UNIVERSITY OF TWENTE.

Faculty of Engineering Technology

Part optimization design studies in the modern aircraft industry

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Internship report

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MSc Internship Report:
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Preface

Being part of the curriculum of the master program Mechanical engineering at the University of Twente every student has to perform an internship to get into contact with the industry to gain more practical knowledge. These internships can be performed worldwide at Universities, research centers or even at companies.
Due to my interests in the topics composite materials and especially the aircraft industry I tried to perform my internship at a company which provides both of the features.
After having a chat with the professor dr. ir. Akkerman of my department Production Technology (PT) we found Premium *AEROTEC* as the perfect solution to be the host company for that internship.
For my internship I went to Augsburg, Germany for the time of four months (20 EC) from 11 January till 29 April 2016.
Within this internship I mainly worked on different projects which all had one aim: saving of weight and costs by part design optimization. In addition to these projects also some smaller tasks within the Door Surround department were performed in which I supported my colleagues in projects with upcoming deadlines.

First of all I would like to thank professor dr. ir. Remko Akkerman of the Production Technology group for all his time and his effort to come up with the perfect place for my internship.
Furthermore I would like to thank his contact-person at Premium *AEROTEC* , Mathias Friedrich, for asking his colleagues if there are possibilities for this internship. It was quite nice for me to be able to choose the better fitting internship project regarding my study background out of two different projects from two different departments. In addition to that also a big thanks to him for his personal tour through the production location at Augsburg and all the information he told me regarding all aspects of the production process.
I also would like to thank Sergej Zeeb, my supervisor and chief of the department, for the great time during my internship and all the guidance and answers to my questions. The way of introducing me to the colleagues, the friendly atmosphere, the trust in my abilities from the first day on and the quite nice selection of projects, which i

was allowed to perform, would not been possible without you. In addition to that I again want to thank you for the opportunity you gave me to extend my internship at Premium *AEROTEC* on a voluntary base.
Also a big thanks to all the colleagues of the Door Surround Department which made me feel as a colleague of them from the first second on.
Special thanks to Tudor, for the support in getting to learn all things of Catia V5 as fast as possible, and Peter, Stefan, Björn, Simon, Andre, Matthias & David in assisting me at the various tasks I performed and answering all the questions which came up into my mind.
Last but not least I want to thank a colleague of another department, Christian, for his support regarding all the Additive Layer Manufacturing (ALM) topics and for widening my knowledge on these kind of subjects. I definitely would say the conversations with you were one of the reasons why the idea of performing a master thesis assignment in the field of ALM techniques came up into my mind.
In addition to that I want to thank my prospective master thesis supervisor, dr. ir. Ton Bor, for becoming my ad interim supervisor for this internship due to the absence of prof. dr. ir. Akkerman.

Fabian Plura, Enschede, July 15, 2016

Summary

The internship is performed at the Composite Door Surround Department of the company Premium *AEROTEC* in Augsburg, Germany. Being an independent company within the Airbus Group the core business is the construction and production of primary aircraft structures from different materials such as carbon fibre composites, titanium and aluminium. Especially in the internship period the topics were all related to the development and optimization of parts mainly based on the Airbus A350 with the aim to save weight.

During this internship two different parts in the Door Surround region were being analyzed and optimized.

First of all different concepts were generated and tested by use of calculations or even by building prototypes with the Additive Layer Manufacturing method 3D printing. Regarding the first two projects further input of technical experts or extra test data is required to be able to proceed with these topics. In addition to that the documentation of the self-reliant work and providing the necessary information in a structured way to colleagues was also one of the main topics.

Also some smaller tasks were performed to assist colleagues in daily- and weekly projects with approximating deadlines like tolerance analysis or optimizing some parts for the Passenger Door Surround.

Furthermore getting familiar with the process of Design to Cost (DtC) and the acquisition of new projects were two extra parts within all the remaining projects.

Finally the last topic was to gather all the required information for setting a concept version over to a detailed design. In this case an innovative design for the Dado Panel of the A330neo needed to be detailed. While working on this detailed design iteratively performed optimization steps took place to come up with a lighter design in the end. Due to reasons of confidentiality this part is left out of this report.

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List of acronyms

AFP	Automated Fiber Placement
ALM	Additive Layer Manufacturing
A350	Airbus A350
A/C	aircraft
BDS	Bulk Door Surround
CDS	Cargo Door Surround
CFRP	Carbon Fibre Reinforced Polymers
DPM	Design, Production process, Material
DtC	Design to Cost
EOP	Edge of part
FDM	Fused Deposition Modeling
GFRP	Glass Fibre Reinforced Polymers
JEC	JEC Group
MSN	Manufacturers Serial Number
NRC	Non Recurring Costs
PDS	Passenger Door Surround
PAX	Passengers
PEI	Polyetherimide
PLA	Polylactic acid
RC	Recurring Costs

ROI Return of Invest

RSDP Reference Structure Design Principles

SLM Selective Laser Melting

XWB xtra wide body

Chapter 1

Introduction

In this report all the findings and tasks which were done within the internship period will be presented. First of all a short information of the company will be given to get a feeling about the size, production locations etc. This section will be continued by giving some background information regarding the aircraft programme and a selection of the performed tasks.

1.1 About Premium *AEROTEC*

The company Premium *AEROTEC* can be described in the most efficient way by the following quote out the press kit of the company:
"Premium AEROTEC is one of the world's leading tier 1 suppliers of commercial and military aircraft structures and is a partner in the major European and international aerospace programmes. Its core business is the development and production of large aircraft components from aluminium, titanium and carbon fibre composites (CFRP). Premium AEROTEC is Europe's no.1 in this segment with its roughly 9,400 employees at various sites in Germany and Romania and a turnover of 1.6 billion in 2013. Premium AEROTEC is represented by its products in all commercial Airbus programmes. In addition, the company is making an important contribution to the Boeing B787 "Dreamliner". The current military programmes include the Eurofighter "Typhoon" and the new military transport aircraft A400M." [1]
This internship is performed within the Composite Door Surround Department at the Premium *AEROTEC* facility in Augsburg, Germany. Especially in this department most topics are related to the Airbus A350 programme which will be explained in more detail within the following section.

1.2 Airbus A350 XWB programme

The Airbus A350 (A350) is the latest project within the commercial passenger aircraft section of Airbus and one of the most advanced aircrafts in terms of usage of Carbon Fibre Reinforced Polymers (CFRP) due to the wing structure and fuselage which are made from composite material. [2]
Having nearly the same passenger amount and the state of technology it is a direct competitor of the Boeing 787 Dreamliner. Airbus had planned three subtypes of the A350, namely the -800, -900 and -1000. These are mainly varying in the number of frames included or subtracted from the baseline model and thus leading to different passenger numbers but also the need for adaptations like a different set of engines etcetera.

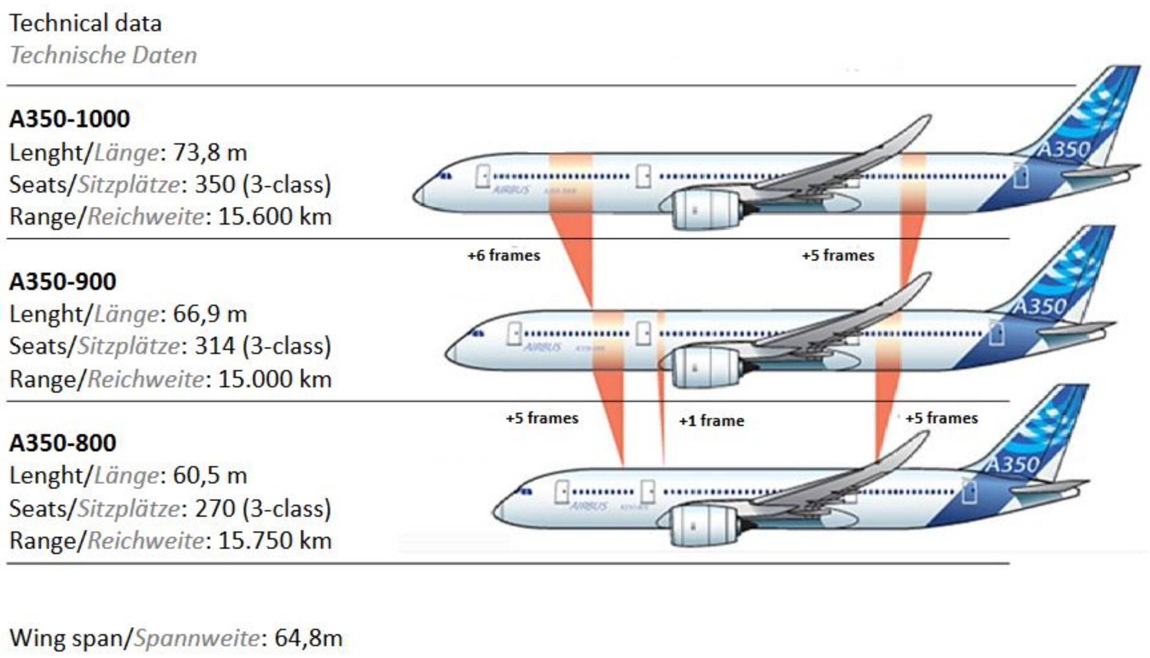


Figure 1.1: The three different subtypes of the A350 [3]

The actual differences in the number of frames can be found within figure 1.1. Due to the market demand of most aircraft carriers the two mostly bought versions are the -900 and -1000 with respectively 605 (-900) and 181 (-1000) open orders. [4]

1.2.1 Sectioning of the airplane

Within the production of the A350 XWB the four panel concept is used meaning that one section consists out of four panels, namely the left- and right-, upper- and lower shell. The first named ones have quite big dimensions while the other two ones are quite a lot smaller in size. [5] Also primary structures like the Door Surround etcetera are joined to the skin-shells before all these panels are joined together and form a section of the airplane. Every aircraft of the Airbus family is subdivided in different sections which are assembled on different locations and by different suppliers. After finishing all the required tasks on the sections they will be shipped by cargo-airplane, ship or truck to the final destination and assembled together. For the A350 this action takes place at Toulouse, France.

So lets have a closer look at the sections in which Premium *AEROTEC* has it's main contribution. These are the section S13-14 just in front of the wings and the section S16-18 placed after the wings which can be found in figure 1.2.

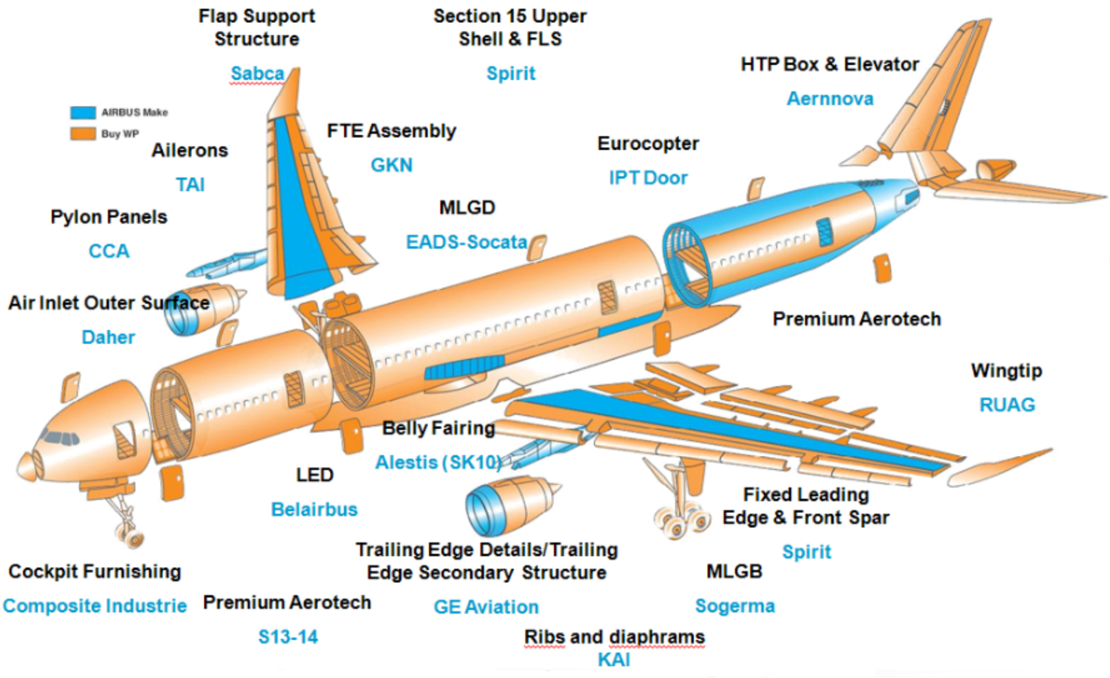


Figure 1.2: Extended enterprise view of the A350 with company names taking part in the programme [6]

Being one of the tier 1 [1] suppliers for primary structures also different parts are produced and even developed by Premium *AEROTEC* . Especially the department of the Composite Door Surround plays a quite big role in this development. The A350 Composite Door Surrounds in the previous named sections are developed within this department.
So what is a Door Surround Structure and how does it look like? How are essential parts named? Where is it located and what is it's function? Answers to all of these questions will be given in section 1.2.2.

[1] tier 1 $\widehat{=}$ company supplying parts directly to the original manufacturer

1.2.2 Door Surrounds

Every aircraft needs to be equipped with doors to guarantee the transfer of Passengers (PAX) or Cargo into or out of it. But how can those quite massive doors (e.g. the main cargo door) be joined to the section?
The answer for that is the Door Surround structure.

Passenger Door Surround (PDS)

Every passenger door in the Airbus A350, even as in other aircraft programmes, is equipped with a Door Surround structure (see figure 1.3 for the original picture & figure 1.4 for the CAD version). This structure guarantees that the loadings acting on the region of the door are safely transferred within the whole structure of the aircraft. In older aircrafts most of the components are made out of titanium or aluminum alloys.
Within the new A350 and the sections Premium *AEROTEC* is developing and producing most of the parts of the Door Surround structure are changed to composite materials. The new frames of the Door Surround consist out of 15% of aluminium and titanium and 85% CFRP which means next to quite significant weight savings also cost-savings compared to the traditional way of building Door Surrounds. [7]

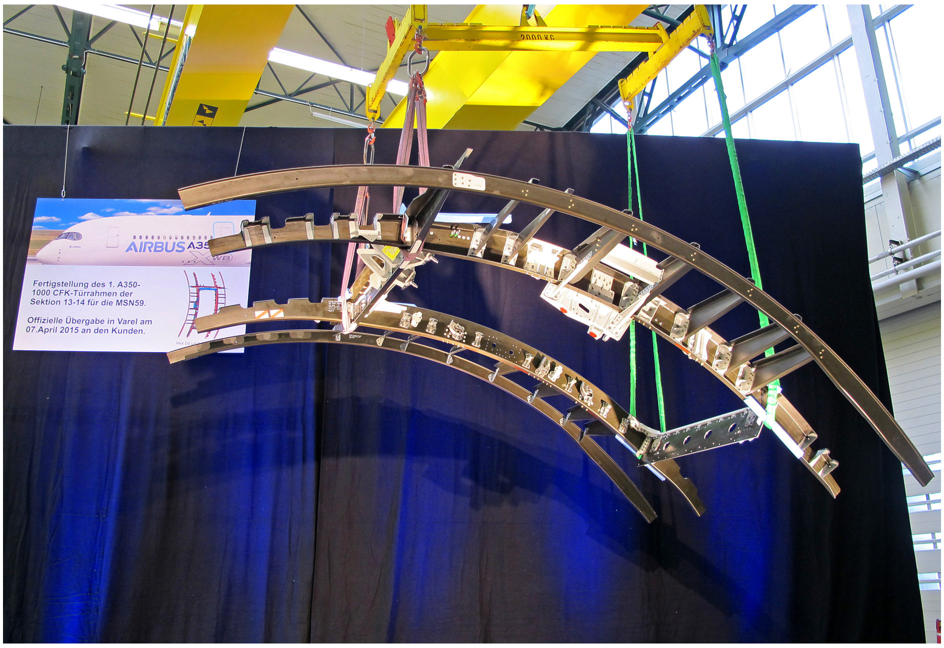


Figure 1.3: Composite Door Surround Section 13-14 of the A350-1000 [8]

With a total number of four PAX doors in the sections 13-14 & 16-18 a high amount of savings can be generated. For being such an innovative concept in the composite

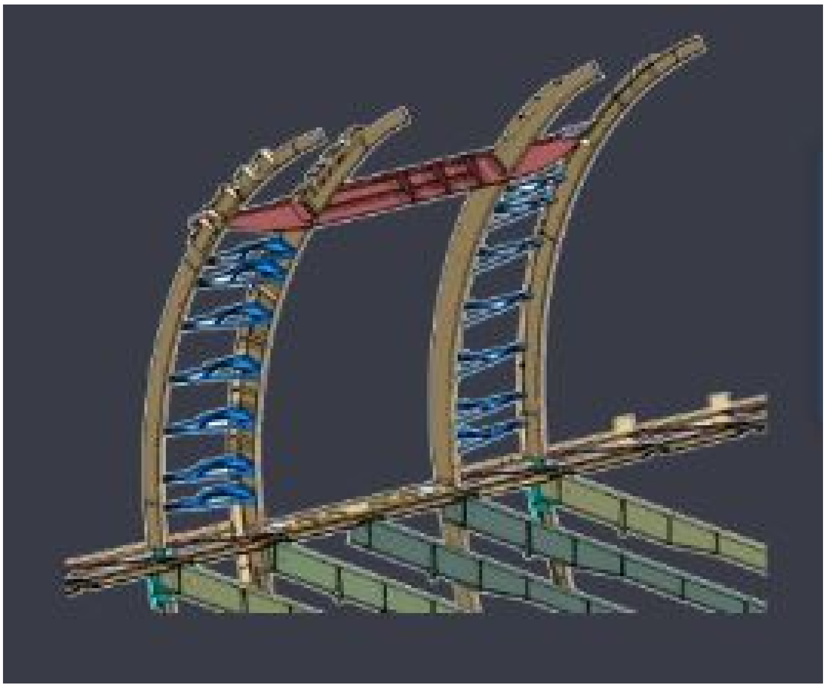


Figure 1.4: CAD model of the Passenger Door Surround [9]

world the JEC Group (JEC) [2] Innovation Award of the year 2016 was handed over to Premium *AEROTEC* in the category Aeronautics. [10], [11]
From the previous questions still the one regarding the naming of the parts remains unanswered. So the reader is back-referred to have a closer look at figure 1.4.
The blue colored parts are called Intercostals, the red ones above the entrance opening together are called Lintel, left and right frames of the entrance are called Door frame, the two external frames are called Auxillary frames.
Last but not least the green colored ones are the Floor Grid beams where the passenger deck is mounted on and directly inside the entrance the so called Shear plate is present.
So why are these names so important? In section 2 the first project of the internship will be described in detail and it might be already useful to know some special terms to get insight over which component or region of the airplane is talked about.

Cargo Door Surround (CDS)

Even as for the PDS also for the CDS an extra structure is necessary to transfer all the loads and to mount the quite huge Cargo Doors. In section 13-14 only one big opening is present where the cargo gets into the aircraft. In section 16-18 a quite small compartment called Bulk, which is also a cargo department, is present. Due

[2]JEC = largest Composite industry organization in Europe

to only being involved in projects of the PDS and the Bulk Door Surround (BDS) the Cargo Door Surround will not be discussed in that much detail within this report.
In the upcoming sections 2 - 4 the main projects within this internship will be described. Some of them will be addressed in more detail while the others will give a more global overview due to the sensitivity of the content.

Chapter 2

Design to Cost of the Drain Funnel

One of the first projects after studying all the Airbus Reference Structure Design Principles (RSDP) regarding the A350, becoming familiar with the CAD software package *Catia V5* and it's *Enovia VPM* environment was to think about a redesign or even a new design of the Drain Funnel for the *A350*.
The interested reader directly will ask: "Why is there any need to redesign or even to come up with a new design for a part which is already built into flying aircrafts?" "Are these parts not fail safe or what is the reason why those parts need to be adapted?"
The answer to those questions is quite simple. Every new airplane is designed in a way that safety factors are used. An aircraft company would run into quite big problems if parts do not withstand test-flights done with test aircrafts of the same aircraft (A/C) type. The appearance of these kind of failures in early stages would lead to not getting the required approval of flight authorities which directly implies that adaptations need to be made but also that time and spend money will increase till the first in-service flight by one of the worlds airlines can take place.
As one example for such a part a connection joint can be used. With the known data of previous A/C programs and the expected load cases in service life dimensioning of parts can take place. For the first aircraft numbers of the new type these data will be multiplied by a safety factor leading to slightly higher amounts of wall-thicknesses for example in the connection joints.
For aircrafts produced at later stages improvements in terms of weight or even the change of parts can be done to increase the total performance of the aircraft. The manufacturer in that case is planning such a start date by choosing a aircraft number called Manufacturers Serial Number (MSN) in the production schedule. Communicating this number and starting date to all the suppliers will guarantee that every design department knows from which airplane on changes are allowed to be made.
One of those examples for bigger adaptations could be the change of the Door Surround structure where a lot of parts will change in material, dimensions and to-

tal number of needed parts. But also smaller changes are possible if they provide enough weight-/cost- or time-savings within assembly.
One of those cases might be the Drain Funnel of the A350, the first project within the internship. To be able to come up with a good solution the problem is analyzed and characterized first. After finding suitable concepts the best one is chosen and presented in a brief technical description including all the relevant facts and details, expected amount of savings compared to the actual state etcetera. This package afterwards is delivered to a special Design to Cost (DtC) team which checks the input, looks if there are any synergy effects and presents it to the management.
After a go decision of them further steps like detailing the work, thus the generation of CAD data and drawings will take place. But also in case of a no-go the idea will be stored and maybe used if the business case due to other changes and combination of those gets more attractive.

2.1 Function of the Drain Funnel

So what is the function of the Drain Funnel? The Funnels are used to gather and safely lead away condensation water to a storage tank called bilge and thus preventing dripping or streaming of water in regions where this won't be useful such as electronic systems but also in case of the primary structure. Last one could lead to corrosion problems over time when the used material tends to corrode.
But where does all that water come from?
The air carries a certain amount of evaporated water but also every passenger is transpiring a quite huge amount of water to the cabin air while the airplane is flying. The low outer air temperature of -50 °C leads to an undercut of the dew-point of the air at the inner side of the skin of the airplane. The result in that area is the forming of ice or the occurrence of water droplets. After landing at an airfield this ice is starting to melt and due to the presence of the Drain Funnel the water will stream safely into the bilge where it can be pumped out of the airplane by ground service crews.

In addition to the earlier described problems one extra problem occurs in the Door Surround section. Passengers which are entering the aircraft might have wet shoes due to rainy weather or even rain could get into the aircraft in case that the door is open and no passenger boarding bridge is used. Also this amount of water has to be safely removed so there is indeed need for those Drain Funnels.

2.1.1 Location of the Drain Funnel

Within the Door Surround four Drain Funnels are used. Two are placed inside the Lintel and two under the Shear plate. At the lower side of these hoses are attached which guide the water to the bilge. The bilge is a storage tank located down in the aircraft which can be accessed by airfield employees via a flap while ground services take place. With a connected hose to that service-point water can be pumped out of the aircraft quite easily.

2.2 Current state of art

The currently used Funnels are made out of aluminum and are produced by use of a turning process. After finishing the parts these are mounted from below to the Shear Plate by use of four rivets (see figure 2.1 & 2.2).

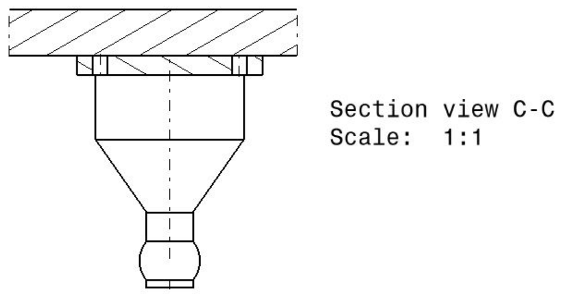


Figure 2.1: Section view of the current Funnel

At the lower side the Funnel will be equipped with a hose which guides the water to a collecting tank. To prevent the hose from getting loose it is secured by a tie-rap. The usage of a fastener like this guarantees a short assembly time but even a safe mount of both components.

The Funnel itself is a part within the primary structure but the expected loadings on it are not that high because the flow of forces will take place on other components of the structure. This leads to the fact that the highest expected load-case will only be reached while the part is being installed to the Shear Plate of the Door Surround.

2.2.1 Requirements of the Funnel

For being a good and new solution the following requirements should all be met: Even as in the actual version the new concept should not fail when certain assembly- and in-flight loads are applied. It would be good to generate a lot of weight-, cost- or number of parts-savings to end up with a good business case. Also saving assembly

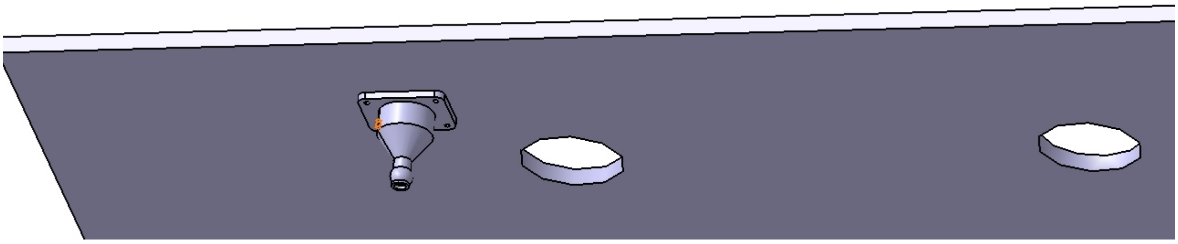


Figure 2.2: The current Drain Funnel with schematic Shear Plate

time by function integration, such as fastening components which are attached to the part, might be a key to success within the DtC inspection.

2.3 Concept generation

The concept phase is used to generate ideas which might be useful for solving the problem. Due to the case that it is a further development of an already existing part which has not a complex product structure a morphologic scheme will not be used. Instead of it the reader is referred to the triangle of product properties, the Design, Production process, Material (DPM) triangle (see figure 2.3).
Out of this figure it can be seen that every change in one of the categories is also influencing the other categories which all together prescribe the final design. Due to the given facts the final product should be made by performing adaptations in these three categories. Performing certain actions on those will lead to different sets of possible solutions which are all choice dependent.

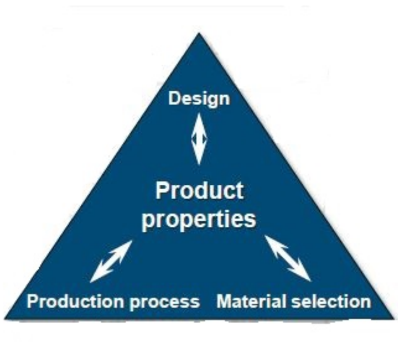


Figure 2.3: DPM triangle [12]

Having a closer look into the given problem it is obvious that in this case the design is already restricted to quite big changes. The interface points of the hose and the dimensions of the connection to the hose are prescribed in standards. If possible less changes to the Shear Plate should be made. The reason for this is quite simple. The Shear Plate is part of a huge assembly drawing. Changes to a part connected

to this assembly or even the need to change dimensions of a connection will induce a quite big change in the drawing set. All of these points lead to a high workload package which induces high costs. So that is the reason why the other two categories will be the ones in which the biggest adaptations will be made to come up with a lower weight or even lower costs.
By having a look into the material section it can be stated that already a light material, namely aluminum, is used in the actual version. Further savings in terms of weight could only be obtained by changing to a polymeric based material. The options still left in the material section with lower densities which are certified for the aircraft industry are the use of composite materials such as CFRP, Glass Fibre Reinforced Polymers (GFRP) or the use of polymers.
For a decision between those two the load case and the expected costs in terms of production will be used. The Drain Funnel is only exposed to very low loads and there is no direction-dependent reinforcement necessary. Furthermore the tooling costs for an Invar [3] tool are quite high and therefore it is chosen to only use a polymeric material.

Due to the choice for a polymeric material, also the production process is preselected in a certain way. One advantage of this choice is the possibility to add functional features in the part which is not possible within the metal section. By integrating these function to the part this results into a decreasing number of fastening components and thus might lead to a decreasing assembly time. Both of the named ones will make a business case even more attractive.
The Funnel could be injection molded or 3D printed. The first one has high tooling costs compared to the second one. Also the fact that 3D printing is an upcoming business and that knowledge regarding the design and construction of those parts can be obtained it is a quite logic choice to choose for this production technique. As certified material for the 3D printing process but also as an allowed material within the primary structure of aircrafts in this case a Polyetherimide (PEI) with the tradename: ULTEM 9085, is used.
The only remark which has to be checked beforehand is if the position of the Drain Funnel lies in hydraulic areas of the A350 because PEI is not allowed to be used in that kind of regions. But after checking the RSDP for this issue this does not seem to be the case.

When generating concepts the used material and production process also must be taken into account at early stages. For 3D printed products there are extra guidelines to increase the quality of the print or even save material. So a short investigation into this process might be useful.

[3]Invar = FeNi36, nickel-iron alloy, with low coefficient of thermal expansion

2.3.1 The printing process in general & Design rules for 3D Printing

For understanding the problems and challenges in 3D printing first of all the process must be known. The main category of the process often is called Additive Layer Manufacturing. Within these techniques there is a differentiation between metals and polymers. For printing of polymers the subcategory is called Fused Deposition Modeling (FDM) whereas for metals it is called Selective Laser Melting (SLM).
So what is 3D printing of polymers and how does it take place?
Within the process the semi-liquid thermoplastic polymer filament, which is wound on a spool, is extruded through a print head (1) onto a heated print-bed (see figure 2.4). By applying this layer (2) movements in the x- and y- direction are possible which are controlled by a CAM software package. After finishing one layer the print-bed (3) moves down with the height of one single layer and the print of the next layer takes place. One thing which should be kept into mind is that in the printer which is used for the certified parts the minimal layer thickness is equal to 0.25mm.

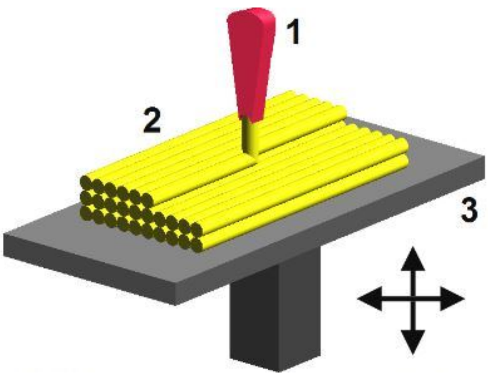


Figure 2.4: Schematic model of Fused Deposition Modeling [13]

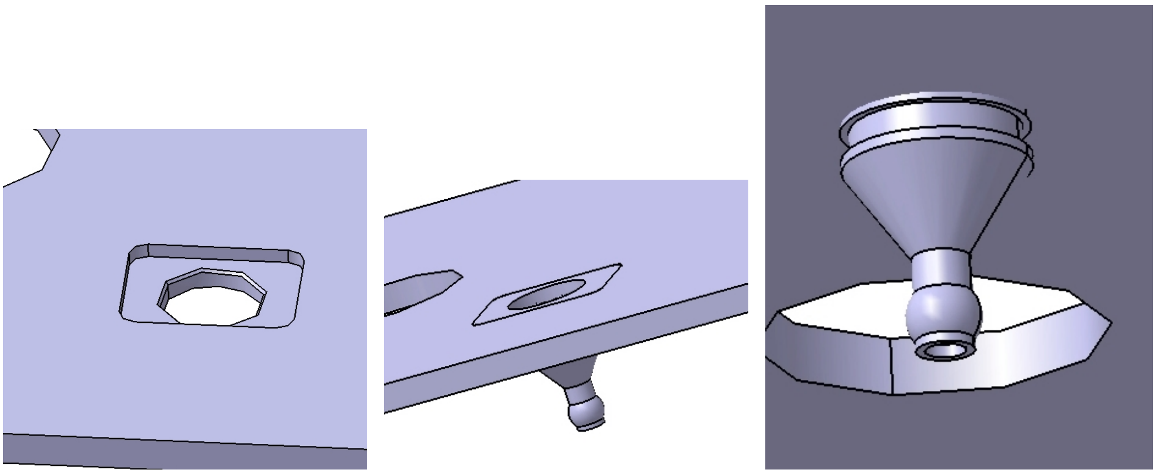
What are the main design challenges?
Due to the prescribed layer thickness the designer has to take care that the final product dimensions are a multiple of the layer thickness to be able to produce an accurate part. Otherwise the part will be too small or even too tall.
Furthermore it is important to know that the printer only prints a prescribed number of perimeters [4]. After completing those in most cases the enclosed area will be filled by a 45 degree filling pattern. But also other patterns are existing like a linear or diagonal pattern. The infill rate [5] of this filling pattern can be set as a percent value but the user should be aware that a too low value might lead to a too low stiffness of the part, whereas a too high number leads to extra weight and more time to print the product.
Overhangs of the structure should be avoided or if possible the printing direction

[4]perimeter = outer contour-lines of the part
[5]infill = procentual rate of the density of the fill

has to be chosen in a smart way to prevent those overhangs. Otherwise a support structure with filling pattern will be printed below of the overhang which needs to be removed after completing the print in a tedious way. Last but not least slopes should have a value of 45 degree to be printable. The length of those lines should be a multiple of the nozzle diameter; this is also valid for the wall-thicknesses of the part. So basically the designer needs to have quite a lot of things in mind when designing a high quality 3D printed product.

2.3.2 Concepts

By using all the knowledge of previous steps brainstorming might be a quite good way to generate as much as possible solutions for the Drain Funnel problem. Out of these ones the best solutions are extracted and further developed. The overview and the working principle of those concepts will be explained below.



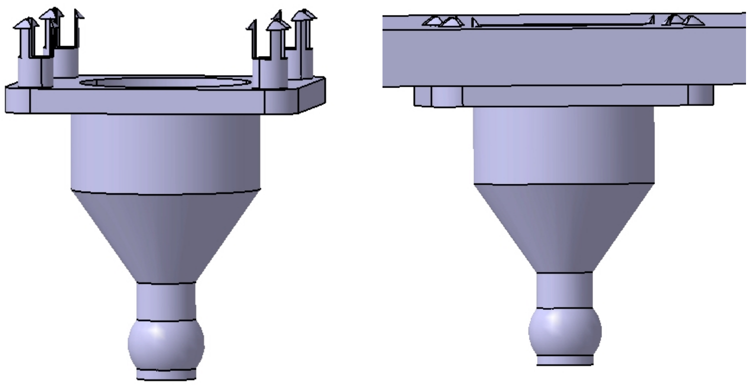
(a) Pocket for the Drain Funnel *(b)* Flush mounted Drain Funnel *(c)* View from below: Funnel with groove for the tie-rap

Figure 2.5: Concept 1 - Pocket for Drain Funnel and fastening it by using a tie-rap

The first concept (figure 2.5) makes use of a countersunk opening in the Shear Plate. The Drain Funnel is inserted from the top to it and secured from below by a tie-rap in a printed groove to keep it in its final position.

The second one (figure 2.6) uses the slightly adapted design of the actual Funnel which will be equipped by extra snap hook connectors on top. The Funnel will be placed from below into the Shear Plate and the snap hooks will click it into position such that the Funnel stays at its place. Even the combination of concept one and two would be possible but is not shown as a visualization.

In this case the countersunk shape will be used to flush fit the Drain Funnel from top to the Shear Plate and click it to position by downwards facing snap hooks.

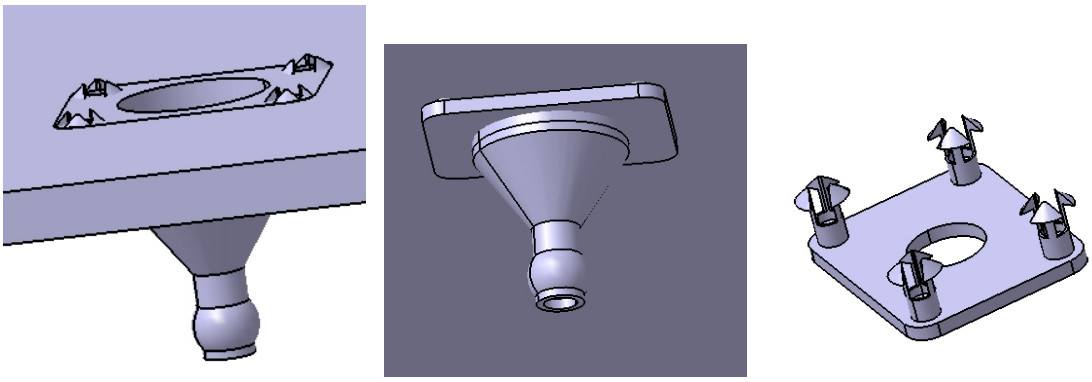


(a) Drain Funnel equipped with snap hooks

(b) Drain Funnel attached to Shear Plate - top of the snap hooks guarantee a safe connection

Figure 2.6: Concept 2 - Mounting the Funnel by use of upwards facing snap hooks

The third concept (figure 2.7) is a slightly adapted one which might use the countersunk version but also the current version of the Funnel. The connection will be established by an extra ring equipped with snap hooks. From below the part will be bolted into position.



(a) Countersunk Funnel - Position secured by an extra snap hook ring

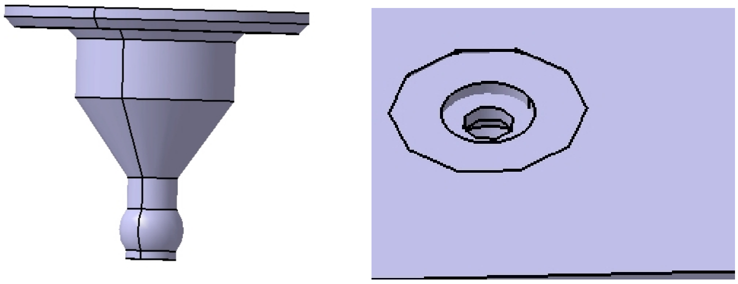
(b) Use of current Funnel- Position secured by an extra snap hook ring

(c) The extra snap hook ring

Figure 2.7: Concept 3 - Use of an extra snap hook ring to secure the Funnel

Last but not least the forth concept (figure 2.8) makes use of a printed thread at the Funnel and the counterpart at the Shear Plate. By simply positioning the Funnel from the top both parts can be screwed into each other.
As a slightly modification of this concept a bayonet fastener system could be used

to keep the Funnel on the desired position.



(a) Drain Funnel equipped with metric thread on the vertical surface

(b) Drain Funnel is screwed into it's final position in the Shear Plate

Figure 2.8: Concept 4 - Printed thread is used to screw both parts together

Out of these concepts the one with the added snap hooks seems to be the most function-integrative one. As a result it is expected that this version saves the most time within assembly but also due to the integration less extra parts are necessary to fasten all the components together. As being told earlier both of these savings are a good way to persuade the DtC team of this new solution.
But first of all some points need to be checked carefully. The snap hooks could be quite challenging to print due to the size and it needs to be checked whether those can be mounted. Therefore a short calculation is made and due to the availability of a 3D printer at a colleague a prototype is printed from the material Polylactic acid (PLA). Even if the material is quite different the production process is the same and maybe extra insight could be obtained by having a closer look at this printed part as well.

2.3.3 Prototype and short calculation

After printing a short attachment ring with snap hooks of the same size as for the Funnel the following result was obtained (see figure 2.10).
The problems by printing such fine and tiny snap hooks are quite obvious. Even if the layer thickness in this case could be set to 0.1mm which is twice as small as the certificated printer does, it is nearly impossible to print the structure in the right way. Small filaments are remaining in and at undesired positions (see figure 2.9).
Also the support structure needs to be removed by hand which forms chances to break the whole snap hook away as it has happened with the left lower one in figure 2.10 . Even a too hard impact on it might lead to a defect which means that the part can't be used anymore.

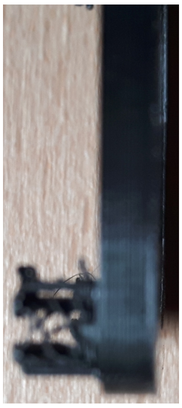


Figure 2.9: Detail snap

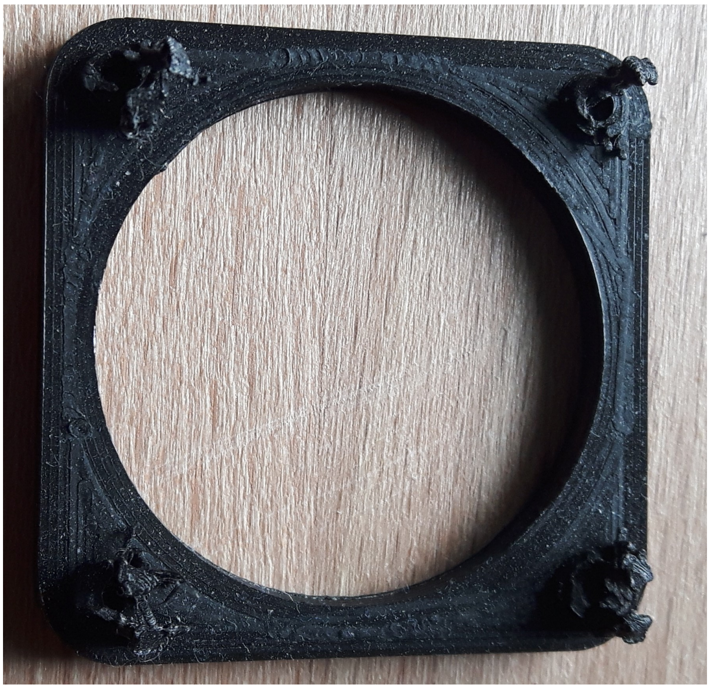


Figure 2.10: 3D printed prototype with snap hooks

Furthermore a short by hand calculation was done to check whether the snap hook connection will work properly or if there are any problems which are already expected due to the tiny size of it. The snap hook connection is assumed to be a cantilever beam with rectangular cross section. For the maximum deflection of the snap hook equation (2.1) is valid [14]:

$$y = \frac{el^2}{1.5t} = \frac{e * 16mm^2}{2.25mm} = 7\frac{1}{3}mm * e \tag{2.1}$$

In this equation *e* stands for the allowable strain in percent, *l* for the length from base to snap hook and *t* for the thickness of the material.
For the strain there seems to be a printing direction dependency which lies in the

range of approximately 2 - 6.5 % for the elongation at break. [15]
In the printed version the direction of the snap hook is located into the z-direction which means the lowest value needs to be chosen for calculation purposes.
Filling in the found value of the paper (2.3%) results into a maximum deflection of 0.164 mm which is way to less. The needed value lies in the range of *2mm*. The snap hook connection needs to be way longer but due to limitations and the thickness dimensions of the Shear Plate this is not possible. So another solution needs to be used.

2.3.4 Final decision

After recognizing all the problems with the snap hook connection the remaining question is which concept would be the best one to solve all the problems. Increasing the sizes of the snap hook would not be possible due to the space under and above of the Shear Plate. The reason for that are further secondary structures like e.g. the doormat which is placed in that region.
Still the tie-rap concept seems to fit quite well and even the idea to only change the actual design to a 3D printing optimized part would be an idea. As one key to success a short investigation of the synergy effects needs to be done.
One of these quite crucial points are the changes made on the Shear Plate of the A350-900. From a certain moment the material is changing from a metal to a composite one. For the A350-1000 this is not the case because it is directly starting of with a composite version, which is actually the same Shear Plate as the A350-900 composite one. Drilling a countersunk hole would be quite more tedious work and there is need to change the drawings twice which implies extra costs.
So it would be better to develop one solution which is feasible for both situations. Therefore the technical drawing of the Shear Plate will not be touched for the small amount of remaining metal versions and a solution for a composite plate is generated.

Remarks

There is only one unknown variable left in this process which still needs to be checked. For using rivets a certain tightening torque is necessary. If this torque is too high the structure in the area of the rivet might form a sunk spot. In case that the wall-thickness falls below a certain value there will not be enough material to carry the loads of the fastener connection. In addition to that the number of used perimeters also needs to be high enough such that the rivet connection will hold and not break through because of too low values of fully printed thicknesses.

To get a feeling for the obtained quality test parts are already printed on the certified printer with a wall-thickness of 2.5mm and testing with different rivets will take place. In case that the actual used rivets will fail other ones could be used. In case that none of them succeeds the wall-thickness of the part might be back increased to a value of 4mm. For the last named case existing test data is available and therefore it is possible to use rivets with a torque of 2.5Nm.

2.4 Conclusion

The result of the new Funnel is a 3D optimized design made from Ultem 9085 which is around a factor of two lighter and a factor of three cheaper in production costs compared to the aluminum funnel. With help of an internal company workload sizing tool the amount for the change is estimated.
Together with the solution, the amount of parts and drawing sets which need to be adapted and the estimated workload and lead time is handed in at the DtC team. If the DtC team and management is giving a green light signal the detailed CAD model based on the findings of the rivet test, the drawings etcetera need to be made. For obtaining a better business case the change should be placed at a moment where even other changes at the assembly of the Shear Plate take place due to the workload which is quite higher for an assembly drawing than for a single part drawing.

Chapter 3

Design to Cost of the Sealing Transition

The second project within the internship time was to think about a solution how problems in the area of the Sealing Transition can be solved. Even as it was the case with the Drain Funnel the problem, function etc. will be described first.

3.1 Function of Sealing Transition

The Sealing Transition is a part which is used to get a more smooth crossing from a structural part in the lower half of the Bulk Door Surround to the skin of the aircraft. For the left and right side two different shapes and sizes are used which both equal up onto the same level of height. Onto this part an elastomer seal is placed to tightly seal the Bulk door.

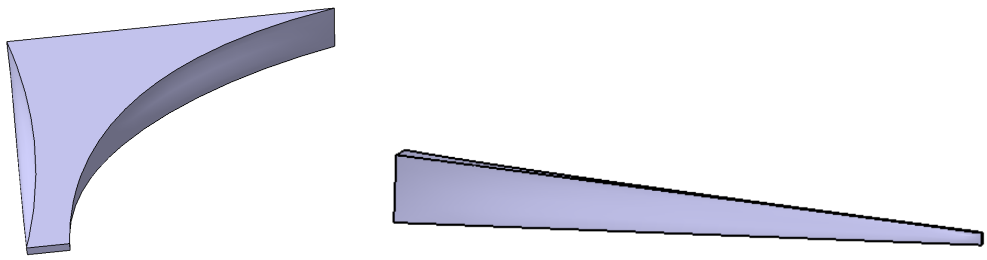
3.2 Current state of art

In the current version these doubly curved parts are made from milled titanium (see figure 3.1). Due to the form and the chosen production process these parts are quite expensive to manufacture and it would be great if a cheaper solution will be found. In addition to that the manufacturing department wants changes to this part due to the high amount of needed production time and high chances of producing parts which do not pass quality tests. Previously it was also tried to manufacture these parts from aluminum or even GFRP composites but both of the solutions did not satisfy at all.
So the main achievements to establish are even as for the Drain Funnel a weight- and especially cost reduction. Furthermore it would be positive if the gap between

end of the Sealing Transition slope and the skin will get smaller for an even more smooth transition of the seal.

3.3 Concepts

Even as in the previous problem the DPM triangle (see figure 2.3) will be used to access and solve the problem. Due to the limitations in space and the need for not changing the transition slope that much the design can not be adapted that much. The doubly-curved surface cannot be prohibited because the transition still needs to be fitted to the primary structure and skin.



(a) Sealing transition *(b)* Side view Sealing transition

Figure 3.1: Plain visualization of the Sealing transition

By reasons of the broad variety of already chosen materials not that much certified construction materials are left over. For benefits of weight reasons polymers could be used. Even as with the Drain Funnel an application of an ALM technique would be possible because it would fulfill the wish of lowering the gap between skin and end of the slope in a quite easy way due to the minimal layer height of 0.25mm.
One reason which is being said against it is one very crucial point. The presence of hydraulic pipes, hydraulic cylinders or even hydraulic hoses in the Bulk Area also indicates that it might be declared as a hydraulic area. Having a closer look into the right chapter of the RSDP states what was already expected.
Ultem 9085 as earlier mentioned is not allowed to be used in hydraulic fluid areas because of it's poor abilities to withstand hydraulic fluids. A possible solution is an surface protection coating and the extra application of an abrasion protection coating which due to standardization reasons needs an extra claim at the technical experts of Airbus.
Another challenge is caused by the application of the 3D printing process. One of the main goals in production of 3D parts is to use as low as possible support material. Due to the doubly curved surface only two surfaces could be used to lay the product onto the print bed.

Placing it onto the lower side like in figure 3.1b results into a good surface quality where the transition is mounted onto the skin of the aircraft. The slope where the sealing runs over will result in a stair like surface. Being able to investigate if this forms problems for the sealing department and also for the department of surface protection a prototype has been print out of PLA.

3.3.1 Prototype

The results of the printed prototype where the following ones. It was quite tedious work to activate the surface due to the stair-like structure. From the surface protection department it was claimed to provide a new or even better concept which prevents that kind of steps. Even the actual stair slope would be a problem for a safe function of the sealing.
So what are possible solutions to cover that problem?
One of them is to apply an extra surface treatment like looping after 3D printing of the product. The result would be that activation of the part and application of the protective coats will become easier. A quite big disadvantage of this is that the price of the final parts will increase quite rapidly due to the extra steps of processing. So are there any better ideas to solve this kind of problems?
Definitely there are better options. One of them is to construct that part as a mirrored part and produce the different layer steps at the opposite site (the one which gets bonded to the skin) and bend it into position during the assembly of the part to the Bulk Door Surround.

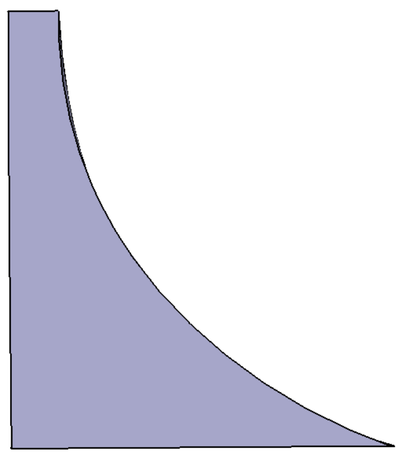


Figure 3.2: Printing solution for good surface quality - Sealing transition placed on short flat side

Another option is to print it on the small flat surface like in figure 3.2 and support it by extra material at the sides such that it will not fell onto one of the other sides within the printing process. The result of this would be that both surfaces get the desired surface quality. The only remark about the last one is that it is unclear if this technique is possible on the certified printers and that it takes a lot more time to produce that part due to a higher number of layers and in addition to the previous one that the part will gain extra weight due to less use of filling patterns in general.

3.4 Conclusion

Producing the part in an upwards standing position would be the preferred choice. If this is not possible due to manufacturing reasons a mirrored part should be constructed and bend back during assembly.

The overall advantages of the new sealing transition would be a weight which is reduced by a factor of two and costs which are reduced by nearly a factor of ten.

The remaining problem with the hydraulic fluid area and the problem of PEI not being allowed in this area still needs to be solved. Maybe an exception can be given for that part by simply applying coatings as it is also the case for some brackets.

Chapter 4

Acquisition of new projects

Also the acquisition of new customers plays an quite important role in everyday business. Being not fully dependent on one business partner also opens possibilities to gain extra revenues by using the existing knowledge of producing and constructing parts of high quality. So how can new projects be obtained? One action which could be taken into account at this point is to put some effort in approaching other company's to present them all the produced products and afterwards to get some new production contracts. But in the other way around things work out much more easy. Being one of the leaders in that business other company's try to get offers for certain parts produced by Premium *AEROTEC* .

In case of an incoming request for a production offer it might be useful not only to answer the explicit question by simply doing all the things the customer is asking for but also to present an alternative which might be better in terms of production costs, weights or used technology. Therefore one of the best ways to make good offers or alternative offers is to shortly discuss with a certain group of different departments if they see any possibilities for sending an improved offer. If from engineering point of view solutions can be thought of these should definitely be included into an alternative offer to the company to increase the chance of winning a new production- or even design-contract.

Also within the internship period offers needed to be made. The necessary actions and extra steps to come up with an offer will be described within this section. For reasons of confidentiality given numbers will not represent real project values and are only used in a fictitious way to present the way of performed tasks.

4.1 Problem statement

First of all the problem has to be defined into detail to be able to think about any solutions. So what needs to be solved?

Within this request for an offer the customer asked for the production of composite frames by using a certain production technique, namely a hand-layup technique. The produced parts afterwards shall be used for a certain aircraft type of his aircraft programme which has different subtypes. For every type of aircraft a certain number of different designs of frames is present but also some frames have common dimensions.
From engineering and cost-engineering point of view these inputs are still too less to make an good estimation of the total problem. Extra information regarding the total contract length, produced number of aircrafts etcetera is needed and has to been asked at the customers company or has to been gathered with help of the worldwide web.

4.2 Production numbers

Before being able to come up with the definite calculations of the costs production numbers need to be analyzed. Due to the fact that a production contract will be made for a certain number of years also the change in the production rate needs to be taken into account for a more precise offer instead of assuming a constant production rate for each year. The actual production sizes can be find in the table 4.1. As already stated earlier the numbers are still fictitious due to reasons of confidentiality. As it can be seen in the table the production of the different aircraft derivate's is nearly splitting up into the following percentages (20/60/20).
In addition to that the number of involved frames for each derivate are given below in this table. One of the conclusions out of this table is that most parts need to be made for derivate two and that the contract length seems to be for a time-span of three years.

4.3 Production technique

As it is being stated earlier the customer has asked for an offer regarding a hand-layup of the composite material onto a production tool. One of the reasons why this is still possible to do by hand is due to the simple shape of the C-like profile (see figure 4.1) and the presence of no ply-drops [6] etcetera. For the part different layers of composite tape will be laid down in the required stacking routine onto a form which is provided by the company. After finishing the total laminate and curing of it the part will be cut to it's final form at it's Edge of part (EOP).

[6]ply drop = reduction of ply numbers by omitting certain ply orientations on a slope to obtain a smaller thickness of the laminate

Table 4.1: Estimated production numbers of the different aircraft derivates for the upcoming 3 years

	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16
Derivate 1	2	2	2	2	2	2
Derivate 2	7	7	7	7	7	6
Derivate 3	2	2	2	2	2	2
Total number	12	12	12	12	11	10

	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
Derivate 1	2	2	2	2	2	2
Derivate 2	6	6	6	6	6	6
Derivate 3	2	2	2	2	2	2
Total number	10	10	10	10	10	10

	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17
Derivate 1	2	2	2	2	2	2
Derivate 2	7	7	7	7	8	8
Derivate 3	2	2	2	2	3	3
Total number	12	12	12	12	13	13

	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
Derivate 1	2	2	2	3	3	2
Derivate 2	7	8	8	9	9	8
Derivate 3	2	3	3	3	3	3
Total number	12	13	13	14	14	13

	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18
Derivate 1	3	3	2	2	3	3
Derivate 2	9	9	8	8	9	9
Derivate 3	3	3	3	3	3	3
Total number	14	14	13	13	14	14

	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Frames per Derivate	Total number frames
Derivate 1	2	2	3	3	3	2	2	160
Derivate 2	8	7	9	9	9	8	6	1644
Derivate 3	3	2	3	3	3	3	4	360
Total number	13	12	14	14	14	13		2164

Due to the knowledge obtained in the development of the Composite Door Surround every design engineer of the department would think about a better production technique to gain more weight- and cost-savings. One way to come up with an alternative is to vary the amount of used composite layers over the total length of the frames. At places where higher loads are passing through the frame will be made thicker and at other spots thinner.

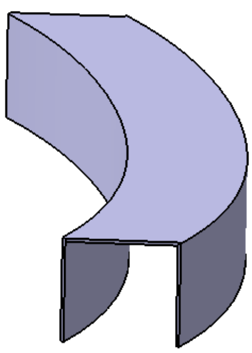


Figure 4.1: Simplified and shortened C-profile shape of the frames without EOP

For being able to produce a part with varying thicknesses ply drops will be needed. In addition to that a faster way for that could be used to increase the producibility. One of the suited production methods could be the use of an Automated Fiber Placement (AFP) process.
The questions which might arise at this point are: What are the main differences obtained in that case beside the earlier named ones? How is the selection of the hand lay-up or AFP process influencing the total cost performance within the 3 years of contract?

4.4 Calculation of the Return of Invest (ROI)

For both situations, so the hand lay-up and AFP process, it might be good to know at which point the initial invest is earned back. In addition to that also the estimated revenue at end of the project might be an important information for a go or no-go decision regarding the sent offer. So this is one of the reasons why the Return of Invest even as the total revenue will be calculated. All the given numbers presented in this calculation are fictitious values.

Assumptions

For a realistic scenario it is assumed that buying new AFP equipment and programming of it has a leadtime of approximately one year and that the total production contract is made for 3 years in total, meaning the AFP production will start one year later. For a fair comparison also an identical starting point with the hand lay-up process will be used.

Table 4.2: Investment costs for both production scenarios

		Hand layup	AFP directly starting	AFP 1year delay
Estimated costs old titanium frame			30000	
Total number frames		2164	2164	1443
RC costs single frame		15000	8000	8000
Possible scrap part number (5%)		108.2	108.2	72.15
NRC programming		n.a.	800000	800000
Manufacturing activities			1000000	1000000
NRC Tooling		3000000	4500000	4500000
NRC new AFP machine			8000000	8000000
Extra costs to compensate scrap per frame		756.931608	403.6968577	405.5440055
New RC costs frame		15756.9316	8403.696858	8405.544006
Saving compared to old situation		14243.0684	21596.30314	21594.45599
ROI	NRC/ Savings	210.628772	662.1503646	662.2070037
Produced earnings		26477864	31919336	18528043

Calculation

Table 4.2 gives an overview of the estimated and approximated values. First of all an estimation for the costs of the old titanium frames is done and a rough estimation of the Recurring Costs (RC) for the frame produced with the two techniques is made. Also it is estimated that 5% of scrap parts will be produced (like parts which do not pass quality tests). The lost money in this area will be earned back by adding a certain value to the RC costs of a single frame.
For the hand lay-up Non Recurring Costs (NRC) for the layup tools are assumed whereas for the AFP process costs for a new machine, programming of it, certain tools and manufacturing activities are taken into account.
The ROI value can be estimated by using the following equation (4.1):

$$ROI = \frac{NRC}{RC_{Savings}} \tag{4.1}$$

For the ROI value it can be stated that in case of the hand lay-up a number of 210 frames needs to be produced to earn back all the invests. For the AFP process this value is slightly higher (662 frames).

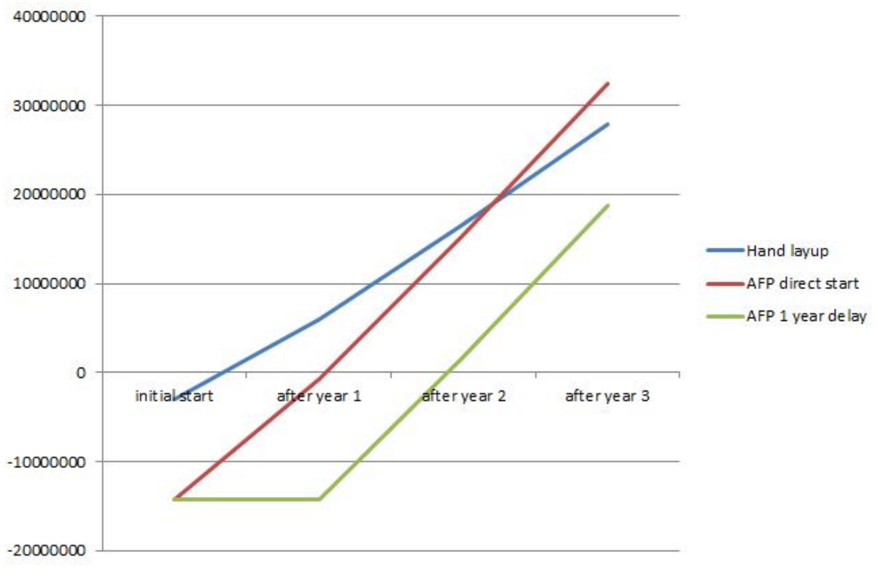


Figure 4.2: Fictitious comparison of the revenues after ending of the contract

Having a closer look at the final revenues in figure 4.2 it can be stated that from a certain moment the AFP process will get into leading position under the assumption that hand lay-up and AFP production will start at the same moment.
By applying a lead time of one year for the AFP process it will take slightly longer to be at the leading position but from a certain moment on this will definitely be the case. So it is still important to perform some cost engineering calculations and check all the inputs in the right way.

Being familiar with a certain production technique does not mean that you always should use it. For a short period contract and a very simple design as it is the case within this fictitious project it might be better to use the production process of hand lay-up.

Chapter 5

Reflection

Within this last chapter a short reflection on the performed internship at Premium *AEROTEC* , Augsburg, Germany will be given.

Before being able to start of with the first projects in the company quite essential design guidelines (RSDP) needed to be studied. Without knowing them or knowing where important information can be found an engineer in the aircraft business will not be able to deliver parts which are allowed concerning the strict standards. As an example: The check if Ultem 9085 may be used in hydraulic areas is also one quite nice example. Without knowing about the hydraulic areas of an airplane the final choice for a product of this material is made quite fast.

By studying all the guidelines and especially the ones for the Fuselage it became clear that some contents are quite familiar to me, like standard rules for the stacking of composite materials etcetera. Also regarding the topic stress concentration factors I heard a lot in the past but at the moment of reading the design guidelines I needed just a moment to think back about the meaning of some of those technical terms. Especially in the area of joining techniques like bonding or gluing of composite materials and metals new knowledge could be obtained.

Beside that I needed to learn a new CAD program because in the aircraft industries normally Catia is used. At our University only Solidworks is used; it is produced by the same supplier but there are quite essential differences in working with it. Together with Catia the VPM Enovia environment comes around. At first instance I was quite a bit shocked or let's say impressed about the extent of both tools. Especially the first time my colleague Tudor showed me where to find a certain part in the complex product structure on the Airbus file servers was quite impressive for me. Even the ability to search for special volumes or even special coordinates fascinated me a lot. Being impressed about all the extra possibilities which can be done within Catia I decided to buy a student license to keep learning this program even after finishing the workdays. The first 3-4 weeks of the internship I performed extra assignments on daily basis (approximately 2 hours each day) and improved my skills quite good I

guess. Getting more and more familiar with this program is also one of the reasons why i used Catia V5 instead of Solidworks for all CAD visualizations.
Kicking of with the real work of an construction engineer I started with two projects regarding the Additive Layer Manufacturing, which has been a completely new topic for me. With first support by a colleague I managed to get familiar with this kind of topic and after that more and more colleagues asked me if can perform some extra work in this area for them. In addition to that it was quite impressive that I worked alone most of the time; before start of the internship I thought that I would mostly work together with other colleagues.
The first two projects regarding the ALM projects stimulated me to work self-reliant on all tasks and I tried to finish all my projects as fast as possible. Every time I finished my tasks I directly went to my supervisor asking for new projects. I wanted to learn as much as possible from my practical time at this company. Especially the ALM topics were quite good examples how the work of a construction engineer will look like. The right technical documentation of work such that other colleagues could continue with started tasks but also the preparation of the Design to Cost presentations gave me an impression of more administrative tasks. By talking to my colleagues i also got some experiences in tasks which are even more boring compared to some projects but which still need to be done. One example for this is the creation of surface protection drawings.
By doing a short excursion to the field of a stress engineer, namely the preparation of a Hypermesh model to predict the deformed shape of a cured composite frame, I also came into contact with that kind of job. At the University projects within the Bachelor phase most of the time everyone performed tasks of different fields. Here at the company it is more split up into groups of specialists, everyone has its own extra skills. Only with a good team, a good communication of team members with each other and a good team spirit the department will be able to succeed in making impossible things possible.
So after all I can say that these four months were I quite nice time; I learned a lot regarding ALM topics, team skills, composite topics in the modern aircraft industry and the use of certain tools like Hypermesh and Catia V5.
Fabian Plura

Bibliography

[1] Premium *AEROTEC* . "Premium *AEROTEC* at a glance". http://www.premium-aerotec.com/en/Externe_Seite_1_3.html, Press kit, PDF file published in March 2015. Accessed on: 2016-06-30.

[2] Airbus Group. "Taking the lead: the A350 XWB". https://www.airbusgroup.com/dam/assets/airbusgroup/int/en/investor-relations/documents/2006/untitled/further_pre_a350_xwb_launch_2006.pdf, PDF version, page 7-8. Accessed on: 2016-06-30.

[3] Premium *AEROTEC* , Matthias Spengler. "Automation der PAG A350 Schalenproduktion". http://www.dlr.de/bt/Portaldata/35/Resources/dokumente/zlp-kolloquium_2015/Automation_der_PAG_A350_Schalenproduktion.pdf, PDF version, page 3, Published on: 15.05.15. Accessed on: 2016-07-04.

[4] Airbus Group. "Orders, Deliveries, Operators - Worldwide, Summary to 31st May 2016". http://www.airbus.com/company/market/orders-deliveries/?eID=maglisting_push&tx_maglisting_pi1%5BdocID%5D=108613. Accessed on: 2016-07-04.

[5] Airbus Group. "Optimised - The A350 XWB industrial process: Xtra optimized from start to finish". http://www.a350xwb.com/industrial-process/. Accessed on: 2016-07-04.

[6] Korea Aerospace Industries Ltd. Structure design. http://ma.gnu.ac.kr/course/2012/am/Structure%20Design.pdf, PDF version, page 7-8. Accessed on: 2016-07-04.

[7] Premium *AEROTEC* . "Premium AEROTEC delivers first door frame made of CFRP for the A350-1000". http://www.premium-aerotec.com/en/Premium_AEROTEC_delivers_first_door_frame_made_of_CFRP_fo...html, Press release on 08-04-2015, also available as PDF. Accessed on: 2016-07-04.

[8] Premium *AEROTEC* . Additional picture of the news article "Premium *AEROTEC* delivers first door frame made of CFRP for the A350-1000". `http://www.premium-aerotec.com/Binaries/Binary7769/Premium_AEROTEC_03.jpg`. Accessed on: 2016-07-04.

[9] Airbus Group. "Airbus Programmes (B) Innovation Days - 28 May 2015". `http://www.aspireaviation.com/wp-content/uploads/2015/06/EVRARD_DIDIER_Innovation-Days-2015_Airbus-Programmes-Update.pdf`, PDF version, page 20. Accessed on: 2016-07-04.

[10] Premium *AEROTEC* . "International Recognition: Premium AEROTEC wins the JEC Innovation Award 2016 for its CFRP door frames". `http://www.premium-aerotec.com/en/International_Recognition_Premium_AEROTEC_wins_the_JEC_In...html`, Press release on 15-03-2016, also available as PDF. Accessed on: 2016-07-04.

[11] JEC Group. "28 Companies rewarded for JEC World 2016 Innovation Awards". `http://www.jeccomposites.com/events/innovation-awards-world-2016/innovation-program/2016-winners`. Accessed on: 2016-07-04.

[12] Ismet Baran, Laurent Warnet. Design, production and materials/ solids & surfaces. Download from Blackboard, PDF version: DPM-S&S Intro 2014-2015.pdf, page 11. Accessed on: 2016-07-04.

[13] Ĺ.N. MARCINČÍNOVÁ. Advantages of rapid prototyping for innovation of products. In *: Proceedings of the 1st international conference Quality and Innovation in Engineering and Management . Cluj-Napoca, 2011*, pages p.333–336. ISBN 978-973-662-614-2.

[14] Clive Maier, Econology Ltd. Design guides for plastics. `http://www.tangram.co.uk/Design%20Guides%20for%20Plastics.PDF`, PDF version, page 34. Accessed on: 2016-07-04.

[15] A. Bagsik, V. Schöppner, and E. Klemp. FDM Part Quality Manufactured with Ultem*9085. In *"Polymeric Materials 2010", Halle(Saale)*, page 5, published in: 2010.