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|  | Timespan | Content | Speaker |
| 1 | 0:00.0 - 1:36.0 | [Introduction to Company D] | Moderator |
| 2 | 1:36.0 - 1:51.1 | So now I would like to know more about your general experience in design for additive manufacturing, roughly how many product or components have you designed for additive manufacturing? | Interviewer A |
| 3 | 1:51.1 - 1:57.1 | Good starting question | Moderator |
| 4 | 1:57.1 - 2:02.2 | I can answer that on easy from my side then so.  For a production point of view | ID06 |
| 5 | 2:02.1 - 2:07.7 | Is that the question you are only looking for series production? | Moderator |
| 6 | 2:07.7 - 2:09.9 | Yes only for series production. | Interviewer A |
| 7 | 2:09.9 - 2:32.4 | I think for series production just one. There is another one. Mhm the two components you can see in front of you, one of them is currently in production, one of them is in development. So is not decided yet that would be the final solution but this particular component is a final solution, is in production and we do actually sell it. | ID06 |
| 8 | 2:32.3 - 2:42.7 | I know one for you and what about the (()) holder. That is in production, isn't it? | Moderator |
| 9 | 2:42.7 - 2:46.0 | Yeah, I didn't do that original design. | ID05 |
| 10 | 2:45.9 - 2:52.7 | No, no no is not. I assume you wanted us to answer in behalf of Company D Instruments not just the individual person. | Moderator |
| 11 | 2:52.7 - 3:04.6 | Well potentially it would be nice the individual person. In the sense that we are looking at the knowledge of the designer itself. If it is not a problem for you. | Interviewer A |
| 12 | 3:04.7 - 3:07.7 | What about your arrow? | Moderator |
| 13 | 3:07.6 - 3:08.8 | I’m gonna go with just like three. | ID05 |
| 14 | 3:08.8 - 3:24.7 | And how often have they come up? How frequently do these projects about components for series production come out? | Interviewer A |
| 15 | 3:24.7 - 3:35.1 | I only deal with additive for mainly now series production or like end production applications so. | ID05 |
| 16 | 3:35.1 - 4:24.5 | And for me is kind of a difficult one to answer I guess. In the respect of it, it kind of depends on the project you are working on. So both of these are quite low volume quantities per annum; and I think it’s as the 3D Printing technology is advancing, it’s easier to utilise it or just to find (justification) in your project and for the end product mainly because of cost, quality and material. So, I have been here just over two years and I have had one project, which I have utilised it on and one project that I might utilised it on, so you can say once a year, but I guess that doesn't really answer the question fully. | ID06 |
| 17 | 4:24.4 - 4:28.0 | I certainly say that is becoming more often, | Moderator |
| 18 | 4:27.9 - 4:28.8 | Yeah Yeah definitely, | ID06 |
| 19 | 4:28.8 - 4:59.1 | Because say four years ago it wasn't even in our minds to use it and then we started using it prototypes a lot and for testing and then it become more. People become more thoughtful and say maybe we could use this in series production and like you say the technology is advancing; so yes perhaps if you said the last three-four years is just only a year; but going forward what could you imagine it being. | Moderator |
| 20 | 4:59.0 - 5:55.7 | I’d foresee it more, more and more. I think one of the biggest issues or two of the biggest issues should I say, one is the cost of and two is the quality of the components. So one of the biggest issues I had with this basket is trying to get that approved by manufacturing guys, who saw 3D printed parts as just prototypes or let’s say we just use it as a jig we wouldn't use it as a final solution, but when you explain the justification behind why we would need to 3D print it and it was, one - the quantity per year, but two - it was the complex shape because it needs to be -- because of what it did then left you with realistically no other option; you either have to completely redesign or you go with the 3D printed part. | ID06 |
| 21 | 5:55.7 - 6:11.2 | Can I ask you another question, since when have you been a designer at Company D? When started to work here? | Interviewer A |
| 22 | 6:11.1 - 6:18.9 | Okay. I started on the 23rd of July 2014, just over two years. Sorry 23rd of June 2014. | ID06 |
| 23 | 6:18.9 - 6:26.8 | I don't know if I fully count but been here for a year and a half now. | ID05 |
| 24 | 6:26.7 - 6:30.5 | So did we explain to Interviewer A that you’re an EngD student. | Moderator |
| 25 | 6:30.5 - 6:46.1 | I am not sure. Yes, I am doing an EngD with XXX Uni and Company D so I have been working with them for two and a half years now; but based here full time for a year and a half and looking at all additive applications across the company. | ID05 |
| 26 | 6:46.1 - 6:53.2 | And in that period of time you already designed and made three components? | Interviewer A |
| 27 | 6:53.2 - 7:08.6 | I have done quite a bit of design, not much has actually gone into end production for series production, but I’ve done a few investigations I guess if it counts, but it always come down to sort of cost or quality. | ID05 |
| 28 | 7:08.6 - 7:25.3 | It is just to contextualise the answer you gave me before about, you said I designed one product for production and you said three, and I just wanted to try to understand and contextualise. Now I want to ask you another interesting thing. What proportion of your projects with additive manufacturing are series production for end-user and what other proportions are tooling and prototypes? | Interviewer A |
| 29 | 7:42.2 - 7:46.0 | and one-off. | Interviewer B |
| 30 | 7:45.9 - 7:49.0 | What number of projects? | Alici |
| 31 | 7:49.0 - 8:09.6 | Yeah. If one hundred percent is your number of project in Company D, how many are the projects that are end-user components? How many are the projects that are prototypes? in which you use additive manufacturing only for prototyping and how many are the projects that you use additive manufacturing for tooling or for one-off? | Interviewer A |
| 32 | 8:09.6 - 8:20.4 | Mine is probably about 70% end production, 20% prototyping, 10% tooling. I think. | ID05 |
| 33 | 8:20.4 - 8:49.2 | Mine is probably 2% end product, 10% tooling, probably 60-70% prototype. Yeah 50% prototype. | ID06 |
| 34 | 8:49.2 - 8:52.1 | How does that add up to a hundred? | Moderator |
| 35 | 8:52.0 - 8:58.6 | Ah sorry it doesn't. Eh do you mean just components that we make? | ID06 |
| 36 | 8:58.6 - 8:59.5 | Well. | Interviewer A |
| 37 | 8:59.5 - 9:04.6 | We don't, because I was thinking we don't prototype everything. So all the components that are made. | ID06 |
| 38 | 9:04.6 - 9:12.3 | So basically the remaining thirty-eight are components in which you have no additive. | Interviewer A |
| 39 | 9:12.2 - 9:13.8 | Okay. | ID06 |
| 40 | 9:13.8 - 9:21.6 | Do you think that this percentage is changing? | Interviewer A |
| 41 | 9:21.6 - 9:24.6 | Yes, definitely. | ID06 |
| 42 | 9:24.5 - 9:25.2 | Yeah. | ID05 |
| 43 | 9:25.2 - 10:37.7 | Definitely. I think we will see a lean towards more production components definitely and certainly prototyping, certainly prototyping. I mean, I cannot speak for, before we had our in-house 3D printer but any prototyping then was probably a lot more limited than it is now; and it would’ve all been metal components and now is almost like a default actually. If you design something we would just test it out in the 3D printer. It advances our processes and takes time of them. A massive amount. Even if we know that the end component would be a machined metal part for example, it’s so much quicker, so much easier just to get it 3D printed just to test out the mechanism or the concept. And that happens a lot all the engineers, we utilise it. I think it comes from the fact that if you want to prove something you don't have to have anybody stand to the machine to manufacture it. | ID06 |
| 44 | 10:37.8 - 11:29.8 | Yeah I would say the same, I guess when I first started, I suppose I was an equal unofficial emphasis put on prototyping and then production additive by I think is kind of become the realisation that is over we are having a rapid prototyping technology but all those other benefits like design freedom and complexity and part count consolidation you are not getting if you are only prototyping a metal or injection moulded part using a 3D printing process; so it has become more, much more of a focus to kind of look at it as an end production option; so that you can get all those other benefits on top of the rapid prototyping style kind of technology. | ID05 |
| 45 | 11:29.9 - 11:48.9 | Okay so in my email I asked you if you could identify some components or products you have designed and then they have been produced in series production using additive, well I have already seen them. Which kind of products or components did you choose? | Interviewer A |
| 46 | 11:48.9 - 13:01.7 | Should do my add-up. This is my first project with Company D actually; so that was originally a twenty-one part piece assembly with silicone sealant. So it had four main injection moulded parts, silicone o-rings, silicone sealant, screws and then some thin switch kind of (went) in the middle to help how direct the air flow. So that was looking at part count consolidation basically, the focus on improving the assembly process. That was laser sintered just in standard PA12. That particular sample has been chemically smooth which is not what we went for, that was literally just what I had on my desk. | ID05 |
| 47 | 13:01.7 - 13:10.4 | Can you show me some of the sketches, CAD files or some mock-ups you have used to make this component, to design this component? | Interviewer A |
| 48 | 13:10.3 - 13:26.6 | Yeah probably. Must be in my MSc dissertation. But I don't have it, I don't have anything with me. | ID05 |
| 49 | 13:26.5 - 13:31.3 | Okay but if it is your dissertation it means we can access. | Interviewer A |
| 50 | 13:31.2 - 13:44.8 | No, no it was part of my EngD master dissertation. So I don't think I could, you could actually use it as a case study. I want to use that for my thesis. | ID05 |
| 51 | 13:44.8 - 14:00.6 | Yes, for two reasons. This one obviously ID05 is using it for her thesis, but also this has some commercial benefits so it is a confidential one. | Moderator |
| 52 | 14:00.8 - 14:04.3 | Thank you to show us anyway. So well. | Interviewer A |
| 53 | 14:04.2 - 14:09.3 | Do you want ID06 to answer as well? | Moderator |
| 54 | 14:09.2 - 16:55.0 | Okay this is essentially a filter and sieve and we did a series of small short-term projects last year where we were targeting specific industries so by there on nature they were quite low production volumes and we needed quite quick turn around on development of them. The shape of it came about for a little bit of research on powder flow. So these have been sold to coffee manufacturing companies. So after they had to ground their coffee beams they needed to size them, the size being quite relevant to the flavour and the type of coffee. So actually needed to measure it, quantify, control their production. There are a number of requirements for it. It had to have a specific volumes and it had to provide quite a linear flow of coffee to the instrument to be measured, it had to be easily removable, it had to filter out some of the (()), some of the coffee beams; so the holes were quite specifically size and we also had to provide two or three different sizes of filters for different types of coffee. In it, one of things I quite like about the 3D printing process, and this is mentioned, is that you can kind of multi-task with a single component. So we needed to sit in a hopper which is a machined component, quite high frequency vibration, but it needs to be easily removable and very quickly removable by the operator, didn’t want to have to use any fixing such like. So we can integrate an o-ring grove in there. So it’s just quite nicely sat, quite nice and tight. One of the earlier design we had slightly issues with some tolerancing so we could easily out some brace pads underneath earing just it gave better grip in certain areas and then because of some issues with air flow around the instrument that it fitted in, we introduced the slip in the front here, which again any other process, look at that and say it’s almost impossible to manufacture any other way. And because of the amount of jobs one little part did, although it was, from essential looking, it was quite an expensive component it meant we didn’t need lots of other components on system and it meant the development time was somewhat quicker. I think we sold probably twenty of these system so far I guess and it came to market expect September last year. | ID06 |
| 55 | 16:55.0 - 17:02.6 | I ask you the same question, do you have some material: sketches, mock-ups, CAD files? | Interviewer A |
| 56 | 17:02.6 - 17:14.7 | I got some CAD files of it. I can find some. I probably got some early iterations of it as well. Have you got anything in your box there ID05 by any chance any of those? | ID06 |
| 57 | 17:14.7 - 17:18.9 | Only I don't know if I bring about, only. | ID05 |
| 58 | 17:18.9 - 17:56.2 | I’ve probably got, I think I can find an earlier prototype. That has got the lip in it, it has a slightly different shape. Again we 3D printed this in our 3D printer which is a plastic FDM printer, but it didn't have the clarity of the holes, so it gave us some information the definition wasn't there for this hole size which again is quite critical because of the powder size. I don't think I have got; but I can find some info for you, it should not be a problem. Does that sound ok? | ID06 |
| 59 | 17:56.1 - 18:03.5 | Yeah we need to check with our commercial team whether is okay to share that. It is a lovely study though, if we can. | Moderator |
| 60 | 18:03.5 - 18:31.4 | Well. Thank you. So how did you decide for these two examples to produce in series this product or component? Why? How it happens that you decided well that filter there probably it will be good to make it in additive or this component here it would be good to make it in additive. How did you decide that? | Interviewer A |
| 61 | 18:31.4 - 19:23.2 | This one was mainly the quite complex shape and then quantity per year that we were selling. I think it’s fair to say especially with the o-ring grove, we could’ve got around there by redesigning it slowly but the only other way I get something like that was probably to press it which would have been white expensive tooling. And for ten to twenty units a year, you would’ve been looking at quite a few thousands of pounds worth of tooling which is ridiculous and then exactly what that mesh would have turn out like, you might’ve had to have many iterations of the tooling to try and get it. So cost of other manufacturing methods and complexity of shape kind of led really to the logical conclusion that 3D printing was the only option. | ID06 |
| 62 | 19:23.1 - 19:27.1 | I think you guys came to me with the add-up, didn't you? | Moderator |
| 63 | 19:27.1 - 20:27.7 | And that was because. So this was been assembled here in Company D and it was quite a messy assembly operation with lots of different components. I think it was like three different assembly steps where you had to put different sub-assemblies on. So I think that was the reason for looking at additive knowing that you can get the complexity, shape complexity all in and get that design all in one component. That particular component, thirty did go out to customers but then production moved to China so the justification, the cost justification and analysis changed. So long term it’s still the injection moulded part. | ID05 |
| 64 | 20:27.6 - 20:30.2 | Is it still the previous design but made in China? | Interviewer A |
| 65 | 20:30.1 - 20:37.0 | Yeah or made here and then assembled in China and then come back here I think isn't it? | ID05 |
| 66 | 20:36.9 - 20:53.6 | Actually yeah the other thing, sorry for that, was the time period of the project, it’s a quite short time scale. | ID06 |
| 67 | 20:53.6 - 21:00.5 | Then, which additive manufacturing technology was used to produce these two components? | Interviewer A |
| 68 | 21:00.9 - 21:37.0 | I looked at FDM, material jetting and laser sintering; but the end choice was laser sintered because of the finish, cost, because obviously then machine productivity is much better for laser sintering than FDM; and material. | ID05 |
| 69 | 21:36.9 - 21:46.7 | Okay this was almost laser sintered. | ID06 |
| 70 | 21:46.6 - 21:58.0 | And you kind of explained a little bit how did you choose selective laser sintering. In your case how did you choose selective laser sintering? | Interviewer A |
| 71 | 21:58.0 - 22:33.9 | So it needed to be a highly chemical resistant material; although it’s fair to say this one, the predominant end-user is the coffee market. It could’ve had numerous and it could still have numerous applications; so we needed to make sure that it has had that chemical compatibility. So it’s 316 is stainless steel, not the easiest material to print and I think it is fairly to say not that many 3D printing processes can do it yet. | ID06 |
| 72 | 22:33.8 - 22:36.0 | Right, no, only powder fusion yet. | ID05 |
| 73 | 22:35.9 - 22:41.7 | So it kind of meant it was that one thing really. | ID06 |
| 74 | 22:41.7 - 22:46.6 | Did you consider any conventional processes? | Interviewer A |
| 75 | 22:46.5 - 23:57.1 | We certainly did with this product. It was quite quickly realised that maybe we should go down the design for additive manufacture because of the shape, because of the complexity, because of the time scale; but it's not currently a normal manufacturing process for us, should we say, they are more special cases. So we did look at more normal processes such pressing, such as machining; but has mentioned earlier, the shape of it is like it is for numerous reasons and trying to get that shape from other processes meant to be really, really difficult; so it kind of meant you rather have to redesign the all system and think of a really crazy way of doing it or utilise that and time scale said we can't really think about it too much. | ID06 |
| 76 | 23:57.0 - 24:06.2 | Well you already answered this question but, do you remember what were the main considerations for using additive manufacturing? | Interviewer A |
| 77 | 24:06.2 - 24:23.9 | The main for mine really, was the complexity of the shape, with the very close second, the time to market. | ID06 |
| 78 | 24:23.8 - 25:05.2 | Yeah, I’d say the same. It’s definitely the freedom, freedom of design and being able to improve your functional performances or your customer interaction features and part count consolidation and the design and production and supply chain benefits, I would say. | ID05 |
| 79 | 25:05.2 - 25:19.1 | Now also you answered already this question, but was the component previously made with another technology, in your case you said injection moulding and in your case? | Interviewer A |
| 80 | 25:19.1 - 25:21.8 | It wasn't, it was a completely new product. | ID06 |
| 81 | 25:21.7 - 26:50.0 | Yeah I probably add, I expand on that. So that is something that is sort of come up in my work a lot is the difference between designing or developing an existing design for an applying additive technologies and developing a complete new concept. And it has all come up a lot how much more freedom you have when you are designing new product from start and also when you are comparing the different processes, particularly cost, it's much more difficult to justify additive I think purely due to so what costs are accounted for when people say manufacturing cost. And definitely you got more design freedom when you are designing from scratch, because I think a lot of the type that, for instance, I couldn’t change any internal geometry, because of the air flow and the impact that would have on the all instruments' performance, it would have to go through quite a lot of re-testing, which is obviously added resources needed, so there was constraint for that on not changing any of the internal geometry and therefore what I could kind of do with regards to make it more cost effective manufacturing process or something like that. | ID05 |
| 82 | 26:50.0 - 26:57.7 | I guess what would’ve been really interesting is if you would be able to look at that process right from the start, what else wouldn't you have needed. | ID06 |
| 83 | 26:57.6 - 27:22.5 | Yeah I mean, what I would have like to be able to do and I think it’s an interesting application for additive generally, is looking at CFD, isn't it? CFD and that kind of building up your geometry around your perfect airflow if you like; so that’s what would’ve been nice to do with that. | ID05 |
| 84 | 27:22.5 - 27:36.0 | So if yes, how did the design of the product or the component change after it was decided to be made in additive manufacturing? | Interviewer A |
| 85 | 27:35.9 - 27:57.1 | About literally all the components were just consolidated into one and then could include things like part number and material info, I guess it was on the moulding already. Yes, this is probably it. | ID05 |
| 86 | 27:57.0 - 29:11.0 | I guess the main addition to this one, after testing was the lip on the front. This is just touch on against some markings on it; so because we had different filter sizes, we could actually put the sizes of filter on and also the arrow letter to show which way of the front was. Yeah, I think this is probably about it. It just gave the -- we knew that after testing we needed, airflow was critical across the top of the component and this seals are quite closely to it and another (fit) funnel. So we knew that we needed to restrict the flows, the airflow so there were coming through the system but having the design freedom of the 3D printing process, it meant we could just go, or we needed the front of that a little bit taller, if it had been a machine part or especially a moulded part. It would’ve meant modifying your tooling or changing your CAD/CAM program but as it’s a 3D printed part it just go: I want a little bit more here please. | ID06 |
| 87 | 29:11.2 - 29:51.7 | Now I am going to use a metaphor and ask you to immerse yourself again in the experience of designing that product and that product; so let’s imagine that all the development, all the design process that you did to design those components had been video recorded completely and is now stored on a DVD and we are taking the DVD out and we are playing it; so my first question is how did you design that component as it is now, I mean why the design is as it is? | Interviewer A |
| 88 | 29:51.7 - 29:56.4 | Do I have to base on that one or can I base on my general experience? | ID05 |
| 89 | 29:56.3 - 30:06.8 | On this one. Specifically, on this one. | Interviewer A |
| 90 | 30:06.8 - 30:10.9 | No, you might have to repeat the question again. | ID05 |
| 91 | 30:10.8 - 30:19.3 | Basically how did you design this component? What did you do from the very, very beginning. How? | Interviewer A |
| 92 | 30:19.3 - 30:31.4 | I think you are asking how to talk about the video. You just imagined they created from watching you design it, from the start, the beginning, so what were the steps? | Moderator |
| 93 | 30:31.4 - 31:49.8 | Okay, so I am taking myself back like two years. So, I’m pretty sure the first things I did was look at the physical components and hold the assembly, took everything apart and put it together. And I kind of looked, understood what all the function of the different parts was, and then literally took out any components that were no longer needed like o-rings and joint the CAD files together into one model. I then got rid of any features that were purely there for conventional processes like drafts or. I kind of made sure all the walls joined up equally, took out any draft angles. I think I probably thickened up some features for strength. It's all about it I think. Then the whole complex process selection process. | ID05 |
| 94 | 31:49.7 - 31:52.4 | For finding out the best process of ... | Interviewer A |
| 95 | 31:52.3 - 31:54.2 | Yeah, yeah. | ID05 |
| 96 | 31:54.2 - 31:56.5 | But for a geometry that you already had? | Interviewer A |
| 97 | 31:56.5 - 32:28.2 | Yes. Yeah, I think that was one thing that it. I don't know if it's for Company D particular but kind of getting the functional performance is the kind of really important thing and then. Well depending on the component and then going through your process and material selection. I’d say that depends on the application of part, when I, anyway, start thinking about exactly what additive process might be used. | ID05 |
| 98 | 32:29.2 - 36:54.8 | Okay, so we have a standard product, a standard powder feeding product and initially look at that. We also have a special product for dealing with semen, so coffee itself is quite difficult powder, difficult sample and it's known for, because it's difficult to handle, because the way it flows and how sticky it is. We also know that semen is an issue, so it kind of drew some inspiration from what or should I say started with a cross between our standard component and the semen package that we offer. There were some constraints with how the coffee package had to fit on the system, the semen package is too big. Essentially the first process was to shrink that to fit inside a system and to make a prototype which was a machined part. Then to get an understanding of how the coffee would flow in that system, what worked and most of it was what didn't work actually. There was quite a lot work went into different types of surface coatings on the actual tray that this. The tray on the hopper, this feeds into but in hand in hand with that was how this flow the powder onto to the surface. The surface coating was on thing, you needed to be a non-stick, should we say, but the way this fed the powder onto that non-stick surface was quite critical. So it started off as, a very simple filter element with basically just the hole that you can see there; then developed more into the crucible, should we call it, it had to. We knew there was a non-volume that had to hold and there was also an extendable volume feature so, there was a feature; so, sorry, a funnel that fits above this, so it’d say went from the simple filter to a hopper as well, a feed hopper, it had to have some user interactions, so the user had to take it in and out. There were numerous iterations with the shape of it. And then the last bit, I guess, was just refining the design, so that it would pass tolerance analysis process. So that we made sure that it’ll always fit. The fit is quite critical in the hopper as I mentioned it vibrates so we don't want it to come loose, but we want it to be easily removable by the operator. The final tweaks were the growing of the lips trying to help with the air flow. I am no gonna say it designed itself because that would mean I wasn't needed, but they, the process itself by sort of making something, testing it, finding out, it kind of help design itself but there was also quite a lot of research in powder flow itself. So it’s a known issue in every industry that uses a powder sample, should we say, from (road) manufacture, flower, storage to coffee; it’s a very difficult thing, it’s the science behind it itself and the shape of it; it is that way because of the research and from the powder flow and what works well and what's known, how other industries have got around that. Say it was -- other industries have used multi-components that may use air jet for example to try to disturb the powder. What we were trying to do with this is make it all in one piece so didn't want to have the air flow in there; although that’s how the semen guys utilise it. It must tweak to the shape after a little bit of testing. It’s quite step by step. Little tweaks. It’s not massive changes if you saw the first one and the last one. They are not, you know, (choc and cheese) should we say, but it did, the process helped design itself. | ID06 |
| 99 | 36:54.7 - 37:05.4 | What were the design considerations at the concept stage, so when you had to generate basically the idea to solve this problem? | Interviewer A |
| 100 | 37:05.4 - 38:29.9 | The design constraints. For me, one was the volume of sample that was required each time, the number of different samples as well. One of the tricky things of this project was -- we went from a sample range of quite a few microns in size to a couple of millimeters in size; so we had to deal with what is for us quite a large range of sample size, the chemical compatibility, the easy of use by the consumer, it had to fit in a given shape or a given size, a space envelop that is already there, on the instrument that already exists so we had to make that the fit -- it would fit to that. Cost was an issue, it was in consideration and initially the cost of that did rise a few (eye brows), but when you look at what it did, and what else you didn't need because of it, and how it worked, it kind of wasn't quite so much of a consideration anymore. | ID06 |
| 101 | 38:29.9 - 38:40.0 | When you were designing this product, this component did you follow any design guidelines, any specific design guidelines? | Interviewer A |
| 102 | 38:40.6 - 39:12.0 | No when I did that there weren’t any. There was just nothing. I say now is slightly different in that, you can get some kind of guidelines from say service bureaus, machine manufacturers. Which they kind of say this is the minimum wall thickness you can have, this is how hole features come out. By yeah there was just nothing for that. | ID05 |
| 103 | 39:11.9 - 40:20.1 | I think for this the any rule that I can think of, what you have already mentioned, is the minimum wall thickness and the other one was the minimum feature size, so things like the text, for example, is only on there to show for a visual marking you don't want to be three millimetres high for example. And then the filter itself, so that it should’ve got the wire thickness. We looked at radiusing but because it’s so small and so thin, we did try one and it did not actually improve the flow; but the print didn't come out as consistent, because the feature size was quite small other than that no I think it’s fair to say, they weren’t the constraints. I think one of the things about the manufacturing process itself, and it’s one of things I love, is that you can almost, if you can think it, you can design it. There is -- you don't have to worry about getting tooling in, for say if it’s a machined part; how do I get the cutter in there, how do I get the drill in there. You don't really need to think about that. | ID06 |
| 104 | 40:20.1 - 40:23.3 | How did you learn these rules? | Interviewer A |
| 105 | 40:23.3 - 40:37.4 | The minimum feature and the minimum thickness came from the manufacturer for the capability of their machine, the rest of it, well. | ID06 |
| 106 | 40:37.3 - 40:39.1 | Trial and error, isn't it? | ID05 |
| 107 | 40:39.1 - 42:02.7 | Yeah and just years worth of. It is tricky because you have got your head around the years worth of how to design something to manufacture it and you are thinking about more traditional manufacturing techniques. So, you have to -- you design something a certain way because that's how you are thinking about how it’s going to be made; so I was just mentioning about tooling access; whereas for this process, you kind of don't need to do that, and when you’ve always been used to designing something one way to kind almost forget that, and just go completely freedom. Try to integrate as many parts as possible onto one thing because you can, because you can now make it. Wouldn't you got your head around that way of thinking, it kind of comes naturally I suppose. It just -- it’s changing the way you think about designing something. Mean your laptop for example. The casing is made in a certain way so that you can take it apart, so that it can be moulded, so that it can have components inside, but if those components that are added inside, could it be part of the casing and you can make the casing in one piece because you don't need tooling that splits, then it’s just a different way of thinking and it’s just getting your head into that kind of design space. | ID06 |
| 108 | 42:02.6 - 43:57.8 | Yeah, I’d say the same for me. It’s just been a gradual experience. I mean I start learning about the technology back in the university and then I did internship on it and just doing more projects with Company D and I think what I find useful is reading up on case studies and seeing other case studies of other people have done. Where they have changed designs and you can really kind of see the freedom of design that they have got. And then in my mind I kind of split it down, so the first thing I think about is function, what exactly does it need to do, and depending on the application, it might be that immediately you’ve got a specific material you need or you’ve got an accuracy or a surface finish that you need, which would then dictate your additive process, but if you don't have that, then it’s just thinking what is the function? What geometry do you want? I always ask what added value can you give to it. So like, can you put writing on it? Instructions? Can you reduce any fixture points? Or anything like that. And then is focusing on the more manufacturing process specific guidelines like making sure all your wall thicknesses are big enough for that process, or your feature size is appropriate, whether you can make any changes that would make it print quicker or use less material depending on what that process is because some it does not make as much difference as others. So yeah, I’d definitely say I kind of -- I now split it down into get your function and design and as much value as you can into the part and then look at the process specific alterations you might need to make to your detail design. | ID05 |
| 109 | 43:58.0 - 44:25.5 | Did the introduction of additive manufacturing knowledge change the design of other components inside the product or the product itself? When I mean a product, I mean the product where this component gets assembled? | Interviewer A |
| 110 | 44:25.4 - 44:55.0 | Oh yes, and there were another actual constraint was trying to make sure that whatever happened to that component didn't mean you needed subsequent changes to other components to that assembly because obviously you’ve got like, if that mating was an injection moulding component, changing the tooling for injection moulding if you needed to do that to make that work, is just another cost. So yeah, that was definitely a constraint. | ID05 |
| 111 | 44:55.0 - 46:45.8 | For mine, I don't think so, other than, like I just mention this would fit into an existing component also an existing instrument accessory; so I couldn't have any impact in those parts again (()) the top for example was a moulded component so I didn’t want to change that. The rest of it, it was being designed at the same time so, it didn't really. I don't think it influenced the design of the other parts. Only so much as the external shapes of this fits into a hopper and then the internal shape of the hopper, it does not exactly reflect this; but it partially does; but that I would not say is to do with the manufacturing process, is just because of, how it needed to be. I guess you can say that the o-ring, the grove for the o-ring, we can incorporate that into the 3D print which meant that the machine component that fits into, was simplified it was an easier part to machine which would have saved cost and time, so yeah I must’ve actually (expected you) could say the same for the lip on the front there, if we couldn't have put that on the front, it would have probably gone on the funnel above it which again it would have meant it was a more complex machined part. So okay I convinced myself, yes it did. | ID06 |
| 112 | 46:45.7 - 47:21.3 | Yeah, I thought it was quite a good point actually if you are actually simplifying an existing part and making that subsequently potentially cheaper. I guess what that comes down to is what that component is and what it’s currently manufactured with, because like we pointed out you’ve got a bit more freedom and ease to change a machining process that you might an injection moulded part where you got to, either you have material on or off that tool. I guess you have to think about that. | ID05 |
| 113 | 47:21.2 - 47:32.4 | Now do you think there were any draw backs or limitations as a result of using additive manufacturing for your component? | Interviewer A |
| 114 | 47:32.4 - 47:33.1 | Like? | ID05 |
| 115 | 47:33.1 - 47:55.4 | Or the fact that, that component. Do you think there are any draw backs or limitations as a results of that component being designed for additive, not specifically being made but being designed, so because it is being designed for additive, are there any draw backs o limitations? | Interviewer A |
| 116 | 47:55.4 - 48:03.0 | So this one was cost. That was a drawback. | ID06 |
| 117 | 48:02.9 - 48:09.4 | Yeah, I can only think of process drawbacks not design drawbacks. | ID05 |
| 118 | 48:09.4 - 48:56.5 | We got an, ID05 helped out trying to find, we got a manufacturer which we used on another projects in business that there is a filter specialist, should we say, but they also offer a 3D print process of filters and they were by final way the cheapest manufacturer for this. I think some of the other guys, the 3D print specific companies should we say, manufacturing companies, they were considering more expensive. So I don't say we single source, because we can get it from other people. It’s just they were the most economical place to get it from and it was still relatively expensive I suppose when you consider shape, size and material. | ID06 |
| 119 | 48:56.4 - 49:21.5 | Yeah, I would say it is just process, process drawbacks. I guess from a design, not that I had it on that, but wall thickness could have been a constraint, but it was like the surface finish of the process and that kind of aesthetic quality and cost. | ID05 |
| 120 | 49:21.5 - 49:49.1 | Yeah, I guess the surface finish on that as well. So everything else, especially a costumer facing part, you want a high surface finish on it. If you’ve got your plastic coated one, so we looked at it as part of a cost down, we looked at printing them in a plastic and then coating them; so this was a nickel coated and the base plastic was? | ID06 |
| 121 | 49:49.0 - 49:50.7 | Just an SLA resin. | ID05 |
| 122 | 49:50.6 - 50:50.6 | And then coated, so you can see it is -- there is – I’d say that was probably a slightly better finish although you can see the layer definition on it compared to this one, but just some handling point of view, it’s quite, quite a rough finish and it isn't, it is not ideal for a costumer facing part, it wanted to have a better degree of surface finish on that, but it’s not, it’s not to say it’s horrendous, in some respect, should we say -- give it a little, because this fits into a part, it gives you some degree, if it slips, you won’t be able to pull it out. I think that's one of the major drawbacks that (everyone says) it's surface finish on this product. This again, it will be a customer-facing part. So, although you know you see this much of it, this border around here still needs to be a high degree of quality and finish. | ID06 |
| 123 | 50:50.1 - 51:02.1 | That's like, as soon as you start needing these finishes, you're increasing cost. Then especially when you've got low volume, (as that) the volume of the finishing process doesn't reduce as much as high volumes. | ID05 |
| 124 | 51:02.1 - 51:22.4 | Yeah, the point of using it, is because it is economical if it is for a low volume quantity component but as you just mentioned, if you then gotta have an extra process to smooth it, to paint it, to whatever you need to do to it, you then start to ask the question: 'is it really the right process for the job?' | ID06 |
| 125 | 51:22.4 - 51:34.6 | I want to come back to something you said before. You said about the limitation, you said, well, I would say also wall thickness. Why? Can you explain that a little bit? | Interviewer A |
| 126 | 51:34.5 - 52:07.0 | Wall thickness? Well could be purely because you might not be able to go down to a minimum or below minimum thickness for a wall depending on the process you are using obviously. I'm trying to think, I haven't, I don't think I actually have that problem with any of my projects currently. No, I have actually, and it was too thin and too brittle basically. | ID05 |
| 127 | 52:06.9 - 52:25.3 | That would've been better if the material between the holes was as small as possible. But you can't print it to be much finer than that. Your holes will be square, holes will just be a mess. | ID06 |
| 128 | 52:25.2 - 53:28.3 | Yeah, I think once that starts to become very complicated when you're looking at the design and the process, is how your process set-up, how your build set-up, like build orientation, choosing layer thickness, is going to be different materials and each machine whatever it is, how that then impacts what you can get out from a design perspective. So it may have been able to be built on different orientations to get smaller walls between the grades, but then that could've been impacted on the surface finish on the internal bit. All the costs if ti was -- get building higher and higher. I think that's when it gets really complicated and there is no way of knowing exactly how your design or how the designed features are gonna come out until you build it and you test it. And then you get a few in and you see how they all coming out and compare each other because the repeatability can be a bit sketchy as well. | ID05 |
| 129 | 53:29.0 - 54:23.6 | We had moved into the first prototype. There was a difference in the roundness. They were (oval) for one of the (fair) explanation. And you could see, if you really look closely, you could see how some of them were printed in this orientation, some of them were in that orientation. The ones were better, or the same, the ones were different. The process itself is not as repeatable as machined components where there is a metal, press the button, and the tool will cut it and cut it the same every time. For one of a little bit wear on the tool, should we say, the parts will be consistent, reliably. This could be depending on the utilization of the machine, how it's been set up. | ID06 |
| 130 | 54:23.5 - 55:03.6 | I think that's the thing when you start considering it for the series production, we know all these things can impact this, so you do design, and you get prototypes and stuff, but then it's the guarantee that your supplier is gonna build it in exactly the same way, with exactly the same machine set-up, with exactly the same support structure design, as all the others. And therefore you know you are gonna get out of the same part every time. There is not really that kind of control in place at the moment, which makes it difficult when you are looking at the processes for series production. | ID05 |
| 131 | 55:03.5 - 55:30.7 | It could be stated on the drawing, it has to be built on this orientation, but if it's a third party manufacturing it, if you're filling their machine for them every build, that probably will be a kind of problem. If that's where it needs to be and you order enough to fill the space, great. But if they try to fit it in around the other components, you can't really blame them for saying if I tilt this 15 degrees more that way I can get another component in, which means I earn X amount more per build. | ID06 |
| 132 | 55:30.7 - 55:40.1 | And there aren't that many suppliers at the moment willing to take on the responsibility making sure you get your parts to exactly the same specification each time. | ID05 |
| 133 | 55:40.1 - 56:15.6 | We asked the question to the supplier: 'can you recommend, or which orientation did you build this particular batch? Because we knew they work well'. It's not really the question they wanted to answer. So we just had to tweak the design so we had to make sure that even if it wasn't quite as round as we wanted it to be, it will still fit. It had to build in a degree of variation into the component to ensure it did what we wanted it to do; rather than the supplier going okay, this is the best way, we'll make sure it will do all the time like that. | ID06 |
| 134 | 56:15.6 - 56:51.4 | It's really a good point. Normally I specify build orientation because I've got an idea of obviously what are important features and etc etc. But if you don't have that kind of understanding or, because is a new process and material or you don't want to constrain the cost and build time, which you could potentially do, yeah, if you cannot get that information from the supplier, then you can't really, that's going be really difficult to take that into account during the design process. So. Tricky. | ID05 |
| 135 | 56:51.4 - 57:00.1 | Can I come back to the one of things you said? You said you usually specify build orientation. How do you specify build orientation? | Interviewer A |
| 136 | 57:00.1 - 57:27.2 | On my drawing, which will always go with the supplier I normally use. And that would go with my S T L file and that would go through, they've got a quite stringent process control in place. The only ones that I know, actually they do and they will set up the part and inspect it as per the drawing. | ID05 |
| 137 | 57:27.1 - 57:30.1 | So basically, in your drawing, there is... | Interviewer A |
| 138 | 57:30.1 - 58:01.7 | I've literally got, like, a view of it and an arrow saying build orientation, build base. And then I put sort of notes in the corner just saying what process I want, what material I want, build orientation as specified, and what accuracy I might need. They normally, I just specify what the machine is capable of and what the supplier guarantees, which they don't have too much freedom about that at the moment. | ID05 |
| 139 | 58:00.8 - 58:14.6 | Thank you. OK, so, now, I would like to ask you, did the use of additive manufacturing change your design process or practice? | Interviewer A |
| 140 | 58:14.6 - 59:27.3 | Yeah, definitely. For me, I've definitely found, I've got so much more freedom, which gives me more time and scope to look at different concepts and not have to be thinking. So I did product design at Uni, and obviously you're kind of taught from the very beginning to consider what manufacturing process is, and like what ID06 is talking about, you're immediately putting limitations or even what you start imagining, because you know that if you want it to be a polymer, for example, it's probably gonna be injection moulded, therefore, you know you are gonna have to have different separate components and draft angles and not very complex geometries etc etc. So knowing from the start that you've got that freedom, just, yeah, allows you to focus so much more on the functionality and the functional performance and value of the part rather than sort of constraining what you can do and deliver. | ID05 |
| 141 | 59:27.3 - 1:00:08.6 | Design is all compromised. You know what you want it to do, and in ideal world, it'll be the most perfect doing whatever you ask it to do. But you have to think about how this is gonna be made, how much this is gonna cost. Sometimes cost isn't relevant, most of time though, it is. But usually the biggest is how hell we are gonna make this and that would then mean you have to pick out some of the most important features, sorry, most important criteria, and say we are gonna 100% satisfy these but these [ID06 actually meant those in this scenario], I'm afraid, it's gonna have to compromise because we can't make it in any other way. | ID06 |
| 142 | 1:00:08.5 - 1:00:53.8 | I found that freedom also has actually spanned up my kind of design and development process, not just from a rapid prototyping perspective but purely because I know I don't have to be thinking all that drafts and everything. Is it constant wall thickness everywhere? You've just got that scope, kind of just saying, OK this is my design, mock that up on CAD, and you've kind of got it, and you know it can be manufactured because you are printing it for your prototypes. It's definitely a lot quicker [or 'not' quicker??] You can consolidate all your parts, that you've got one part design rather than seven. And then subsequent drawings and design reviews. | ID05 |
| 143 | 1:00:53.8 - 1:02:24.8 | It definitely well helps, when you are designing, or you've got the process in mind, or you've got additive in mind when you're designing the whole thing rather than just the component from it. It's difficult to justify the additive process when it's just one part, so, this, for example, like you said, you couldn't change the geometry, it had to fit inside something, the internal part had to be this way. When you try to design around something that is already there, it is more difficult to justify it. I kind of like in it, last place I used to work out. [these two sentences do not carry useful info]. I'd used to do a little bit of composite manufacturing. We've get [I think it's 'got'] a number of customers, say, I want one of these but I want it in a composite. And you could never very, very rarely seldom [ maybe sell them a] product because you would've just taken something that already got and just giving (it them) back, which might have been better in some circumstances but it would've cost them more. What you really need to do, would say, okay can I look at the whole system and then incorporate this, this, this and this, which is why, when you look at the additive from the clean sheet design point of view, you can incorporate so many parts into it, and it makes a lot easier to justify yourself. | ID06 |
| 144 | 1:02:24.5 - 1:02:48.2 | Thank you. So, now, we just want to ask you some general reflections about additive manufacturing as a production process and design for additive. So what are your views on additive manufacturing as a production process for end-user products or components? | Interviewer A |
| 145 | 1:02:48.1 - 1:04:37.1 | I think that it's at a point now where it can be used, but you have to make certain sacrifices potentially, depending on your design application of accuracy, or material specification, or surface finish and so post-finishing processes. But I just think that the potential for being able to use it for true functional design and the subsequent impacts on the supply chain is amazing really. I think it's gonna be used more and more when the processes are getting better and better and cheaper, so. And the cost is possibly the limiting factor at the moment, but I think it's more the understanding and the analysis of the true costs and true impacts on costs additive can give. So if you're reducing lead time, or you're reducing your market introduction day, or you're simplifying your supply chain, or whatever that is, that's gonna have cost impact which isn't necessarily considered when you're comparing it with conventional processes; because you don't always take all those into account when you cost a conventional manufacturing process. So I think the understanding of all the business impacts is still not quite there, which is why potentially has not been justified as an end production process as much as it should be. But it also needs to be improved and developed. | ID05 |
| 146 | 1:04:37.0 - 1:05:10.6 | I think it's massively exciting the way is getting if you just look at it in the last five years, how the whole industries progress. I know it kind of at the moment, it might seem science fiction but you can almost see in the future where every household has a 3D printer and you tend to not buy products, you just buy the program, and get it printed at home. So at the moment, it is science fiction, you need a printer that would do multiple different materials maybe but that's probably not beyond the realm of fantasy. | ID06 |
| 147 | 1:05:10.5 - 1:05:14.6 | It can already technically... | Alica |
| 148 | 1:05:14.6 - 1:05:56.0 | You kind of can, whether or not a manufacturer produces something that's got a couple of different heads on. Could you imagine a future where you design a product, and you didn't have actually to worry about the supply chain, it was just printed over there in the corner. There is a big negative on that - a lot of people would probably out work I'm afraid. It's quite good for the environment, I'm guessing, depending on materials and energy required. Yeah, it's definitely an exciting prospect. | ID06 |
| 149 | 1:05:56.0 - 1:05:59.1 | Customisation. | ID05 |
| 150 | 1:05:59.1 - 1:06:01.8 | Yeah, everyone wants some customisation. | ID06 |
| 151 | 1:06:01.8 - 1:06:09.7 | That's a whole life maker movement as well, home makers and entrepreneurship | ID05 |
| 152 | 1:06:09.7 - 1:06:32.5 | Yeah, it means you can manufacture something without having a massive outlay. You were that home entrepreneur, you designed that, what I know is I need to get some aid, you would be looking at tens of thousands of pounds worth of outlay at the moment. As the current manufacturing stands to get the tooling made. Then you would have to find someone who's willing to do in a small run. | ID06 |
| 153 | 1:06:32.5 - 1:06:35.6 | You can have a completely positive cash back, can't you? | ID05 |
| 154 | 1:06:35.6 - 1:06:39.0 | Yeah, yeah, once you bought your machine and you got some material. | ID06 |
| 155 | 1:06:39.0 - 1:06:51.5 | Oh yeah, only you got that machine or unless your use service bureau. So you design something, so design to customer, and then you just give it to service bureau to print. | ID05 |
| 156 | 1:06:51.5 - 1:07:15.5 | Yeah, yeah, I'll tell you a step further. You've got a final product and it works and it's here but someone else in Australia needs it. I can take it 24 hours to get it to you or hold on a minute, there you go, in three hours, it's made, just send the file. Yeah, it's exciting. Potentially, it's just. | ID06 |
| 157 | 1:07:15.5 - 1:07:17.5 | Yeah, it's just the time scale and we'll build it. | ID05 |
| 158 | 1:07:17.5 - 1:07:21.5 | Just waiting for the technology to catch up to the fantasy ideas I guess. | ID06 |
| 159 | 1:07:21.5 - 1:08:08.7 | It would also be really nice to see more drive coming from sections which aren't aerospace, automotive and medical. Because obviously they've got very specific benefits that they can get, which justify a potentially high cost with regards to. It might be their spare parts in supply chain or reducing weight. And then medical, you've got your customization and obviously that's a big driver in kind of development of processes and materials and different case studies and research. But other kinds of applications that take it out of just, can you say loads weight, which we'll say loads fuel cost 'cause fuels really expensive, it's gonna be really interesting to see, I think. | ID05 |
| 160 | 1:08:08.7 - 1:08:17.5 | In general, what do you think designers need to know for designing effective parts for additive? | Interviewer A |
| 161 | 1:08:17.5 - 1:08:43.8 | Material properties is a definite. That's [ID06 was showing an example] 316 stainless but how does it behave compared to what traditionally manufactured component at 316 stainless, so it's pressed or machined. | ID06 |
| 162 | 1:08:43.8 - 1:09:48.6 | I think first someone needs to understand exactly what the differences between additive and conventional processes are. I think it, like the concept behind a subtractive process compared to an additive process, and the shape and functional complexity and all those benefits that you can get, and that's the first thing. Because someone's got to understand why with all my knowledge about machining, and now I'm going to design something for additive, I don't know anything about. And yeah, first, understand what those capabilities and benefits are. And then I would say, the different processes linked with materials. So the process capabilities with regards to the materials and mechanical properties, functionality. And then how the kind of build set-up can impact what you are getting out in the end. | ID05 |
| 163 | 1:09:48.6 - 1:10:18.4 | I guess the current limitations of processes, so, as we were looked at these before [ID06 was showing the frames for one of the Company D machines], how parallel those are, the lengths of them, the repeatability of it, it's one thing designing it, so it's a nice fit, it works well but what's the reality when it is printed. I guess what are the current limitations of the process. | ID06 |
| 164 | 1:10:18.3 - 1:10:46.8 | Yeah, so this I was talking about. They left out the the scoop in the wall [ID05 was talking about the frames], which I suggested just to leave it in, because the laser sintering process and the heat and the impact that can have on warpage, particularly on this U shape part. Just to leave it out so you can then control the kind of heat and distortion a bit better. So it's kind of, yeah. | ID05 |
| 165 | 1:10:46.8 - 1:10:56.3 | Understanding your design, understanding how the manufacturing process impacts your design and how you design impacts your manufacturing process. | ID05 |
| 166 | 1:10:56.3 - 1:11:20.9 | Trying to remember what you learn but partially forget it. Don't be constrained to, this is how we have always done it, this is how the traditional manufacturing techniques work. So I can't design it this way because it's too complex, it can't be machined. It's going, forget that. That's a difficult mind-set to get out of, especially if you've been doing it 30 years, for example. | ID06 |
| 167 | 1:11:20.9 - 1:12:23.4 | You kind of do need to design, knowing that you're gonna to use additive from the start because the design process for conventional processes whether that'd be machining or injection moulding, and the design process for additive process, it might be completely different, purely because what functionality and complexity you can get out in the end. And there is no way, I don't think, that you can get an optimal design for an additive process that could still potentially be manufactured with conventional processes. You have to change that design so much or you should, because you should be designing the full capability of additive. You have to change so much for it to be manufactured conventional [I think it should be 'conventionally'], I just think. You have to have it in your mind from the very beginning that additive is an option and therefore what can you do, what value can you create in that part. | ID05 |
| 168 | 1:12:23.4 - 1:12:35.4 | Sorry, can I ask you something about this component? So you said, basically this element here is just like this in order to avoid distortions? | Interviewer A |
| 169 | 1:12:35.0 - 1:13:16.1 | It wasn't originally positioned there to avoid distortion but we talked about whether it should be solid or whether they keep that groove in there. And I literally just suggested to keep in because I was aware from that project that this kind of shape in laser sintered parts can, you know, you can get a bit out of shape and warped. I knew that by removing kind of material volume for laser sintered parts can help minimize the heat and impact that would have a distortion. | ID05 |
| 170 | 1:13:15.3 - 1:13:21.8 | How did you learn that? How did you learn how to design for additive? | Interviewer A |
| 171 | 1:13:21.7 - 1:14:22.1 | Yeah, well I mean, partly, it was trial and error, getting a few of those prototypes done and measuring. And then massive support from the supplier. And talking to the people that actually operate the machines. And understand kind of the mechanical design consideration. I think when I say talked to the experts who operate the machine, I think there is a difference between someone that knows how to load up the build platform, put the material in, set up layer thickness and generate support to someone that kind of can link all that to exactly what geometry is being built and the application is being built for. Being able to speak to someone that can combine the knowledge of both, that's been really really crucial I think. (Suddenly in mind) development [ID06 was coughing]. | ID05 |
| 172 | 1:14:22.2 - 1:15:39.6 | It's just get your head around the process. We took the material out of there, put that groove in there because it's not needed, you didn't need the volume. So the thinking behind that was what if we take that out then it's quicker to print, because it's not having to put it in there in the first place. That's kind of exact opposite if it'd been machined. You could (put it), but you wouldn't want to take that material out, because you get the machinist probably throw the drawing back at you. It's just trying to get your head around that process and go, I think, you just learn by doing it, maybe. It's just looking at your design and thinking about this is gonna be printed, well, I can just make whatever shape I want and then it doesn't make it more complex to manufacture. If I'm in that circumstance, you actually made it less complex, because the machine has to do less in order to get the same part up. And hopefully, because the reduced volume doesn't put so much heat to it, so makes it hopefully not distort much, give you a even better product. | ID06 |
| 173 | 1:15:39.5 - 1:16:03.7 | Again, it might not be an issue that this is a really hard thing to know. It might not be an issue and actually that geometry could be built absolutely fine with no heat distortion or anything. But it's just so geometry dependent, it's just really hard to know. It's just kind of gotta go out with a () and see what happens. | ID05 |
| 174 | 1:16:03.6 - 1:16:22.2 | I think it is quite a new process, it is a pioneer. You can't get it work and just try then, see what we get. Because it's easy to get another one, it doesn't require x amount of thousands on some more tooling to be made. Oh okay, let's just tweak the model and have another go. | ID06 |
| 175 | 1:16:22.2 - 1:16:39.7 | I keep saying to people like it doesn't matter if you need to change something like even the night before it's so easy to change your CAD file and send a new STL file. You could do that in six months into a new product introduction. [ID06 was coughing] | ID05 |
| 176 | 1:16:39.7 - 1:17:28.5 | I think that's one of the benefits from the production as well. If you got to do modification, it's so easy to change the design. You haven't got a worry about the impact on your supply chain, on your tooling, how long that's gonna take to introduce. You can just change it, from the second you send the file, once your components that come in, that what you want them to be. [grammar doesn't seem right]. That could be a modification 'cause there is a problem with something or it could be because you're changing your product line, you want it to do this, this and this now, or you just want to change the look of it, or you want to personalize it. It can just be done almost like that [ID06 was scraping his fingers to create a sound 'da']. | ID06 |
| 177 | 1:17:28.5 - 1:17:49.5 | Any reference and material that you have used? Any training you have done? | Interviewer A |
| 178 | 1:17:49.5 - 1:19:48.0 | I have been to a couple day long sections held by machine manufacturers. I can't remember what they called them. So the Stratasys use conference, for example. I think I've been to one with Materialize as well, which they held up in Sheffield. Can't actually remember what the point that was. That was definitely design orientated as well. Can't remember what they called this. Then they just tried to put stuff like PDFs, design guidelines from machine manufacturers. And I had found and there were some guidelines for FDM and powder bed fusion and stereolithography but then they are normally not, there were nothing all on the same kind of document because one manufacturer, like, might only have laser sintering process they've got design guidelines for laser sintering and then service bureaus might have stereolithography and F D M, so they've got like some broad guidelines for those processes, like try to pull together the information from those different areas now. Yeah, I'd like something that could kind of take you through the process of what's, for example, if you've got a function that's got very specific material requirement, then you can kind of look through design guidelines and processes depending on what that material requirement was. Just be so complicated I guess. There are so many different processes. I don't know. | ID05 |
| 179 | 1:19:47.9 - 1:20:30.5 | I can't think of something I have done specifically. I think because the design freedom that the process allows you, other than the obvious things like the size of the printers, the resolution of the print, which you might have to look up and have some guidelines on, you can almost do anything. So, I don't know how you could [ID06 was stopping] get the processes, it's infinitely what you can print. So the guidelines on that, I don't know how you do them. I guess [ID05 started talking]. | ID06 |
| 180 | 1:20:30.5 - 1:21:47.3 | I guess you usually want something that can enable you to imagine the freedom of the design and how that freedom of the design and then something can take you through all the like, 'cause even someone that doesn't know all the processes, how do they even decide which manufacturing process, people think of additive manufacture as like machining, whereas it's kind of one, basically one manufacturing process and don't really comprehend there's seven different process categories with loads of different machines, each machine might have slightly different ways of consolidating material. So it's like you are not learning one manufacturing process, you are learning seven effectively and trying to get your head around once you've got your design and you've got like complex geometry and freedom and your perfect design. It's then choosing like the material and the process, and how that process might impact your design and your design impacts that process, what to consider to build set-up and orientation and layer thickness and how that would then impact to your surface finish and accuracy and different dimensions and different orientations and yeah. After you've got your design, then it's got a bit complicated. | ID05 |
| 181 | 1:21:47.7 - 1:22:00.9 | I guess it's actually start to refine the design you wanted, you start to put it in there. OK, now I've got my requirements, I've (hit) it exactly what I want it to do, now I need to think a little bit more about the maintainability. | ID06 |
| 182 | 1:22:00.9 - 1:22:46.1 | Because unfortunately, there is no one process where you don't have to make compromise yet. So everything I did, I've got, you might have poor surface finish or you've got poor mechanical strengths in Z direction or you've got only one material option or (are there) photo polymers whatever that is. So there is no one process where you literally don't have to think about support structure, don't have to think about build orientation, impact on accuracy and surface finish. Just haven't got that yet so. Maybe there might come a time where the technology is there and you literally, there are no manufacturing constraints or considerations but it's not there yet. | ID05 |
| 183 | 1:22:46.1 - 1:24:54.3 | I guess it's not so well-known in the fact that you haven't got the history there. So people know how to machine things and how to plastically mould things, for example. It's quite a new player in industry, should we call it? So there isn't, because it can be a little bit niche maybe, because it seems more as a prototyping solution. I know it's starting to become more production solution. It would only be certain companies that would then start to utilize it, play with it because they've been using it for prototyping. Especially it depends on the companies as well, that's it's been utilized then. On site, we are limited in the amount of manufacturing machines that we've got here. We've got our own prototype shop with lathes and millers. So we would think that way to manufacture for certain things but we are a little bit open in the fact if you want something plastic moulded because we don't do it here. We won't design that way because we know there are other people that would do it. But if we had more in house, for example, I mean, wanted to manufacture just in house, we'd only design to what we do in house. And quite a lot of manufacturing companies are like that. You might utilize 3D print just for prototypes. Because it's a little bit niche maybe. It's not as well-known, maybe there would be in ten years time, we look at it as everyone knows how to machine, everyone knows how to plastic mould, everyone knows how to laser sinter, everyone knows how to bla bla bla and you will have that knowledge how to go (back and getting it). I don't know. | ID06 |
| 184 | 1:24:54.2 - 1:24:59.4 | Did you come up with your own rules for design for additive? | Interviewer A |
| 185 | 1:24:59.3 - 1:25:48.5 | Ugh, in my head, yeah, but it was more to stop myself from limiting my imagination, I guess and concept design from what I've been taught. So it's constantly just saying, you know, what is the functionality, what does it actually need to do, and where can I add value, what else can I get with this, what else can I do with it to make it kind of better, perform better or look better. | ID05 |
| 186 | 1:25:48.4 - 1:27:04.9 | Yeah, I guess, because you could, there is no reason why you couldn't, there can be kind of reasons but in some circumstances there is no reason why you could make the whole component from 3D printing in one, for example. So that (this system to) this fits into. It's not beyond the realm of fantasy that, that on the hopper and the tray it will fit onto was [or 'wasn't'] one whole 3D printed part. This would be a need to take it apart to clean it but maybe you can get around that but it wouldn't, you would probably lose some functionality. (Maybe it might actually, you could design it and you're getting some) but the cost of it would be crazy. It would, yeah, it is like what you're saying, it is limiting yourself, your imagination, so you can imagine it, you can see it, you might () what the whole thing would look like, and in one part, it solves all the manufacturing issues because it is one thing, great, but actually you need to be a bit more realistic and say this is not the best process for the whole thing. (Are the reals attended?) | ID06 |
| 187 | 1:27:04.9 - 1:28:25.1 | I think, I'm just trying to think, I think there are a number of, kind of, headings or considerations, which, first of all, I'll ask myself is application and function. What is application and function? That you'd base your design, your conceptual design, your geometrical design on. And then it's asking, are there therefore specific material requirements, accuracy requirements, surface finish requirements. And depending on the answers to those, that might immediately point you to one process. So I guess it's kind of in parallel, you've got your geometrical design going alone where you're just thinking about application and functionality. And then kind of parallel to that is considering what processes it might need to be but I don't let that necessarily influence my design until the very end because actually the impact of just making sure you've got wall thicknesses which are big enough for laser sintered. It's probably not going to impact your design functionality as much as a conventional process would. | ID05 |
| 188 | 1:28:25.1 - 1:28:50.8 | There is no, I mean, we don't have a design guideline rule book, should we say. I guess one of the nicest things about it is because you've got such a freedom, you don't need that rule book. | ID06 |
| 189 | 1:28:50.8 - 1:30:53.8 | It would be nice (not though). It would be ideal not to use a rule book. I think for me, I see the only reason needing rule book is because of the difference between different additive manufacturing processes and exactly how they work with like a laser and a powder and how that therefore might limit, but people talk about additive not having any limitations but it does, it does have some manufacturing constraints and specifically some manufacturing considerations when you think about build time and cost. But, yeah, I guess, for an actual design, conceptual design idea, you don't really want a rule book. I did, guys with using things like to topology optimization, CFD, FEA could be really good. It's not something I've got training in yet, so haven't managed kind of used these tools for additive design. But I think that could really help free up a designer's imagination in terms of geometry and form. I think, CAD doesn't match up to it either. I mean most CAD packages, conventional CAD packages based on the idea that you are forming or extruding shapes, which is what conventional manufacturing processes are kind of based on, which I think it really limits additive because, it is difficult to do like complex curvy forms in conventional CAD packages. | ID05 |
| 190 | 1:30:53.8 - 1:31:07.8 | Because it's the same that the way use CAD is the similar kind of way as traditional manufacturing methods. It makes you mind, makes your brain think along that route, you're kind of forced into it. | ID06 |
| 191 | 1:31:07.7 - 1:31:12.9 | You do extrusions and cuts, revolves, that kind of stuff. | ID05 |
| 192 | 1:31:12.9 - 1:31:28.3 | () [ID05 and ID06 were talking at the same time] something that fancy revolved shape over here, you'd have to add a big block and then do revolve. It's doing what you do if you're machining it, starting out of something and then cutting a hole in it. But actually what you want to do is just make the outside of it. | ID06 |
| 193 | 1:31:28.3 - 1:31:57.6 | I think, really, badly, I know I've definitely done it in the past, is altering your design, not here [ID05 meant 'not at Company D Instruments'], at Uni, because of what you can, because you CAD ability, basically, and what you are capable of modeling in CAD, which completely takes away the whole point of additive that you can get complex geometries in freedom. | ID05 |
| 194 | 1:31:57.5 - 1:32:41.5 | They are difficult to model and they are difficult to machine. I guess there is kind of a link between how difficult something is to model and how difficult it is to machine, should you say, and then mould, because a moulded part needs to have a tooling machine. But it makes no difference to an additive manufacturing process if you've got a flat part here and a flat part here where you've got a (ruly funky) curve going on, it doesn't matter. But to try to machine that, it's pretty hard. To try to model it, it's really hard. | ID06 |
| 195 | 1:32:41.5 - 1:32:56.9 | There are, I haven't used any, but there is stuff you can use like, you start with a ball of clay, then you, like, pull, you can pull it and manipulate stuff. But even then you are starting with a ball. | ID05 |
| 196 | 1:32:56.9 - 1:33:04.3 | Synchronous [a CAD package] on Solid Edge is trying to get out of that way of thinking. | ID06 |
| 197 | 1:33:04.2 - 1:33:29.2 | Yeah, which I have actually been using a lot. But I still, well I haven't found yet, that it helps with any like generating organic forms. You're still pulling bits out, cutting things away. | ID05 |
| 198 | 1:33:29.2 - 1:34:06.9 | OK, so, well, that was all the design rules, you told me that you have never developed your design rules, somehow, you haven't proved your design rules as well, everything is in your experience that (is inside of you). OK, so, thank you so much for your time and your thoughtful observations. It's been very helpful for us, your contribution. Before we go, I'd like to ask you a few details about your background. So what is your education background? | Interviewer A |
| 199 | 1:34:06.9 - 1:34:15.9 | I did a masters in product design and manufacture and then start this [ID05 meant her EngD research] two and a half years ago. | ID05 |
| 200 | 1:34:15.9 - 1:34:38.6 | After a sixth form, A-levels, I did an apprenticeship and () (H&C) in CAM engineer. That was a four-year apprenticeship, (day release and day complete). | ID06 |
| 201 | 1:34:38.5 - 1:34:40.9 | You studying in XXX, right? | Interviewer A |
| 202 | 1:34:40.9 - 1:34:41.7 | Ugh. | ID05 |
| 203 | 1:34:41.7 - 1:34:43.1 | And you, where did you study? | Interviewer A |
| 204 | 1:34:43.1 - 1:34:50.0 | I went to Stourbridge College. | ID06 |
| 205 | 1:34:49.9 - 1:34:56.3 | How long have you been working as a professional designer? | Interviewer A |
| 206 | 1:34:56.2 - 1:35:05.9 | Well, I'm not. | ID05 |
| 207 | 1:35:05.9 - 1:35:21.4 | OK, if you take the apprenticeship into account, because I guess you could say I was working at that time, it was 99, so that's 17 years. | ID06 |
| 208 | 1:35:21.4 - 1:35:29.3 | Yeah, I wouldn't count myself as a professional designer. | ID05 |
| 209 | 1:35:29.3 - 1:35:33.8 | You get paid and make parts, that's by the definition of professional? | ID06 |
| 210 | 1:35:33.8 - 1:35:39.1 | I just do research, technically. | ID05 |
| 211 | 1:35:39.1 - 1:35:45.6 | OK, can I confirm that it is OK for me to take some pictures and have copies of the drawings? | Interviewer A |
| 212 | 1:35:45.6 - 1:35:57.9 | I think, no. I think, having (sides) been useful for me to sit and listen, actually, I think the combination of the information that ID06' given, particularly in the coffee maker, with pictures, it's. | Moderator |
| 213 | 1:35:57.8 - 1:36:03.4 | It would be too sensitive, OK. So none of these projects are in the public domain? | Interviewer A |
| 214 | 1:36:03.3 - 1:36:06.2 | No. | Rowana |
| 215 | 1:36:06.2 - 1:36:43.0 | And again, we cannot use that as cast studies? OK, so, in the following weeks, we will transcribe the interview and we will send a copy to you so you can, of course, check if everything that's been written down is correct. And also, if you want to add something or remove something, you said, yeah I said that but actually I think it should be done in this way, then you can. Ugh, OK, just one last question, would you be happy to be named or do you prefer to be anonymised? | Interviewer A |
| 216 | 1:36:42.5 - 1:36:44.8 | I don't have issue with it. | ID05 |
| 217 | 1:36:44.8 - 1:36:45.7 | Yeah, I don't have bother. | ID06 |
| 218 | 1:36:45.7 - 1:36:48.0 | It's fine | Moderator |
| 219 | 1:36:48.0 - 1:37:05.1 | Well, this gives me towards the end of the interview. Thank you very much for your contribution. Please let us know if there are any questions or anything you want to say. | Interviewer A |
| 220 | 1:37:05.1 - 1:37:09.8 | So where are you at in this project? Right at the beginning? | ID05 |
| 221 | 1:37:09.8 - 1:37:41.5 | Ugh, we've been in this project for six months, out now. Now we are working the first five months really just on collecting material and reviewing the references and the documents that are out there. And then now we are starting, we have done a survey recently. The survey now has finished in the sense that we have reached our target. | Interviewer A |
| 222 | 1:37:41.5 - 1:37:44.7 | Was that on the online one? 'Cause I just did that as well. | ID05 |
| 223 | 1:37:44.8 - 1:37:58.7 | OK, that's great! So basically we reached our target of 100 correspondent or 100 participants. Although the survey is still open, actually if you would like to participate. | Interviewer A |
| 224 | 1:37:58.6 - 1:38:01.3 | I've already done the online one as well. | ID06 |
| 225 | 1:38:01.3 - 1:38:20.9 | OK, that's great. So that survey is done. We will keep it alive still for another two months in order to collect as many participants as we can. Although we will not make it public, we will not disseminate. | Interviewer A |
| 226 | 1:38:20.9 - 1:38:40.5 | And now we are going around and interviewing expects in design for additive, in order to understand what they do when they design components for additive. While the survey was more to understand what designers know, generally speaking about design for additive and what they would like to know. | Interviewer A |
| 227 | 1:38:40.5 - 1:38:48.0 | I was interested if you'd manage to get kind of why, as mentioned earlier about, the () in aerospace and automotive. | ID05 |
| 228 | 1:38:48.0 - 1:38:50.8 | It was kind of, just a pure guess. | ID06 |
| 229 | 1:38:50.8 - 1:39:15.0 | So I just said about costing, is I always make sure I get quotes for what the production volume would be. And not just one-off, because it can change significantly when you're getting 20 rather than one. So I always try to make sure you get production costs. | ID05 |
| 230 | 1:39:14.9 - 1:39:41.1 | I think they were about 3 or 4 times cost for prototypes to production, which is, that's not say everything, isn't like that, of course most things prototypes are always expensive but maybe looking at couples of times of price, yes, the quote for the one-off definitely makes people kind of get [ID06 meant the cost was very high], you can't use that. | ID06 |
| 231 | 1:39:41.1 - 1:40:11.0 | And that difference between the one-off cost and production cost can be completely different depending on process. You get much better cost efficiency with production volume on powder based, powder bed processes. Then you do, for example, on material extrusion, it doesn't take any less time to build two on a machine then it does build one because you've only got one extrude head. So, and then therefore, you can't really reduce the cost that much with your volumes on material extrusion. | ID05 |
| 232 | 1:40:10.7 - 1:40:15.1 | Sorry, what is the production volume for that component you mentioned? | Interviewer A |
| 233 | 1:40:15.0 - 1:40:17.0 | It's about 10-20 a year. | ID06 |
| 234 | 1:40:16.9 - 1:40:59.3 | [People were packing things up] | All attendees |