaching value, because it shows very clearly where the boundaries of a casting process lie, and what happens when exceeding them. This static concept however, scores very low on feasibility (dependent from foundries) and adjustability (hardly adjustable once made) what explains the low final grade.

4.4 CONCEPT SELECTION

EDS quotation book

This concept scores relatively high on most criteria, but only excels in approachability, as it makes it very easy to obtain information about a complex topic (costs). It scores low on fit EDS working structure as it would require substantial extra time from both purchase as engineering to shape this book.

EDS process selector

This concept scores relatively high on approachability, feasibility, and adjustability. This concept however, might only be beneficial for people that do not know much about casting, and also do not want to learn it. Therefore, it scores very low on teaching and fit with EDS working structure.

Conclusion

Based on the established selection criteria the EDS kick-start concept scored highest of all concepts. As this concept was also fully supported by EDS, the EDS kick-start concept was chosen to be further developed.



5. EMBODIMENT DESIGN



This chapter describes the 3 phases that were defined for the EDS kick-start, the learning goals that were established for every phase, and the design decisions and considerations that were on the basis of the final design proposal.

5.1 KICK-STARTING ENGINEERS

When satellites are orbited around the earth there are 3 main phases that can be distinguished. In phase 1 the satellite is launched by the main rocket. During this power ascent the satellite reaches in a short time a very high altitude. When the main rocket is burned out it is discarded, and the second stage fires, initiating phase 2. During this phase the second power source pushes the satellite to its orbit around earth. Once in position phase 3 begins and the satellite can perform its function. During this third phase the satellite is subject to solar winds, atmospheric drag and gravitation from the moon and the sun. To stay in its orbit, the satellite is actively checking and correcting its position. A satellite that fails to do so will start malfunctioning as its position is inaccurate, and will eventually miserably burn out in earth's atmosphere.

The 3 phases described for the launch of a satellite will be used to define the phases that apply for kick-starting engineers at EDS (Figure 21).

Phase 1: Learning the basics of casting and forging

Phase 1 takes 1 week, during this phase the engineer is boosted with brute force in an effort to teach them as much as possible about casting and forging.

Phase 2: Learning to do EDS projects

Phase 2 takes 3 months, as this is the length of the EDS trial-period. During this second phase the engineer is pushed to reach a skill-level that would enable him to perform EDS projects independently.

Phase 3: Learning by doing

During phase 3 the engineer is fully productive for EDS. While the engineer executes projects he should be fully enabled to reflect on them, and learn from them, this way becoming a better engineer. Failing to do so, might stagnate the growth of the engineers, and the company in general.

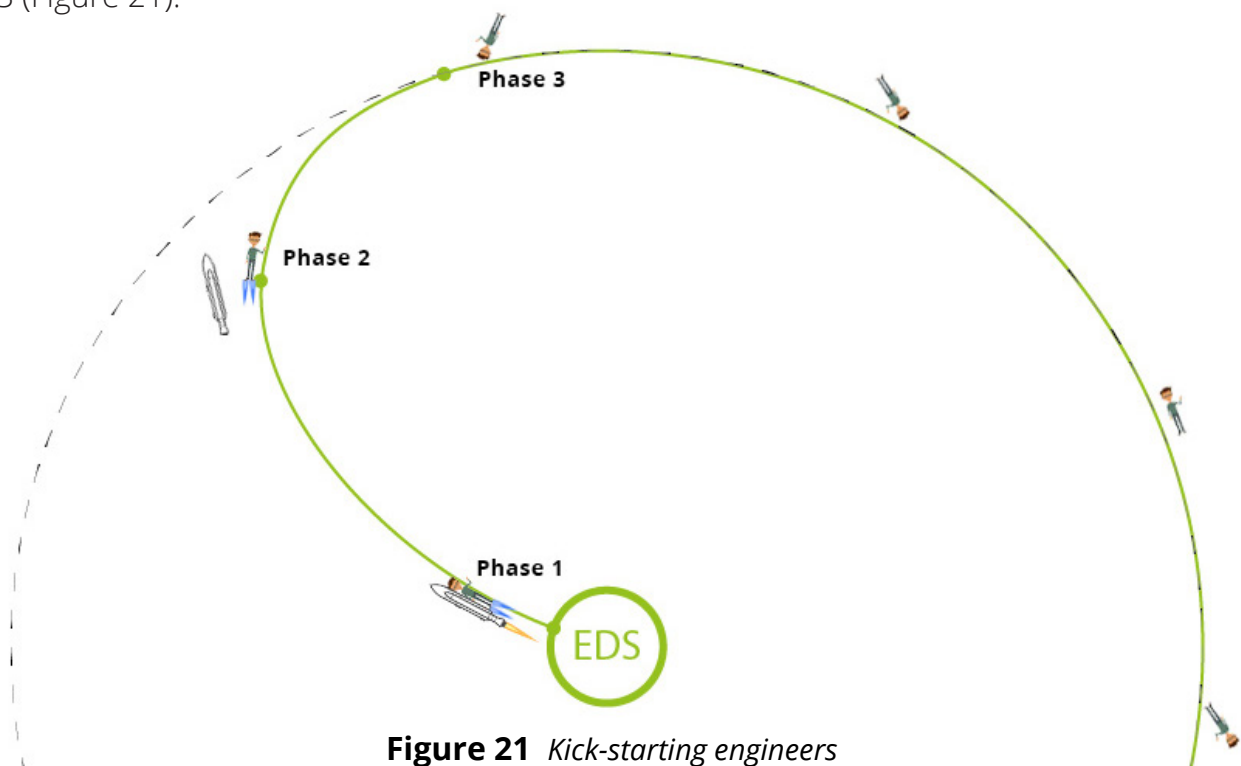


Figure 21 *Kick-starting engineers*

5.2 LEARNING GOALS

For the development of the 'Kick-starting engineers' it was chosen make use of constructive alignment. Constructive alignment is about learning activities that fit with intended learning goals, and having a form of assessment to validate if the intended learning goals are achieved. The here presented learning goals are formulated using Blooms Taxonomy (about learning levels). In appendix 13, constructive alignment and Blooms Taxonomy are further elaborated.

Blooms learning levels

<i>Level 1</i>	<i>Remembering</i>	<i>Level 4</i>	<i>Analysing</i>
<i>Level 2</i>	<i>Understanding</i>	<i>Level 5</i>	<i>Evaluating</i>
<i>Level 3</i>	<i>Applying</i>	<i>Level 6</i>	<i>Creating</i>

Phase 1 After 1 week, the engineer is able to perform simple EDS design projects under supervision (level 6)

- 1.1 The engineer is able to propose a casting or forging processes for a product (level 3)
 - 1.1.1 The engineer is able to reproduce the right terminology for and within the manufacturing processes (level 1)
 - 1.1.2 The engineer is able to illustrate the shaping process of the main casting and forging processes, indicating what is the positive and the negative shape (level 2)
 - 1.1.3 The engineer is able to indicate the draft and the parting line of a product (level 2)
 - 1.1.4 The engineer is able to draw up the unique selling points and disadvantages of the most common casting and forging processes (level 2)
- 1.2 The engineer is able to improve a design that is subject to casting defects (level 3)
 - 1.2.1 The engineer is able to reproduce the characteristics of the most common casting and forging materials (level 1)
 - 1.2.2 The engineer is able to explain the principles of melting temperature and material viscosity (level 2)
 - 1.2.3 The engineer is able to explain the effects of shrinkage on a casting or a forging (level 2)
 - 1.2.4 The engineer is able to explain the influence of gating systems (level 2)
 - 1.2.5 The engineer is able to explain the effects of turbulence on a casting (level 2)
 - 1.2.6 The engineer is able to explain how geometry influences the manufacturability of a casting or a forging (level 2)

5.2 LEARNING GOALS

- 1.3 The engineer is able to support his design decisions when designing a casting or a forging (level 5)
 - 1.3.1 The engineer is able to indicate the costs-drivers of the most common casting and forging processes (level 2)
 - 1.3.2 The engineer is able to handle design guidelines while designing (level 3)
 - 1.3.3 The engineer is able to sense when design guidelines might not apply anymore (level 5)
 - 1.3.4 The engineer is able to derive general tolerances from a drawing using ISO 8063-3 (standard about tolerances) (level 3)
 - 1.3.5 The trainee can apply machining allowance to a design (level 3)
 - 1.3.6 The engineer is able to derive the different interests of design decisions when designing (level 4)

Phase 2 After 3 months, the engineer is able to execute intermediate EDS projects while having only limited mentor guidance (level 6)

- 2.1 The engineer is able to create and communicate concepts (level 6)
 - 2.1.1 The engineer is able to determine if a manufacturing process fits a certain design (level 5)
 - 2.1.2 The engineer is able to determine design criteria and choose a preferred concept based on these criteria (level 5)
 - 2.1.3 The engineer is able to come up with fruitful ideas and concept directions (level 6)
 - 2.1.4 The engineer is able to make presentable visualizations of his ideas (level 6)
 - 2.1.5 The engineer is able to iterate on his concepts effectively (level 6)
 - 2.1.6 The engineer is able to utilise the design possibilities of the chosen manufacturing process (level 6)
- 2.2 The engineer is able to use CAD effectively (level 3)
 - 2.2.1 The engineer is able to model using the EDS feature structure (level 3)
 - 2.2.2 The engineer is able to create adequate SolidWorks models (level 6)
 - 2.2.3 The engineer is able to perform FEM studies (level 3)
 - 2.2.4 The engineer is able to make technical drawings (level 3)
 - 2.2.5 The engineer is able to make use of Keyshot (level 3)
 - 2.2.6 The engineer is able to make use of the EDS 3D printing facilities (level 3)
- 2.3 The engineer is able to work in the provided EDS structure (level 3)
 - 2.3.1 The engineer is able to judge the potential of parts in the EDS funnel document (level 5)
 - 2.3.2 The engineer is able to use the product analysis document (PAD) (level 3)
 - 2.3.3 The engineer is able to work within the EDS folder structure (level 3)

Phase 3 While being employed at EDS, the engineer is able to fully learn from his practices as described by the learning cycle of Kolb (See appendix 15)

5.3 DESIGN DECISIONS PHASE 1

Phase 1 is about teaching the engineer in 1 week time all that is required to perform simple design projects for EDS. This chapter describes the design decisions that were taken to shape the design proposal for phase 1: the EDS traineeship. The here presented design decisions are based on analysis, reasoning and user-testing (see appendix 10).

Traineeship

As described in chapter 2.4, EDS currently educates new engineers by means of reading literature and performing design projects, while having only limited casting and forging knowledge. This method was found to be sub-optimal.

To better prepare the new engineer (trainee) for these design projects, it was decided to design a five-day traineeship containing many different assignments for the trainee to execute.

Traineeship layout and file structure

The aim for the layout was to be as clear and structured as possible. As many assignments are connected to physical products and/or digital files, it is tempting to put these images in the traineeship file. However, this would result in a very complex document with an abundance of images for some questions and none for others. Therefore, it was decided to put all images and files that are required for the assignments in separated assignment-folders, and make the traineeship document itself without any visuals.

To make this document fit within the general EDS graphical style, it was decided to construct the traineeship document using the 'EDS report template'.

Learning goals in assignments

The purpose of the assignments is to let the trainee achieve the intended learning goals (chapter 5.2). Therefore, all assignments support one or multiple learning goals, and all the assignments together cover all the defined learning goals (Figure 22).

Learning goals	Assignments														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1											x				
1.1									x	x	x				
1.1.1	x														
1.1.2	x			x											
1.1.3				x											
1.1.4									x	x					
1.2			x												x
1.2.1								x							
1.2.2		x						x							
1.2.3		x	x												
1.2.4		x													
1.2.5		x													
1.2.6					x										
1.3										x	x				x
1.3.1												x			
1.3.2					x					x	x				
1.3.3					x					x	x				
1.3.4						x			x						
1.3.5							x								
1.3.6										x	x		x	x	

Figure 22 Learning goals of assignments

Principles of good teaching in traineeship

In appendix 14 the principles of good teaching are analysed. The insights of these principles are integrated in the traineeship by: the close mentor contact (encourage contact with the institution, and give prompt feedback), the hands-on assignments (encourage active learning), the introduction text (communicate high expectations), the strive for diversity between the assignments (respect diverse talents and ways of learning), and the time indication of assignments (emphasize time on task).

5.3 DESIGN DECISIONS PHASE 1

Integrating EDS skills

Throughout the traineeship the EDS skills of the trainee (as defined in chapter 2.4), are stimulated and tested. The trainee is for instance asked to obtain/find knowledge individually (self-reliant), make information summaries (communication and structured working), analyse parts (sees cause result) and design (creativity).

CAsting and FOrging Guidelines (CAFOG)

Design guidelines are very helpful when designing. To teach the trainee these guidelines (and the relativeness of them), the trainee is asked to look online for the guidelines of the main casting and forging processes. To make sure the trainee does not just know, but also understands these guidelines, there are also exercise questions about them.

Documenting (LOG)

For a good learning experience it is important that the work of the trainee can be easily reviewed. Therefore, all exercise questions need to be answered in a digital document. Excel was the chosen medium because of the flexibility it allows (also for the CAFOG). A very basic template is provided, it is up to the trainee to structure and use it.

Mentor function during traineeship

To make sure the trainee has a maximised learning experience and feels part of the company it was chosen to appoint a mentor to the trainee. The mentor will be informed about his role and his responsibilities via an info-sheet. This document also explains in what way and on what topics he should provide feedback to the trainee.

To make sure the trainee can easily communicate questions to the mentor, all questions and answers of the assignments are numbered.

Assessment

The principle of constructive alignment states that within the 'study program' (traineeship) an assessment should take place to see if the student has accomplished the intended learning goals.

For the traineeship it was chosen to not design an explicit assessment test. Instead the testing is done within the assignments in the following ways.

- Almost all assignments end with an 'conclusion assignment', which tests if the trainee has accomplished the intended learning goal.
- On day 4, the trainee needs to perform a design assignment. During this design assignment many of the learning goals should be applied, this way testing them.

Future of traineeship

Four measurements have been taken to ensure the EDS traineeship can grow together with EDS. Firstly, the trainee is asked to fill in an 'assignment feedback form'. This 'assignment feedback form' provides a starting point for the second measurement: Assignment 14, Designing or improving an assignment for the traineeship. Thirdly, the mentor is appointed to be responsible that good suggested improvements of the trainee will also be implemented. Lastly, all source-files of the traineeship are presented to EDS in a clear folder structure, including a folder with all used Photoshop, Illustrator and InDesign files. This way it is easy for EDS to change add or remove assignments.

Conclusion

Many design decisions have been taken while developing the EDS traineeship. The final result of the EDS traineeship is presented in chapter 6.1.

5.4 DESIGN DECISIONS PHASE 2

Phase 2 is about enabling the engineer in 3 months time to execute EDS projects while having only limited mentor guidance. This chapter describes the design decisions that were taken to shape the design proposal for phase 2: the EDS Learning sources overview.

EDS learning sources overview

As the trainee should be productive for EDS from the start of phase 2, it is undesirable to let the trainee perform any more pre-shaped assignments. Instead, the trainee should learn from doing design projects. Nevertheless, there are still important topics the trainee needs to learn in order to be able to perform these design projects.

To make it easier for the mentor and the trainee to decide what and when the trainee should learn, it was chosen to develop a EDS learning sources overview for phase 2.

This learning sources document contains all learning sources that the trainee needs to comprehend, and also contains additional sources which would be valuable for the trainee to be familiar with.

Adjustability

This concept was first developed with the intention to find the best sources, and structure them in the best way. A InDesign checklist type of file was the result (Figure 23 and appendix 12).

Only later on, when an adjustment to the file was required, the real challenge became clear. The purpose of this file is not to be visually pleasing and have sublime content. It should be as flexible as possible to the variety of interesting (yet undiscovered) sources that will be added to the file in the next years. The EDS learning sources

overview should be designed in such a way that it invites for additions, for feedback and for interaction.

Broader use of such a document

As specified in chapter 2.5, there is within EDS currently no structured way of documenting sources. This way many great sources are once mentioned, but quickly forgotten. There is a 'Literature folder' in Dropbox full of many great papers and info-graphics, but nobody actually knows what is in this folder.

The EDS learning sources overview could be the perfect 'table of content' for all these 'lost treasures'.

Content of EDS learning sources overview

There are many more sources to learn from than just books, articles and internet pages. Therefore this EDS learning sources overview can also contain Youtube tutorials, master-classes or foundry visits. This allows EDS to document the value of such activities, and also creates an overview of who knows what information or has done what activity (see next topic 'Ranking and social monitoring').

Ranking and social monitoring

The current library folder contains so many sources that nobody actually knows which sources are worth reading, and which are not. To avoid this problem with the 'EDS learning sources overview' a 'sources ranking system' was introduced that assigns a grade to every learning source.

As grades can be very subjective it was decided to enable every engineer to give an individual grade and a comment about the source. The final grade is an average of

all the grades. This individual ranking also allows to monitor the individual knowledge of every engineer.

Choice of file format

Any EDS employee should be able to adjust the file. Therefore, the format of the file is Excel, just as the 'EDS Lunch list', a document that is updated successfully every day by all employees. Furthermore Excel allows for easy adjustments, and can also easily calculate an average grade for the sources.

Intensity of usage for trainee

As investment in knowledge is a very profitable investment, the trainee is advised to study one hour a day for the full three months of phase 2. This one hour 'study break' could have a positive impact on the engineers working day, by making it more diverse.

Develop concept as recommendation

For this graduation project it was chosen to keep the traineeship the main focus. Therefore, this concept was not fully developed to its final version, but only a general concept is established to show the value of it.

Conclusion

Presented here are the most important design decisions that were the basis of the EDS learning sources overview. The final result of the EDS learning sources overview is presented in chapter 6.5.

<h1>Study material</h1>			
What	Duration	When	Done
EDS traineeship	5 days	Week 1	<input type="checkbox"/>
EDS Work-flow			
• EDS process time-line	20 min	Week 2	<input type="checkbox"/>
• Analysis phase document	20 min	Week 2	<input type="checkbox"/>
• Concept phase document	20 min	Week 2	<input type="checkbox"/>
• Engineering phase document	20 min	Week 2	<input type="checkbox"/>
• Finalisation phase document	20 min	Week 2	<input type="checkbox"/>
• PAD usage	30 min	Week 2	<input type="checkbox"/>
• Meeting agenda document	10 min	Week 2	<input type="checkbox"/>
• Folder structure document	10 min	Week 2	<input type="checkbox"/>
CAD modelling			
• EDS SolidWorks working (methodology)	30 min	Week 2	<input type="checkbox"/>
• EDS SolidWorks technical drawings	30 min	Week 2	<input type="checkbox"/>
• EDS FEM Analysis	1 hour	Week 2-3	<input type="checkbox"/>
• EDS Keyshot renders	1 hour	Week 2-3	<input type="checkbox"/>
• Analyse existing SolidWorks models	1 hour	Week 3-4	<input type="checkbox"/>
• SolidWorks tips and tricks	1-3 hour	Week 3-6	<input type="checkbox"/>
• Parametric modelling	1-3 hour	Week 6-12	<input type="checkbox"/>
• Surface modelling	1-3 hour	Week 6-12	<input type="checkbox"/>
Engineering knowledge			
• Casting design for performance	10 hour	Week 3-6	<input type="checkbox"/>

Figure 23 (Upper part of) EDS learning sources checklist

5.5 DESIGN DECISIONS PHASE 3

Phase 3 is about enabling engineers at EDS to keep on learning while doing design projects. As described in appendix 15 engineers at EDS are currently held back in their learning process as not all information is communicated properly (Figure 24). This chapter describes what can be done to improve the communication between those parties, and describes which design decisions were taken to shape the design proposal for phase 3: the EDS quotation book.

Recommendations for improving communication in design process

To improve the communication between the different departments and companies that are involved in the manufacturing process of EDS products the following recommendations should be executed:

- At the start of the engineering phase the engineer should communicate his design to a foundry, receiving feedback on manufacturability and price reduction of the part
- Purchase should always request for photo's and percentages of rejected parts from the manufacturer
- Purchase should always communicate photo's and percentages of rejected parts to engineering
- Purchase should always communicate quotations to engineering
- Quality reports should always be communicated to the engineer, enabling him to evaluate whether his assumptions for the FEM studies were legitimate

Figure 25 displays the communication that would result from implementing these recommendations.

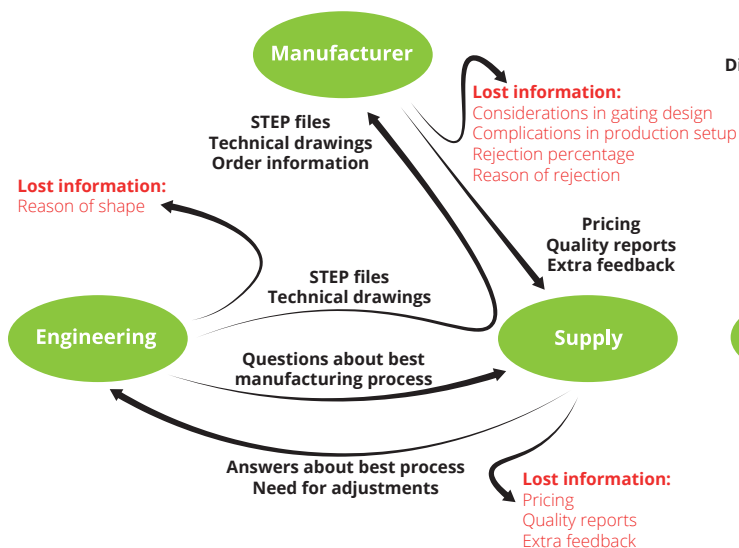


Figure 24 Current communication

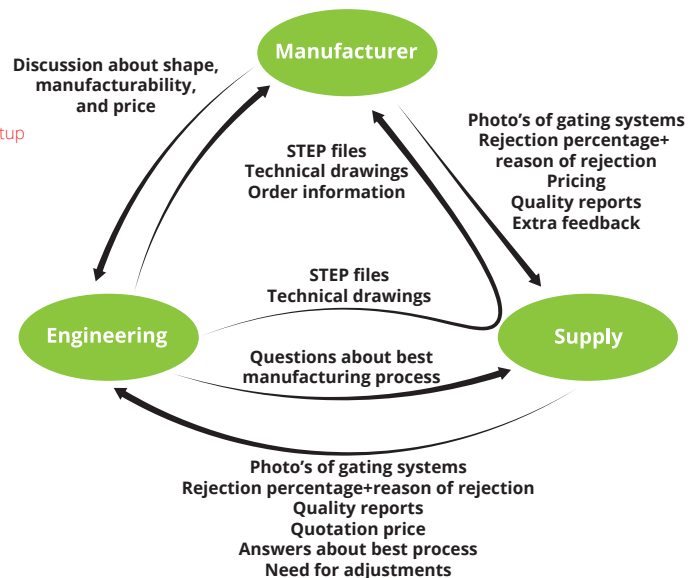


Figure 25 Recommended communication

Storing valuable information

When the recommended measures are implemented, much more information would be communicated to and within EDS. Communicating this information will enable the designer to learn better, but documenting this information will also enable his fellow designers to learn from it. In order for this to happen, it was decided to design a design a system which will allow for storing this information.

EDS quotation book

An EDS quotation book could store the quotations of all projects that are executed by EDS. This way designers can see the cost price of a wide variety of products, and derive from that information how design decisions influence the part price.

Creation of EDS quotation book

As the engineering department is most involved in the creation of the design, it is logical that this department will also be responsible for the creation of the quotation book page. The creation of this page should, however, be initiated by purchase when they receive a representable quotation.

What kind of projects

EDS can decide to integrate only quotations of projects that were manufactured. It is, however, recommended to create a quotation page for every project for which a representable quotation is obtained, and label the pages with 'only quotation', or 'actually manufactured'.

Layout

As the quotation book should be graphically pleasing it is advised to use an InDesign template, and structure the information clearly. To make the book accessible one or multiple visuals of the part should be included in the each entry in the quotation book.

What information structuring

An quotation book page should contain the following information:

- General project info and description
- Manufacturing and material information
- Cost price divided per sub-process
- Text field for an additionally explanation about the cost price, for when there are special conditions that have a heavy influence on the cost price

Chapters in quotation book

Ideally there are enough pages in the quotation book that chapters can be made for the various process-material combinations. Additionally there can also be a separation in project complexity.

Develop concept as recommendation

For this graduation project it was chosen to keep the traineeship the main focus. Therefore, this concept was not fully developed to its final version, but only a general concept is established to show the value of it.

Conclusion

Many design decisions have been made that shaped the EDS quotation book to its final shape as presented in chapter 6.6.



6. DESIGN PROPOSAL



This chapter presents the design proposal of the EDS kick-start. First an overview is given of what the EDS kick-start contains, thereafter the design proposals for the 3 established phases of the EDS kick-start are presented.

6.1 EDS KICK-START OVERVIEW

The EDS kick-start is specially developed to kick-start engineers at EDS casting and forging according to the phases described in chapter 5.1.

The main result of the EDS kick-start is the EDS traineeship. Also recommendations have been done for an 'EDS learning sources overview' and an EDS quotation book. Figure 26 provides an overview of what the EDS kick-start contains. The folder structure in which all document of the EDS kick-start are presented to EDS can be found in appendix 6.

EDS Traineeship (Phase1)

The EDS traineeship teaches new engineers in 1 week time all they need to know about casting and forging to perform simple EDS design projects under supervision. The next alinea's explain all that the EDS traineeship contains.

EDS traineeship assignments

The EDS traineeship contains 15 assignments. Every assignment enables the

trainee to have a learning activity that will contribute to the learning goals described in chapter 5.2.

Chapter 6.2 explains the content of the assignment, Chapter 6.3 shows an example of one of the assignments, all other assignment can be found in appendix 2.

EDS traineeship answer sheet

For all assignments also an answer sheet is developed. At the end of the day the trainee gets these this sheet to check his answers. When the answer is not satisfactory and the trainee still has questions he can discuss them effectively with the mentor. Read more about the EDS traineeship answer sheet in chapter 6.4.

Mentor sheet

The mentor sheet teaches the mentor what the EDS traineeship is about, what his responsibility is, and what he needs to do. The mentor sheet can be found in appendix 4.

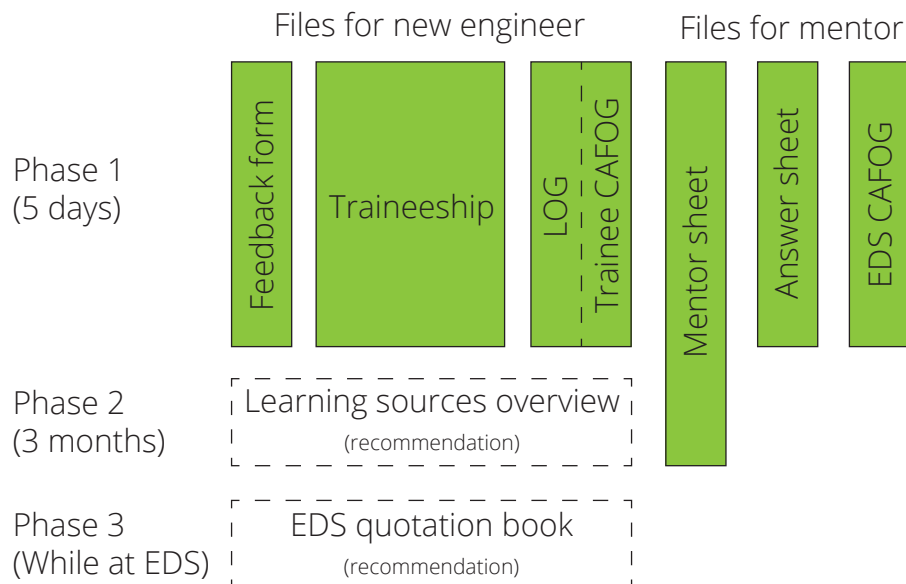


Figure 26 EDS kick-start overview

EDS CAFOG (CAsting and FOrging design Guidelines)

During the traineeship the trainee looks online for casting and forging design guidelines, and documents these values in his CAFOG. The found values however, might not be correct/applicable to the kind of projects EDS does. Therefore, the CAFOG of the trainee will be checked with the EDS CAFOG, and from then onwards the EDS CAFOG will be used by the trainee. Read more about the EDS CAFOG in appendix 9.

EDS traineeship assignment feedback form

As the traineeship should be a self-improving program the trainee is supplied with an assignment feedback form. The feedback form can be found in appendix 1.

EDS traineeship log

During the traineeship the trainee documents his answers and findings in his LOG. A very basic template is provided, it is up to the trainee to structure it in a clear, effective way. More about the EDS traineeship log can be found in appendix 7.

EDS traineeship as talent scout

As EDS is always looking for new talents, the traineeship can be used as a tool to attract prospective employees. For these talents the EDS traineeship would be an interesting opportunity to learn a lot about casting and forging, and for EDS the traineeship is a easy way to get in contact, and evaluate potential employees. For this purpose an adjustmented version of the traineeship should be developed (see recommendations). A possible advertising flyer is shown in appendix 8.

Recommendation: EDS learning sources overview (Phase 2)

The EDS learning sources overview lists all sources that are useful for EDS employees. Furthermore it allows engineers to rate the sources so new employees can easily see which sources are most relevant. As this concept is not developed to its final shape, it is presented as recommendation. Read more about the EDS learning sources overview in chapter 6.5.

Recommendation: EDS quotation book (Phase 3)

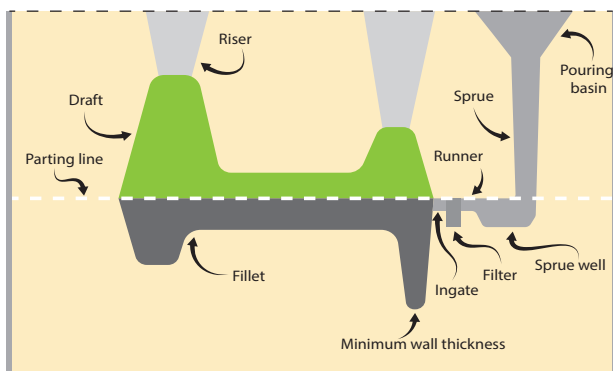
The EDS quotation book shows all projects that EDS has done together with the quoted cost price. This book would enable designers at EDS to better understand how design decisions influence the cost price of a product. As this concept is not developed to its final shape, it is presented as recommendation. Read more about the EDS quotation book in chapter 6.6.

6.2 TRAINEESHIP ASSIGNMENT OVERVIEW

In total this traineeship contains 15 assignments that are distributed over five days. Day 1 is about the basics of casting and forging. Day 2 and 3 are about the design variables of the different processes. During these days the CAFOG is created. During the full fourth day, a design assignment is done. This day serves to test if the trainee can apply all knowledge of the earlier days, and to practice designing for castings. Day 5 is a wrap up day in which several other relevant topics are addressed and the trainee can reflect on what he has learned.

Almost all assignments start with an introduction part in which new content is presented, and conclude with a design assignment in which the obtained knowledge is tested.

Day 1, Assignment 1: Introduction to casting and forging (4 hours)



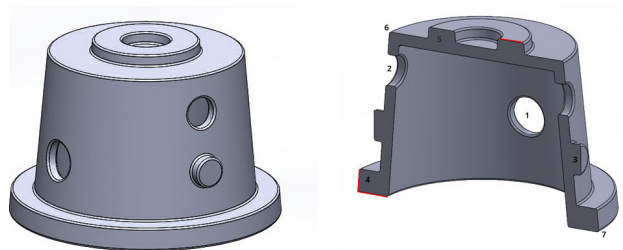
This assignment starts off with watching casting and forging photos and videos, and answering questions about the processes. Real parts that are made with different processes are analysed and literature about casting and forging is read. The assignment is concluded by establishing a shared casting and forging vocabulary.

Day 1 Assignment 2: Gating systems (1.5 hour)



This assignment starts off with creating a perception why gating/feeding is important. Then the gating systems of the 4 main casting processes are analysed. The assignment is concluded by questions about what gating system is best in what situation, and by the task to design a gating system for the parts analysed in the first assignment.

Day 1 Assignment 3 Design for optimal shape (2 hours)



This assignment starts off with reading infographics about optimal design in terms of quality and costs. Then the trainee is asked to make an overview of casting defects. The assignment is concluded with an example of a bad designed casting. The task for the trainee is to redesign the part to make it better castable.

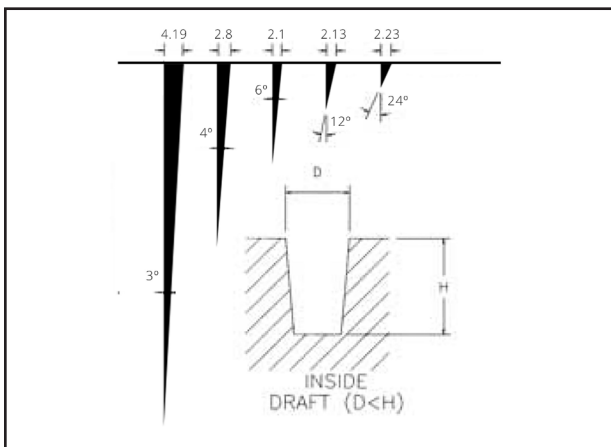
6.2 TRAINEESHIP ASSIGNMENT OVERVIEW

Day 2 Assignment 4 Patterns and dies (2 hours)



This assignment starts off with creating an understanding about the positive and negative shape of a mould or a pattern and the influence of the parting line on a product. Then several examples of patterns and dies are analysed. The assignment is concluded by creating an understanding of the impact that a manufacturing process has on the form freedom of a design.

Day 2 Assignment 5 Product geometry (2 hours)



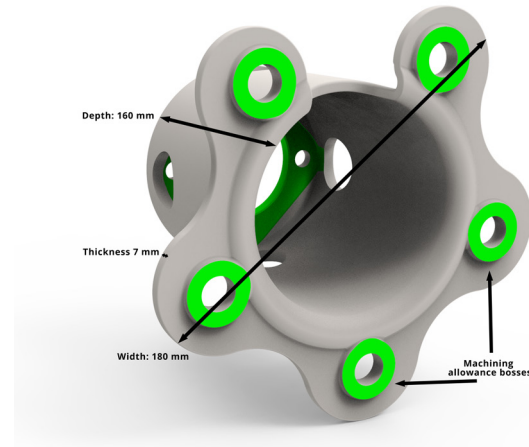
In this assignment the trainee is asked to think about the possible draft, wall thickness, radii, and quantities/weight of the main manufacturing processes. Then the trainee needs to find values for these variables, which results in the first values for the CAFOG. The assignment is concluded by comparing the found values for quantity and weight, with the average quantity and weight of the EDS quotation research.

Day 2 Assignment 6 Tolerances (1.5 hours)



This assignment starts off with analysing the use and function of the 'element clip', and important dimensions are indicated. The mentor explains ISO 8063-3, which is then used by the trainee to calculate the tolerances on these important dimensions. The physical part is then measured with a caliper, so a conclusion can be made about if the part is produced within the given tolerance grade.

Day 2 Assignment 7 Machining and trimming (1.5 hour)



This assignment starts off with watching photos and video's about trimming and machining in practice and questions about machining are asked. Then the principle of machining allowance is explained and applied to a design. Finally, literature about machining is read.

6.2 TRAINEESHIP ASSIGNMENT OVERVIEW

Day 3 Assignment 8 Materials (2 hours)



During this assignment the trainee explores the use and unique selling points of various common metals. The assignment is concluded with a series of questions about the just researched materials.

Day 3 Assignment 9 Manufacturing processes overview (2.5 hours)

In this assignment the trainee is asked to reflect on everything he has learned in the last 2 days and summarize up to 3 unique selling points, and 3 disadvantages of the main casting and forging processes. Additionally he is asked to research online the unique selling points and disadvantages of various other (given) manufacturing processes.

Day 3 Assignment 10 Design for different processes (2.5 hours)



This assignment starts off with analysing the use and function of a welded part

called 'Krabber'. 6 redesigns are shown and the trainee is asked to assign every redesign to a manufacturing process. Then it is up to the trainee to analyse an product called the 'Rail-Bracket', redesign the part for various different processes, and argue in what scenario it would be wise to choose what manufacturing process.

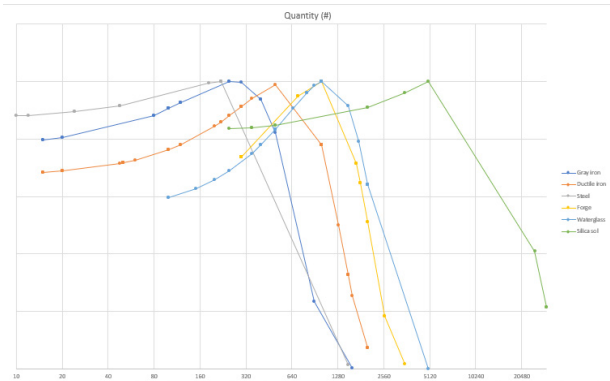
Day 4 Assignment 11 Design for maximal strength (8 hours)



This assignment takes the full 4th day and is about redesigning the 'Draaipuntbevestiging'. Under supervision of the coach the function of this part is analysed, ideas for redesigns are generated, and a concept is made in CAD. Making use of a given load-case and FEM (Finite Element Method), the part is optimized for maximal strength. When finished, the developed redesign is 3D Printed.

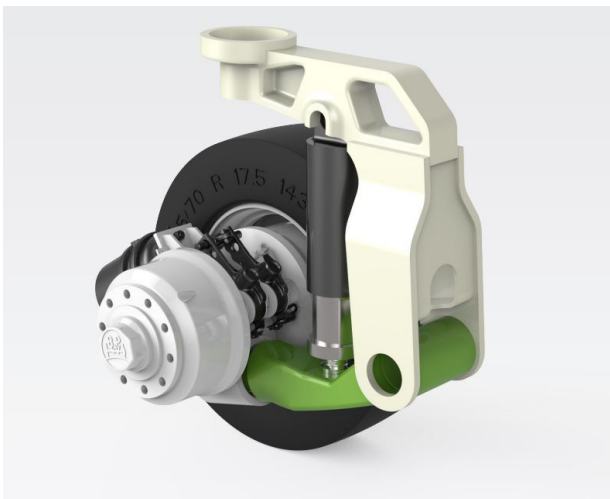
6.2 TRAINEESHIP ASSIGNMENT OVERVIEW

Day 5 Assignment 12 Costs of castings (1 hour)



This assignment starts off with introducing the cost price estimation method that is used by EDS. Then the trainee is asked to think about cost-drivers of the various processes. This assignment is concluded by reading the introduction, method, and results of the EDS quotation research. The trainee is asked what conclusions can be drawn from the results, and how trustworthy any conclusions from this study are.

Day 5 Assignment 13 EDS projects (2 hours)



This assignment is about understanding what kind of projects are performed by EDS. Therefore, the trainee is asked to read/scan several EDS project reports.

Day 5 Assignment 14 Improve traineeship (2 hours)

This assignment is about improving this traineeship by means of designing an assignment. The basis for this new assignment is the assignment feedback form that the trainee uses during the traineeship. The trainee can choose to improve on a topic or assignment that was not clear, or make a assignment for a topic that he missed.

Day 5 Assignment 15 Finalisation (2 hours)

In this last assignment the trainee is asked to reflect on everything he has learned, what went well, and what was still difficult. Then the trainee is asked to indicate what he still wants to learn, this can be a starting topic for the next phase. When the trainee worked quick and is finished sooner than expected, he will be asked to read 'Castings design for performance' (Lampman, 2009).

Conclusion

As also indicated in chapter 5.3, these 15 assignments address all learning goals formulated in chapter 5.2. The assignments are all differed in nature, thereby allowing for different learning styles. By performing these assignments, all 6 EDS skills can be evaluated by the mentor, thereby determining the trainee's talents and the fit of the trainee with EDS.

As the traineeship is made to evolve, the order, and the content of the assignments might change over time, enriching this traineeship even further.

6.3 EDS TRAINEESHIP ASSIGNMENT EXAMPLE

This example assignment is the second assignment that is performed on day 1. From performing this assignment, the following learning goals can be achieved:

- 1.2.2: The engineer is able to explain the principles of melting temperature and material viscosity (level 2)
- 1.2.3: The engineer is able to explain the effects of shrinkage on a casting or a forging (level 2)
- 1.2.4: The engineer is able to explain the influence of gating systems (level 2)
- 1.2.5: The engineer is able to explain the effects of turbulence on a casting (level 2)

Figure 27s 27 - 32 display the images that are provided for this assignment. The answers for this assignment can be found in chapter 6.4

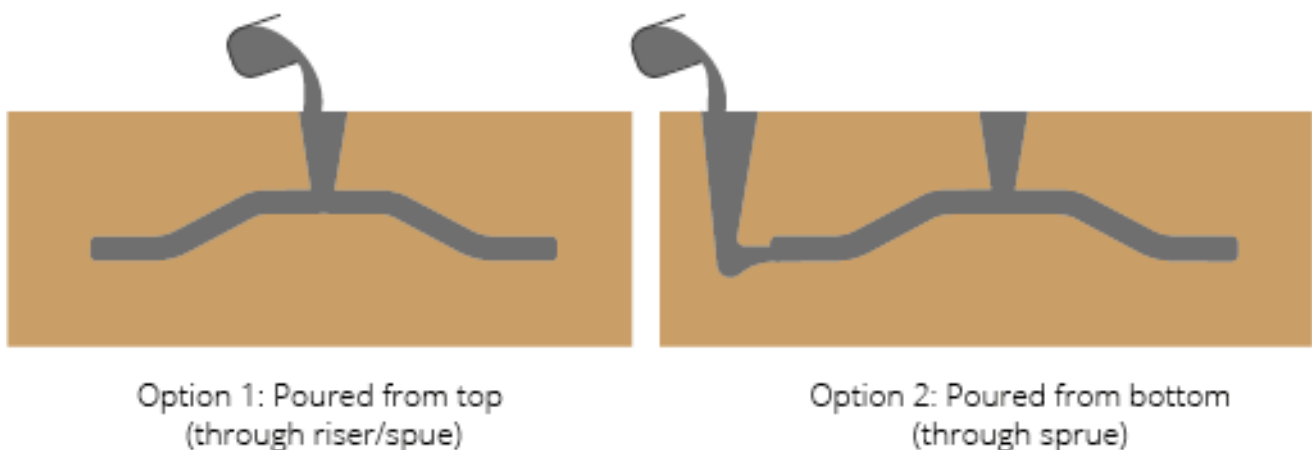


Figure 27 Supplied image for assignment 2.1



Figure 28 Supplied image for assignment 2.2

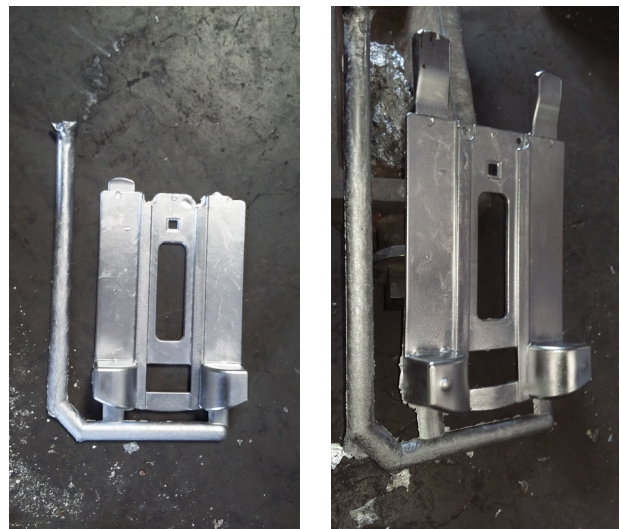


Figure 29 Supplied images for assignment 2.3

Day 1

Assignment 2 Gating systems (1.5 hours)

"Going for the path of least resistance?"

Assignment 2.1 Introduction (10 min)

- Watch the 'Simple gravity die cast' video in the assignment folder.
- 2.1.1 What will happen with a product that has no proper feeding/gating?

For the product in the video it was chosen to pour the metal straight from the top (through the riser), while most castings have a sprue from which the metal is poured (see image: Pouring with vs without sprue).

- 2.1.2 What are the advantage/disadvantages of both pouring/gating methods?

Assignment 2.2 Sand cast gating (10 min)

- Analyse the photo of the copper sand casting in the assignment folder.
- 2.2.1 How many final products are made with 1 sand mould?
2.2.2 How many risers/feeders can you indicate?
2.2.3 What is the thin stick on the right far feeder for/ by what is it caused?
2.2.4 Is this casting itself well designed?

What can be done to fix this cold-running problem,

- 2.2.5 by the designer of the part?
2.2.6 by the designer of the pattern/gating system?
2.2.7 by the foundry employees?
2.2.8 when sending the pattern back to the pattern shop?

Assignment 2.3 Gravity die cast gating (10 min)

- Analyse the photos of the aluminium gravity die casting.
- 2.3.1 How many products are shaped in one die?
2.3.2 How many risers, feeders, and in-gates can you indicate?

This product caused in general no problems, still sometimes a part was rejected.

- 2.3.3 The part on photo 1 was not completely filled, what might be the reason for that?
2.3.4 The part on the right had 2 little spheres on the bottom, how do you think these bubbles got there? What went wrong?

6.3 EDS TRAINEESHIP ASSIGNMENT EXAMPLE

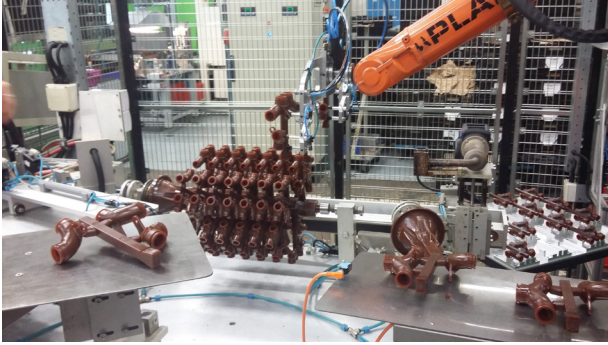


Figure 30 Supplied images for assignment 2.4



Figure 31 Supplied image for assignment 2.5

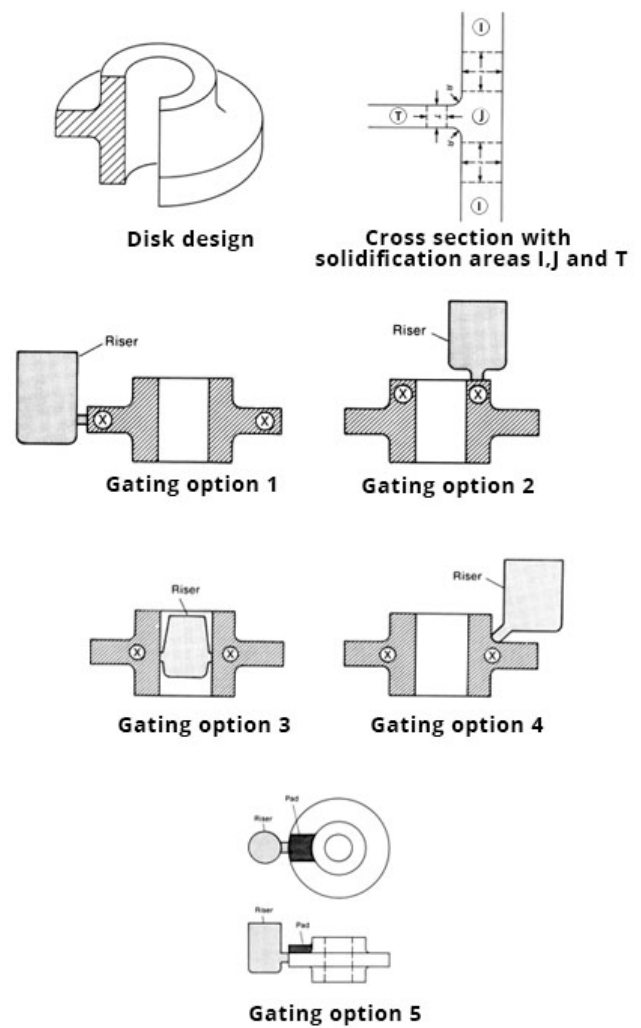


Figure 32 Supplied image for assignment 2.7

Day 1

Assignment 2.4 **Investment cast gating (10 min)**

- Analyse the photo's of the steel investment casting.
- 2.4.1 How many products are shaped by one tree?
 - 2.4.2 How many risers/feeders can you indicate?
 - 2.4.3 When pouring the metal what do you think will happen with the trapped air?
 - 2.4.4 What differences can you expect between parts in the top, and the bottom of the tree?
 - 2.4.5 What is directional solidification?
 - 2.4.6 Why is directional solidification achieved relatively easily with investment casting?

Assignment 2.5 **High pressure die casting (10 min)**

- Inspect the physical high pressure die casting from assignment 1.
- 2.5.1 How many final products are shaped by one die?
 - 2.5.2 How many risers/feeders can you indicate?
 - 2.5.3 Do you think that the part is completely solidified when it is ejected from the mould?
 - 2.5.4 How sound/solid do you think this part is?
 - 2.5.5 Do you think it is possible to give a heat treatment to a high pressure die cast?

Assignment 2.6 **Material yield (10 min)**

- Compare the yield percentage (weight of final part/weight of raw cast) of the gating system of different casting methods.
- 2.6.1 Why is the yield of a method/product important?
 - 2.6.2 Which of the 5 main processes do you think has be highest yield, and which one the lowest?

Assignment 2.7 **Conclusion (30 min)**

The '*gating design*' file in the assignment folder shows different gating solutions for a disk design. Five possible gating solutions are shown, the area that is expected to solidify last is marked with (x).

- Describe for every gating solution the advantages and disadvantages.
- 2.7.1 What solution is preferred when area T is the thickest and expected to solidify last?
 - 2.7.2 What solution is preferred when area T and area I have similar thickness and area J is expected to solidify last?
 - 2.7.3 In what scenario would option 3 be the best solution, and when option 4?
 - 2.7.4 What solution is preferred when area I is the thickest and expected to solidify last?
- Sketch how you would design the gating systems of the parts of assignment 1.
 - Explain your mentor on what assumptions your designed the gating systems, and ask for feedback.

6.4 EDS TRAINEESHIP ANSWER SHEET

From the validation research with the new trainee (Appendix 10) it was found that the EDS traineeship is most effective when answers to the assignments were also available. Therefore, an answer sheet was developed.

At the end of every day the answers sheet (of that day) will be supplied by the mentor. This way the trainee can check his own answers already and the mentor meeting will be more effective as it can be completely focussed on topics that were not clear.

Although the answers on the answer sheet are formulated with great care and checked by the lead engineer of EDS, some answers may still be incorrect or incomplete. It is up to new trainees and EDS to discover inaccuracies, and fix them. Alternatively it might be valuable to have a casting expert from outside EDS review these answers and questions (see chapter 8 recommendations).

Answer sheet day 1

Assignment 2

Assignment 2.1

- 2.1.1 Without proper feeding/gating the casting will not fill good, or will have shrinkage defects when cooling.
- 2.1.2 Pouring trough the riser gives more turbulence, and might result in a casting that is not proper filled, having a sprue is in most cases preferred but results in lower material yield (product volume/total pouring volume) and more trimming operations.

Assignment 2.2

- 2.2.1 2 parts are made with 1 sand mould.
- 2.2.2 The casting has 4 feeders (of which 1 failed to fill to the top) and one sprue.
- 2.2.3 The thin stick is a air vent (allow the air to escape more easily than trough the sand) (the air vent on the other side is broken).
- 2.2.4 This is not necessary bad design as the manufacturer can solve this filling problem. This problem would however not be there if the design was made in a 'safer' way.
- 2.2.5 De designer of the part could have applied safer design guidelines (make part thicker) .
- 2.2.6 The gating designer could have designed a gating system that was thicker or had more/better located in-gates.
- 2.2.7 The foundry personal could increase the pouring temperature, (theoretically) increase mould temperature (very uncommon for sand casting), increase pouring speed, Adjust the gating in the sand mould by hand, or add air vents manually to the sand mould. This is what was done to (temporary) fix the problem.
- 2.2.8 The pattern maker could adjust the pattern.



Assignment 2.3

- 2.3.1 One part is shaped in this die.
- 2.3.2 Feeding is done by 1 sprue and 1 feeder. Two in-gates fill the mould.
- 2.3.3 Most likely this die cooled too much so the first cast fails, but heats up the die to the right temperature. Alternative reasons for not filling could be the pouring speed or material impurities/scrap.
- 2.3.4 The bubbles are shaped by the ejection pins. The foundry-men tried to eject the part too soon.

Assignment 2.4

- 2.4.1 This investment casting tree contains between 100 and 160 parts.
- 2.4.2 There are no risers, the sprue feeds all the parts, thereby functioning as a riser.
- 2.4.3 Most of the air leaves through the sprue while the tree is filled. When problems arise additional air vents can be implemented. According to Cirex engineers (investment casting foundry) smaller amounts of air are also capable of leaving through the ceramic shell. Although this might be hard to believe, it might explain why trapped air is in practice never really a big problem with investment casting.

Note: bubbles trapped within the material (though turbulent pouring) have a harder time escaping. This is the reason that the upside of an investment cast can be more porous than the downside.

- 2.4.4 Difference between top and bottom parts on a tree can exist due to different pressure, and type of turbulence. The exact difference of these parts differs per case.
- 2.4.5 Directional solidification (in most cases ideal solidification) is when the solidification starts at the point most far away from the feeding, and the material solidifies in the direction of the sprue.
- 2.4.6 The tree of investment casting is in most cases circular with a lot of mass on the middle (the sprue). This way the outside of this circle cools down and solidifies first. Thereafter the tree solidifies slowly towards the inside (towards the feeding).

Assignment 2.5

- 2.5.1 1 Final product is shaped per cast with this die.
- 2.5.2 There are 6 metal pieces, but these are not feeders (in my opinion) but rather material overflows to make sure the cavity is filled completely.
- 2.5.3 Part is still solidifying from the inside when it is ejected. This is done to win time, and to not let the part shrink around the tooling.
- 2.5.4 Because of the injection violence (turbulent flow) there is a lot of micro porosity.
- 2.5.5 Because of this micro porosity (little air bubbles in the cast) a heat treatment is not possible.

Assignment 2.6

- 2.6.1 Yield is important as trimming and recycling material costs money.
- 2.6.2 Gravity die casting, sand casting and investment casting have usually low yield. Forging and high pressure die casting have higher yield.

Assignment 2.7

- 2.7.1 When area T will solidify last, it should be fed from there. Therefore option 1 is preferred.
- 2.7.2 When area J will solidify last, it should be fed from there. Therefore option 3, 4 or 5 is preferred.
- 2.7.3 Option 4 requires a core to shape the riser, option 3 requires enough room on the inside to shape the feeder, and special tooling to remove the feeder. Therefore option 3 is preferred when it is made in high quantity, option 4 is preferred in low quantities. Option 5 is preferred when the extra material does not hurt the design so it does not need to be machined away. Option 1 or 2 are preferred when J solidifies last, but when material soundness is not important at that area.
- 2.7.4 When area I will solidify last, it should be fed from there. Therefore option 2 is preferred.

6.5 LEARNING SOURCES OVERVIEW

The EDS learning sources overview (Figure 33) is an recommendation for an Excel document that summarises all interesting learning sources, and enables every engineer to submit a grade and a comment to every source. The learning sources overview can be used for three purposes:

Assess learning tasks to trainee

When the trainee has finished the EDS traineeship there are still many things he needs to read, watch, do and learn to become a good EDS engineer.

Together with his mentor, the trainee can use the EDS learning sources overview to plan what learning sources to use.

Documenting and finding interesting learning sources

The learning sources overview is one centralised place for all interesting links, books and activities that are known within EDS. This way, these valuable sources don't get lost, and it is easy to find them when looking for them.

The grading system makes sure the good sources will stand out between the average sources.

Keep track of knowledge within EDS

From the learning sources document it is easy to see which engineer has experience with what learning sources. When an other engineer needs information about a certain topic or a book, he can see in the learning sources overview who knows that source, and approach this engineer.

Implementation

For this concept a very basic Excel template is made to show how such a learning sources overview might look like. There is however a lot of improvement possible in aesthetics, and functionality of this concept. Therefore, it is advised that EDS develops this template further before using it.

EDS has indicated to recognise the addressed problem, and values the idea of the rating system. Therefore, it can be assumed that, at least parts of this concept, will be integrated in the nearby future.

6.5 LEARNING SOURCES OVERVIEW

Type of source	Topic of source	Description	Location of source	Grade	E	Enzio	K	Khaled	comment	N	Noud	comment	M	Mathijs	comment	V	Vincent	(I	Tim	c	O	Others	comment		
EDS document	EDS process timeline		ISO 9001 dropbox	3.8	4								3												
EDS document	EDS analysis phase		ISO 9001 dropbox	3.8	4								3												
EDS document	EDS concept phase		ISO 9001 dropbox	4.0	4								4												
EDS document	EDS engineering phase		ISO 9001 dropbox	4.0	4								4												
EDS document	EDS finalisation phase		ISO 9001 dropbox	4.0	4								4												
EDS document	EDS folder structure		ISO 9001 dropbox	4.0	4								4												
EDS document	EDS Meeting agenda document		ISO 9001 dropbox	3.7	4								3												
EDS document	PAD Usage		ISO 9001 dropbox	4.0	4								4												
EDS document	EDS SolidWorks working		ISO 9001 dropbox	3.8	4								3												
EDS document	EDS SolidWorks Technical drawing		ISO 9001 dropbox	3.8	4								3												
EDS document	EDS FEM analysis		ISO 9001 dropbox	4.0	4								4												
EDS document	EDS Keyshot renders		ISO 9001 dropbox	3.8	4								3												
EDS document	EDS Trainership		Trainership dropbox	5.0	5		5						5												
EDS document				#DIV/0!																					
Articles	Casting design for performance	Very good reading with lots of exam	Library dropbox	4.5	4																			5 Very good reading with lots of examples for good casting design	
Articles	10 casting design rules		Library dropbox	4.0	4			4																	
Articles	Design for manufacturing and assem	lot of information about cost price	Library dropbox	3.5	4																			3 not applicable for designers	
Articles	Sand casting design rules		Library dropbox	3.5	4																			3 good, yet very basic	
Articles				#DIV/0!																					
Articles				#DIV/0!																					
Articles				#DIV/0!																					
Books	Jevke: Bevestigingsartikelen en gere	for details about bolts, nuts etc	EDS bookshelf	2.8	3																			2	
Books	Materials science & engineering Calli	Material knowledge	EDS bookshelf	4.0	4			4																4 Essential for understanding material behaviour	
Books	Hibbeler: Statica	Mechanical knowledge	EDS bookshelf	4.0	4																				
Books	Hibbeler: Dynamica	Mechanical knowledge	EDS bookshelf	4.0	4																				
Books	Hibbeler: Mechanics of materials	Mechanical knowledge	EDS bookshelf	4.0	4																				
Books	Manufacturing and design	Simple yet clear must read	EDS bookshelf	3.8	4																			4 Great book to get started	
Books	Cast irons		EDS bookshelf	3.7	4																			4	
Books	Making it	Simple and short, all manufacturing	Not available at EDS	4.0	4			4																Very specific, yet valuable	
Books				#DIV/0!																					
Books				#DIV/0!																					
Standards	NEN-EN 1561 (2011)	Founding- Grey cast irons	Standards dropbox	3.0	3																			3	
Standards	NEN-EN 1563 (2012)	Founding- Spheroidal graphite cast	Standards dropbox	3.0	3																			3	
Standards	NEN-EN 1564 (2011)	Founding- Austenitic spheroidal gra	Standards dropbox	4.0	4																				
Standards	NEN-EN 10293 (2015)	Steel castings- Steel castings for gen	Standards dropbox	4.0	3																			5 Essential knowlege to develop technical feasible castings	
Standards	NEN-EN 10340 (2007)	Steel castings- steel castings for struc	Standards dropbox	4.5	4																			5 Essential knowlege to develop technical feasible castings	
Standards	NEN-EN 8062-3 (2007)	DCTG, CCTG, BMAG	Standards dropbox	4.2	4			5																4 Essential knowlege to d	
Standards	NEN-EN 8062-4 (2017)	Draft, DCTG, CCTG, BMAG	Standards dropbox	4.2	4			5																4 Essential knowlege to d	
Standards				#DIV/0!																					
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Standards				#DIV/0!																					
Standards				#DIV/0!																					
Internet source	Solidworks tips and tricks	60 tips in 60 minutes	https://www.youtube.com/watch?v=...	4.5	4			4																	5
Internet source	Solidworks surface modelling	Advanced surface modelling	https://www.youtube.com/watch?v=...	3.0	4																				3
Internet source	Solidworks parametric modelling	Nice model build-up in 25 minutes	https://www.youtube.com/watch?v=...	3.5	4																				3
Internet source	GD&T Basics	Dimensioning and tolerances	https://www.gdantrtbasics.com/	4.5	4																				4
Internet source	Material alloys website	Info about all alloys	http://www.steelnumber.com/	2.5	3																				2
Internet source				#DIV/0!																					
Internet source				#DIV/0!																					
Activity	Analyse existing Solidworks models		Dropbox	3.5	3																				4 Good to learn from each other
Activity	Analyse everyday castings and forging		Everywhere	3.0	3																				3
Activity	Explore casting possibilities online		Foundry websites, tech website	3.0	3																				3
Activity	Master classes (tolerances, solidworks, simulation, etc.)		Everywhere	5.0	5																				5
Activity				#DIV/0!																					
Activity				#DIV/0!																					
Foundry visits	China foundry visit	Many foundries	China	5.0	5			5																	5 Very good for understanding the processes and seeing what is possible
Foundry visits	Cirex foundry visit	Highly automated lost wax	Almelo	5.0	5																				5 Very impressive, but lots of automotive parts in very high quantities (5.000-100.000)
Foundry visits	BNF foundry visit	small (non-ferrous) sand, and gravity	Brabant	5.0	5																				5 Learned really a lot, kind people, maybe I can introduce more EDS'ers
Foundry visits				#DIV/0!																					
Foundry visits				#DIV/0!																					
Foundry visits				#DIV/0!																					
Foundry visits				#DIV/0!																					

Figure 33 Learning sources overview

6.6 EDS QUOTATION BOOK

The EDS quotation book is a recommendation for an InDesign template in which information can be stored of all EDS's quotations. This template would ask for all relevant information like: images of the product, project information, manufacturing information, and costs. Figure 34 shows a possible result for such a page. When multiple of these pages are combined a quotation PDF or quotation book is formed.

Value of EDS quotation book

As discussed in chapter 2.6, it is important for designers to know the financial consequences of their design decisions. However, to know those consequences one has to have a lot of experience with quotations. The EDS quotation book stores this valuable information enabling the designers (but also sales employees) to learn from it.

Creation

The quotation book is not made at once, but grows, as EDS performs more projects. When the purchase department receives a representable quotation, they will communicate that to the main designer of the project. He puts his latest renders, plus the project information and obtained cost price in the template. This way he creates a new page for the EDS quotation book.

Engineers involvement in project status

Currently engineers are sometimes not updated about the status of their project, which is undesirable as engineers put a lot of love in their design. With the proposed interaction an engineer will always be updated about the status of his project.

Implementation

A very basic InDesign template is made to show what such a quotation book might look like. There is, however, a lot of improvement possible in aesthetics and functionality of this concept. Therefore, it is advised that EDS first developments this template further before using it.

Currently there is a shift within EDS to which this concept could contribute. The plan is to make after every project an presentation and a project-document, to let all other engineers learn from a project as well. The developed quotation page fits very well within this project document, making it assumable that at least some elements of this concept will be implemented at EDS in the nearby future.

Name: Zahnkranz
 Project number: CP180786
 Type of project: ED project

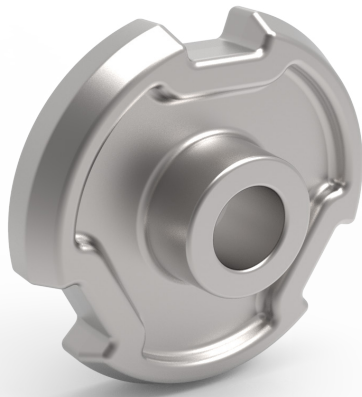


Figure 1 : Zahnkranz as cast

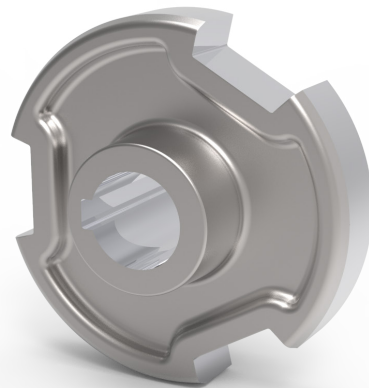


Figure 2 : Zahnkranz machined

Process:	Sand casting
Weight as cast:	1.94 kg
Weight machined:	1.72 kg
Material:	White cast iron
Quantity:	150
Country:	Hungary
Other relevant information:	Surface roughness of 3.2 Ra required
Shaping costs:	€ 4.86
Secondary processes costs	
Machining costs:	€ 4.24
Heat treatment:	€ 1.45
...	
Total part cost:	€ 10.55
Cost per kg:	€ 5.44
Tooling costs:	€ 2400
Note:	Very low quantity/tonnage for sand casting

Figure 34 EDS quotation book page (values are made up)



7. CONCLUSION



This chapter describes the relation of the final design proposal to the problem statement, and explains for every concept how it will help EDS with kick-starting new engineers.

7 CONCLUSION

At the start of this project, EDS expressed their wish to have an in-house document that would centralise their knowledge, making it easier for designers to create and evaluate designs.

This need was translated into the problem statement that new engineers had a lack of easily accessible sources to learn how to design an economical casting or forging. As EDS is a fast growing company that is hiring new engineers in high pace, this identified problem is a very urgent one.

Through an analysis and conceptualisation phase it was found that EDS would be most helped with an EDS kick-start for new engineers. This idea of a kick-start was developed and resulted in an EDS traineeship, an EDS learning sources overview, and an EDS quotation book.

EDS traineeship

The EDS traineeship (the 5-day teaching program) was the main focus of this graduation project. This traineeship was developed and tested on a new engineer at EDS and was found to be highly effective. After the traineeship, the subject could successfully design castings and forgings with only limited supervision.

With this traineeship, the trainee benefits a very steep learning curve. Furthermore, the mentor is saved a lot of time, as it is not required anymore to personally explain everything to the trainee.

Reflecting on the original need, a source that would bundle the in-house knowledge, it can be concluded that the traineeship serves as a perfect mean to do so. With the assignments, this traineeship combines all the knowledge and insights a new engineer

is expected to have. Furthermore, by means of the Casting and Forging design Guidelines (CAFOG) that are touched during the traineeship, a discussion is started about the EDS design guidelines, a document that would capture a great deal of the in-house casting and forging knowledge.

The first test with a new engineer at EDS turned out to be very successful. Therefore, it is expected that EDS will continue using the traineeship program in the foreseeable future. The adjustable nature of the traineeship will ensure that the document will improve and grow together with the company.

EDS learning sources overview

The EDS learning sources was developed from an attempt to create a learning activity that would serve the intended learning goals of the identified 'Phase 2'. However during the development of this product it was found that this document could serve a greater good: managing all learning sources within EDS. This way, also this concept connects flawlessly with EDS their original need of bundling all in-house casting and forging knowledge.

As this concept is not fully developed, it can not yet be implemented at EDS. However, the problems that this concept would tackle are recognized, and the proposed solution valued. Therefore, it is assumed that the insights from this concept will be used in the future development of EDS.

EDS quotation book

The EDS quotation book was developed in the concept phase from an attempt to teach engineers to better estimate costs. During the development of phase 3, it was

7 CONCLUSION

found that this quotation book would also serve as way to capture valuable project information.

This way, also this product contributed to the original need of EDS, centralising and bundling their in-house knowledge.

This concept fits in the current desire of EDS to shape a 'project finalisation document' . This document would summarise a project, enabling engineers to learn from it, and providing the sales department with more material to promote EDS. The quotation book page can easily become part of this project finalisation document. This way it is realistic to assume that a quotation book might be established by EDS in the near future.



8. RECOMMENDATIONS



This chapter describes the actions that could be executed to improve the 3 phases of the EDS kick-start. Furthermore it also describes the discovered topics that are interesting for future graduates to study.

8 RECOMMENDATIONS

During this projects a lot of research and concept development was executed to shape the EDS kick-start. The outcome of this project is more than satisfactory, however, there are still many things that can be improved to maximise the effectiveness of the EDS kick-start, or can be researched in order to help EDS in an other way.

Recommendations on traineeship

Let all employees perform the traineeship.

As a lot of knowledge is put into the guide, and many assignments are designed to create a learning experience, it can be stated that even the most experienced EDS engineer will learn something, or get a new insight when performing this traineeship. Therefore, it is recommended for all EDS employees (including sales and management) to perform the traineeship. Furthermore, the engineers will most likely also have suggestions to improve the guide, giving the next new engineer an even better learning experience.

Execute suggested improvements

The EDS kick-start is designed in such a way that feedback is collected, and proposals to improve assignments are generated, during the traineeship.

There is a risk that many great improvements will be thought of, but nobody will feel responsible to implement these recommendations. Therefore, here an extra reminder for EDS: **The mentor is responsible to implement the approved improvements!**

Check guide with casting expert

Good learning goes by good example. At the moment the questions and answers are established with the best possible

knowledge that was obtained after 6 months of research. However, the questions and answers are checked within EDS, it would benefit the quality of the traineeship to let it also be checked by a casting/forging expert outside of EDS Casting and Forging.

EDS Casting/Forging video

As described in chapter 2.5 there is a need for a informative video that explains, and shows the various casting and forging processes in practice, and explains for what case to use which process. EDS is in a position, and has the contacts to actually make such a video. It would be of a great value for the EDS traineeship, but also for design and engineering schools to have such a video.

Anticipate for different variations

This traineeship was developed for full time trainees at EDS with a starting level of 3rd year HBO or WO. As EDS might hire in the future also more experienced engineers, it might be a good idea to make a second version of the guide that better suits their starting level.

This guide can also be used as a tool to attract new talent, the engineers will get the traineeship documents via email, and perform it from a distance (see appendix 8). There are currently some assignments that require physical products. Therefore, in order to support this use of the guide, an 'at home traineeship version' should be developed.

Recommendations on learning sources overview

Develop a final version

Although the proposed learning sources overview can be used effectively, it is advised to make a final version that has

better aesthetic looks, and is easier in use. This document could for example have click-able links for the proposed papers, and it should be more clear on what criteria the sources are rated.

Encourage designers to use it

The learning sources overview is developed to grow with use. Therefore, it is important that all engineers are encouraged to use the document, add sources, and review sources.

Recommendations on EDS quotation book

Develop a final version

Just like the learning sources overview, also this concept should be developed to its final shape. Especially on aesthetics a lot of improvement can be made.

Integrate in EDS working structure

This concept would require extra activities in the EDS working structure. As the first feedback about this concept was positive, EDS should make this decision definite by integrating this step in the ISO-9001 working structure document.

Future graduation topics

EDS CAFOG (CAsting and FORging design Guidelines)

As elaborated on in appendix 9, a start has been made to create an EDS CAFOG. This CAFOG however, is based on a few sources, experience, and intuition.

Developing an academic CAFOG would be a very interesting graduation project topic for the next graduating intern at EDS Casting and Forging.

Material porosity in FEM

During the development of phase 3 it was observed that designers made FEM calculations with fully sound materials. This is questionable, as castings always have micro porosity that influences material

strength. Researching the influence of this porosity on the factor of safety (FOS), and researching how to estimate the level of porosity would be a very interesting graduation project. This project would also be in line with a previous graduation project at EDS 'Meten is weten', in which hardware was developed to measure the (real) load-case to use in FEM studies.

Costs of castings and forgings

During this project a start was made into researching the costs of castings. Although some interesting conclusions could be drawn, a systematic method to better anticipate costs could not yet be developed due to the limited time and available data.

With a larger quotation database, and by assigning castings more variables, more insight can be obtained into the costs of castings. This could for instance be done by analysing all quotations of one single foundry, or by analysing the quotations of Rayding- linq-U which has a way larger quotation database than EDS.

Maximising feedback during projects

In the development of phase 3 (chapter 5.5), recommendation have been done to improve the feedback within the EDS design process. It would be a very interesting graduation project to investigate deeper into what kind of feedback can be communicated, and how this communication can be best integrated in the EDS working structure.

Conclusion

Casting and forging is an intriguing and diverse area with many possible research topics. During this project I became familiar with EDS the company, and with many of the topics of casting and forging. Therefore, future researchers in this area are more than welcome to contact me for information or support.



9. REFLECTION



In this chapter will be reflected on the graduation project. First the time-frame of the process will be analysed, in which will be elaborated on the activities that took place. Then this chapter concludes with a reflection on my own personal performance.

9 REFLECTION

"ENTPs are as innovative and ingenious at problem-solving as they are at verbal gymnastics; on occasion, however, they manage to outsmart themselves. ENTPs can be prone to "sharp practice" – especially cutting corners without regard to the rules if it's expedient – or, their juggling acts may simply be so over-ambitious they collapse."

Read further about my personality type on: <http://www.humanmetrics.com/personality/entp>

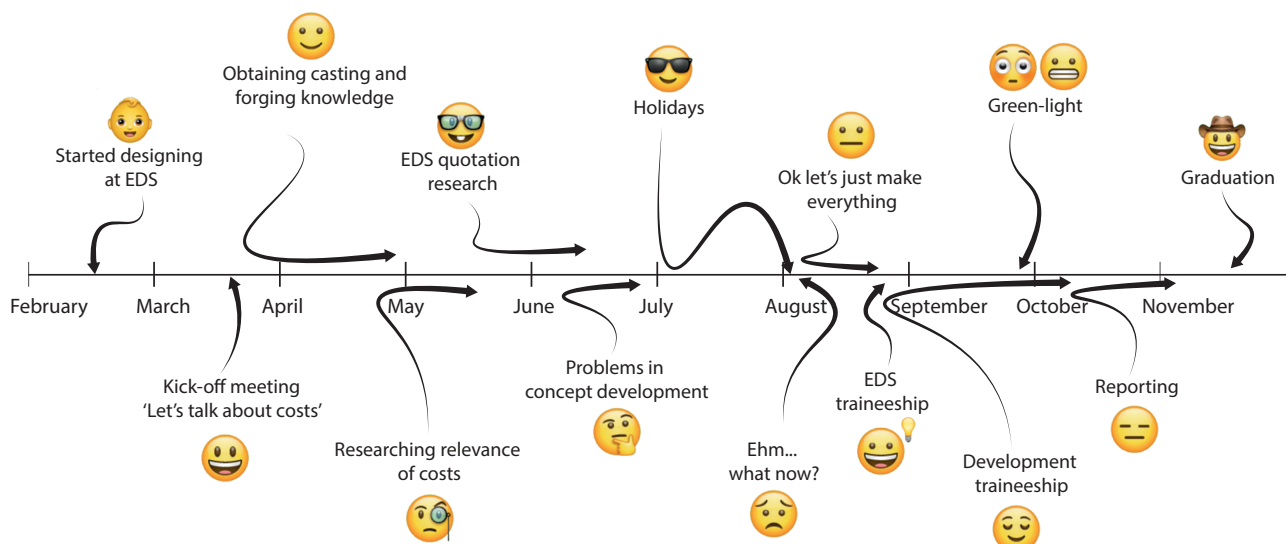
Project overview

This project started at EDS Casting and Forging without a concrete problem definition or assignment. While learning the basics of casting and forging, the insight arose that the ability to estimate cost price better would be a very challenging, yet valuable research topic. With this as starting point the graduation assignment was formed.

In the weeks that followed much knowledge about casting and forging was obtained through literature and 3 foundry visits. Designers both at EDS and at the university were interviewed to learn what the engineers already knew, what they wanted to learn, and how relevant they thought were the several proposed topics. The assumption that it would be valuable to know more about cost price was confirmed, so it was decided to perform a (quantitative) study into all EDS quotations of 2017.

Although a lot of interesting observations could be made during this research, substantial improvements in the approach to estimate cost price were not yet found (as widely expected). A qualitative approach (analysing product geometry) might have resulted in those insights, however, it was chosen to first focus on creating concepts before diving further into this research.

Coming up with fruitful concepts however, turned out to be more difficult than expected. The world of casting and forging is so diverse, that many ideas were either not feasible, or solved only minor problems EDS had. Furthermore, the company and the supervising team seemed to have different interest in the outcome of this project, which did not make it easier to come to a concept that would create value both from a practical (the company) and an academic (the supervisory team) perspective.



As most out-of-the-box ideas were either not feasible, or not supported by the company, the most logical concept direction was developing a casting design guide for EDS. This was a very ambitious task as I had only 4 months casting experience and I do not excel in neither my graphical, nor my language skills.

Luckily, in consultation with the chair I was suggested to develop an activity/series of activities that would teach new engineers about casting and forging. From that idea the EDS traineeship was born and chosen to be the final concept

From that point on, the process was easy. All required knowledge about the casting and forging processes was obtained, more research was done into teaching and learning methods, and the final concept was developed.

For the green-light report I had put my focus on trying to make all chapters visual (instead of textual), which I thought would be my biggest challenge. Unfortunately, because of this focus on the chapter's approachability, it was overseen that many chapter headers were formulated cryptically or vague, which created confusion about the structure of the report. After adjusting the headers/structure of the report and making the planning a bit less ambitious, green-light was granted and both the design proposal and the product were developed to their final shape.

In the end, presented in this report, and supplied to EDS, is a product of which I am very proud. I think I have managed to put all my knowledge and creativity in it, and the company EDS received it gratefully, intending to use it for the foreseeable future.

Personal performance

During the analysis phase I intuitively took a deep dive into casting and forging: reading articles, visiting foundries, and doing design projects often without documenting neither the reason of the activity nor the conclusions. During the concept phase I was looking for a solution that would solve a substantial problem like costs or centralizing design knowledge. I could not accept a solution that would solve a smaller problem. As I can be a real 'thinker' that does not like to give up on puzzles, I got stuck with this goal and stuck in my creativity.

To conclude, during the analysis and concept phase, I do not think that my superiors have seen any sign of the 'excellence', which I was expected to have, (well, that is what they always told me while doing the bachelor honours programme ;). Especially not as I was also overloaded with extra work from EDS, which gave me so much time pressure that most of my communication was full of sloppy mistakes, and the presented work often a bit meager. This way, also the origin of the final idea was unfortunately not completely mine but was suggested by my chair.

It was also during the embodiment phase that I could finally show what I am capable of. Suddenly everything fell into place, and all knowledge I had absorbed could be used. About the origin of the final idea; no I did not come up with it myself, but I think it is fair to say that I saw the value of it, I embraced it, I developed it and made it mine in the embodiment phase. This way I have in the end a very positive feeling about this project, with which I happily conclude my master Integrated Product Design at the University of Delft, the Netherlands.

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