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|  | Timespan | Content | Speaker |
| 1 | 0:23.2 - 3:03.8 | Nice to meet you and thank you very much for being here today...Roughly how many products or components have designed for additive? | Interviewer A |
| 2 | 3:03.7 - 5:08.1 | Well I think as far as Company I is concerned, I think there is three ways we use additive. We are making a lot of components -- the majority of work we do is in the design process so it is using additive manufacturing as a way of simulating other manufacturing techniques and that allows us to test out ideas and design process that is our sort of major use. A use we are particularly interested in and thinking about at the moment is making tooling for other manufacturing processes using additive manufacturing. So that can either be direct tooling, so injection moulding tooling or jigs and fixtures and assembly tooling so that is a second use for it. And a third use for it is perhaps where you are immediately thinking is in the actual component which is in the product that some people buy and the way I see that is the -- the experiences we had so far, I think are very much in the area of products which are made in one-off, so very low volume or late stage customization so that they are specific to an individual so namely steering wheel is an example that was made for -- is a one-off thing made for one person to use. Other examples we are not involved with but I have seen other ways are things like hearing aids where they manufacture all, or dental prosthesis specifically for your ear or your mouth or that type of thing, so I cannot give you any example where we’ve taken a product which has been manufactured by conventional means and made by additive means, because by additive means it tends always to be more expensive so it’s got to be a real reason to do that. Can you think any example of that, I can't. | ID12 |
| 3 | 5:08.0 - 5:10.4 | I dont think we do at the moment | ID14 |
| 4 | 5:10.4 - 5:23.6 | We have done more than one off so. So sometimes you might do a batch production I say one or ten off, but again that is because it is specific and that’s more, because it is early stage, so they could still count as prototype products. | ID13 |
| 5 | 5:23.6 - 5:42.5 | So we have a recent project where I needed to make a hundred of sets for a field trial and they are going on to do a thousand off and we used SLS printing in Nylon to get a robust part for that. | ID14 |
| 6 | 5:42.5 - 5:56.8 | Yeah you are right. There is a gap between the design process itself, where we are simulating as part of the design process and then there is -- then it extends into trials and experimentation where you talk about tens or one-hundreds. | ID12 |
| 7 | 5:56.8 - 6:03.0 | And in that case it was to avoid the tooling cost of -- they are going to injection moulding or even vacuum casting. | ID14 |
| 8 | 6:03.0 - 6:18.2 | There is also the point of shelf display. Supposedly some of those components were left as additive manufacturing components for the same reason to save on the injection moulding costs. I believe that was around five-hundred off so that was for a worldwide display. | ID13 |
| 9 | 6:18.2 - 6:26.4 | It was for a shaver. A new shaver and there was like a point of sales display to explain the benefits of the product to customer. | ID12 |
| 10 | 6:26.4 - 6:28.4 | So it is an electro mechanically driven. | ID13 |
| 11 | 6:28.3 - 6:34.9 | It was like a ten time full size shaver which opens itself up like a flower. We got one outside. | ID12 |
| 12 | 6:34.9 - 6:44.4 | So that had extensive finishing done it. It had paint effects, chrome effects added to it. So the underlying material wasn't that important. | ID14 |
| 13 | 6:44.4 - 6:48.0 | But that was actually manufactured in additive? | Interviewer A |
| 14 | 6:48.0 - 6:51.0 | Not fully but some parts were | ID13 |
| 15 | 6:51.0 - 6:58.2 | That would be very interesting if we can use the components as a case [study?] | Interviewer A |
| 16 | 6:58.2 - 7:05.9 | The most spectacular one is the Bloodhound steering wheel. | ID12 |
| 17 | 7:05.9 - 7:15.7 | It is quite interesting because it is using a sort of latest additive manufacturing technology in term of it is titanium laser sintered so direct metal laser sintered titanium | ID13 |
| 18 | 7:15.7 - 7:21.5 | But also it was designed throughout with additive manufacturing in mind, as the end goal to achieve what we wanted because it needed to be ergonomically designed to one person | ID14 |
| 19 | 7:28.2 - 7:31.8 | So quite complex surface geometries | ID13 |
| 20 | 7:31.8 - 7:40.6 | How do you want to structure the discussion? Do you want to take an example and we talk about more in detail? | ID12 |
| 21 | 7:40.6 - 8:03.5 | Yes now... | Interviewer A |
| 22 | 8:03.5 - 8:08.0 | The third one is the G-max device which is the small batch manufacturer | ID12 |
| 23 | 8:08.0 - 8:22.9 | So they go into horses, this case works and that straps to the horses and it tracks during the race so it is sometimes hit by the (wit) and things like that so it has to be quite durable (little how survival) actually. That's the story.e | ID13 |
| 24 | 8:22.9 - 8:43.8 | Roughly how often do these projects made in additive come up? How frequently? | Interviewer A |
| 25 | 8:43.8 - 9:15.4 | At Company I we do hundreds of projects a year and we are just choosing the manufacturing processes which suit the projects, so we do not do a project for additive manufacturing. It is just that is the most cost effective route in that particular situation. So that one’s which led themselves, as I say, the ones which are going to be either customized to individuals, are very one-off or perhaps few tens off, that's typically because the cost of additive manufacturing is higher than the cost of other alternatives. | ID12 |
| 26 | 9:15.4 - 9:37.3 | there has been some stuff with sports wearings, hasn’t it? It has been in the news, so some of the shoes and that kind of thing so customized for. I think it’s (tightly) with the name of the Olympics so some of the guys there. I think there are the trainers for Phelps | ID15 |
| 27 | 9:37.2 - 9:39.0 | So that's what happened with the steering wheel, we didn't scan his hands but | ID12 |
| 28 | 9:39.0 - 9:43.0 | Yeah there are some clay moulds done and they were 3D scanned so | ID13 |
| 29 | 9:43.0 - 10:03.7 | We use it almost on a daily basis for an iterative part of the design and the development process but that tends to be where it stops and then the production parts would come predominantly plastic injection moulding. It is very common but also sheet metal. | ID14 |
| 30 | 10:03.7 - 10:25.8 | We are just starting this project which is in my mind at the moment of using 3D printing to make the tooling for plastic injection moulding, so it is not going all the way but it is going half way so that means that conventional tooling takes, you know, eight weeks for manufacture if you 3D print tooling you can do it over twenty four hours, so it is a huge benefit. | ID12 |
| 31 | 10:25.8 - 10:39.7 | Potentially I’ll injection mould parts for the next day, so if you put your 3D printing tooling on the printer, leave it overnight, it comes out of the printer in the morning, put it into the injection mould machine, injection mould into it and you got (yourself) real plastic parts so it speeds up the process massively. | ID13 |
| 32 | 10:39.7 - 12:03.8 | There are several limitations with additive manufacturing. One of them is materials availability. We do a lot of medical devices (or attract to very devices) and then you have to -- when you are doing medical devices typically you need materials which complies to ISO10993 for biocompatibility so there are only a few additive processes which can give you that biocompatibility or if you want to put drugs throw them, the materials have to be pharmaceutical grade so VP grade so that means that the materials in the (math) have to be traceable back so you can have known toxicology of materials. So those additional constraints make it quite difficult to find additive techniques there are only a very small number of processes available. So it is not only the cost an issue but when you are in medical devices you got these other additional (things). That is an all interesting area of making, of having qualified additive processes because medical devices, you have to have a quality management system which means you guarantee each product, each component is the same of every other component so then how to do that in additive is not real, you have to have a qualified process and again that is another (eardel) | ID12 |
| 33 | 12:03.8 - 12:31.1 | We’ve been looking at that, one of our suppliers is setting up a dedicated room that would be, it is not a clean room but it meets the minimum requirements for some the medical standards and they have dedicated machines to run those materials and the process for post-curing and for handling the parts as they go through the process so they meet the minimum standards of medical. | ID14 |
| 34 | 12:31.1 - 13:19.4 | It is a bit different to making the injection mould tooling but it has been some work that I have seen recently where people have been making a replacement part with CNC jigs with 3D printers they can just get exactly what they need so within a day or two rather than having to wait say a couple of weeks for some really big expensive parts to arrive, they have exactly what they want almost instantly so it is more than low quantities again but it is more (only lies) to the injection moulding tooling. Some it is actually being used in a factory in quite high pressure environments where it is going to be under quite a lot of force likely break so it needs to be quite durable. | ID15 |
| 35 | 13:19.4 - 13:50.5 | At the beginning you talk about this different uses that you have of additive so in which proportion if one hundred percent is the total number of the projects you have done what is the proportion of the use of additive in the production of end user components as opposed to tooling, prototypes or one-off? | Interviewer A |
| 36 | 13:50.5 - 14:17.0 | Okay we (have) three categories: one is in the developing the design, the next one is testing the design and the next one is the actual product in use. I think you would probably say -- my guess would be eighty percent in terms of design development, fifteen percent in testing, eighteen percent in testing and two percent in real products. | ID12 |
| 37 | 14:17.0 - 14:40.1 | Yeah it is. For the testing, for verification and validation testing, it would be quite low, for learning testing so we are not qualifying the product yet but learning about what sizes we need and the features go together then it’d be relatively high still, but the form of testing is down in the eighteen percent, twenty percent would be about right. | ID14 |
| 38 | 14:40.1 - 15:06.8 | Eighty percent in terms of design development, eighteen percent in terms of testing, for testing, and two percent in the products. But I think with digital tooling which something we are interested in the future that might change the percentage | ID12 |
| 39 | 15:06.8 - 15:09.9 | That comes to the next question, do you think this is changing? | Interviewer A |
| 40 | 15:09.9 - 15:26.0 | All the time. New technologies are coming in, cost balance is changing. You know it is quite an expensive -- 3D printing is quite an expensive process: materials are expensive, processes are expensive, quality control is not that well | ID12 |
| 41 | 15:26.0 - 15:31.1 | It is true but it is a massive time saver and time is money so you are saving in. | ID13 |
| 42 | 15:31.0 - 16:11.4 | I am not saying it is not, but I am saying the downside, the reason is not used all the time is those things but we just bought some new 3D printers. The early generation of 3D printers the manufacturers lock you into consumables and they would sell you a cheap printer and make a lot of money on consumables so the actual unit cost of each thing made is relative high. It could be ten - hundreds of pounds easily for a small component, but now the new generation of manufacturers allow you open source materials so the material cost drop by a factor of ten, so for the Makerbot’s products… | ID12 |
| 43 | 16:11.4 - 16:31.0 | Yes you can have a component for a couple of pounds. It is not only that you’ve got the option much wider range of materials and also the option of blending your own materials potentially so you can mix powders and get extruded into a filament for FDM printing, giving you very cheap components and also with your own personalized material properties. | ID13 |
| 44 | 16:31.0 - 16:42.5 | But to really arrive to production you have to compare the cost of 3D printer materials now with the cost of injection moulding materials is another factor of ten to go so that is going to be… | ID12 |
| 45 | 16:42.5 - 17:06.1 | And also number of machines, so most of the business cases I have seen for using additive manufacturing involves having multiple machines to meet the same output rate that you get from the injection moulding tool so for the cost of one tool I now have to buy twenty or thirty additive manufacturing machines so that cost is actually more than the injection moulding tool cost. | ID14 |
| 46 | 17:06.1 - 17:28.5 | So you’ve got your materials cost that drops by another factor of ten and your rate of manufacture got to go up by a factor of ten. So you’ve got a factor of one-hundred missing at the moment but you can imagine with a matrix of ten by ten FDM nozzles all running in parallel so somebody is going to make one eventually. | ID12 |
| 47 | 17:28.5 - 18:28.3 | When I look to the future of what is coming up, I think it is not going to be a gradual change, I think is waiting for that breakthrough technology in additive manufacture that suddenly allows the injection moulded type of parts to be made using additive manufacturing and then we will be able to (rip) the additional benefits. For example a lot of the downsides with plastic injection moulding is how to get the parts you want off the tool with the warp and shrinkage that distorts the parts and draft angles and everything else. Whereas we tend to get a nice and clean part from – it’s got flat surfaces and it is the geometry that we wanted coming off the machine so I think when someone can offer the quality, the material properties of an injection moulded part but made with additive manufacturing, at a low cost, then we will start to see people lip on to that technology and back it. | ID14 |
| 48 | 18:28.3 - 18:50.2 | We are not too far from with the (DOB) technology. So we’ve got the digital projector technology but then with continuous as well, the continuous projection so it is continuously building through the layers and Carbon 3D obviously (has) wide range of materials as well they claim closer to plastics (where) using for injection moulding | ID13 |
| 49 | 18:50.2 - 19:11.0 | Yes and I think when those kind of technologies are available at cost you will see a rapid change from people want to do injection moulding to wanting to use this technologies but it needs that initial breakthrough of somebody that can actually produce a replica injection moulding parts but using these technologies. | ID14 |
| 50 | 19:11.0 - 19:45.6 | Autodesk have made an FDM printer which has multiple print heads working simultaneously at different points in the part you are printing so it can build up a single large printer a lot more rapidly than a conventional FDM printer can. That will help cut build time quite significantly once it gets few more heads on that. That’s more for the large scale, like printing a wing or something so it’s talking sort of a few (feature meter more) rather than (saying) that many ten centimetres across. | ID15 |
| 51 | 19:45.6 - 19:51.0 | Lots and lots happening. | ID12 |
| 52 | 19:50.9 - 20:30.2 | About the proportion of the products made by additive manufacturing so because you talk about eighty percent for the design process for testing bit. If there are ten final products, all of the ten products were made by additive manufacturing, so how many of them are one-off and how many of them are for tooling and how many of them are for series production only taking about additive manufacturing products? | Interviewer B |
| 53 | 20:30.8 - 21:19.1 | Difficult question to answer because we use both, we use conventional processes as well as additive processes so it is difficult to say it’s a product made in additive manufacturing, typically it does not happen. A product would have a combination of processes and it will have parts in which starts off additive and then turn into injection mouldings. It will have parts which are machined and always stays machined, parts that are machined and then turn into injection mouldings. So there is a lot of techniques used, it’s not as simple as saying we made parts with additive manufacture. | ID12 |
| 54 | 21:19.1 - 21:23.6 | But before when you said the two percent are for production | Interviewer A |
| 55 | 21:23.5 - 21:28.4 | These are all the parts with additive manufacturing | ID12 |
| 56 | 21:28.3 - 21:34.8 | That are made using additive or that the tooling is made in additive | Interviewer A |
| 57 | 21:34.7 - 22:16.4 | No all parts made with additive manufacture in what we do and the one-hundred percent of parts that are made with additive manufacture, eighty percent is used for design, eighteen percent is used for testing and two percent is used as a real product at the end of the day. Parts of additive manufacture are probably, I’m guessing fifty percent of the parts we made here it is hard to tell really we haven’t done that kind of calculation. It is growing, additive manufacturing is more and more important, we just invested, we’ve got -- how many machines we got? Company I’s got three | ID12 |
| 58 | 22:16.4 - 22:18.1 | I was going to ask you to order another one | ID13 |
| 59 | 22:18.1 - 22:27.7 | We got three machines we just order another high spec machine and it looks like we are going to order another low spec machine so. | ID12 |
| 60 | 22:27.7 - 22:58.0 | I think if probably if we go through, if we look at case studies of what we have done, we actually see that the ones that have made it, let’s say, to be put on the market would essentially be the Bloodhound steering wheel, was a one-off single thing, the others that are in trial studies they are not in for sale studies. | ID14 |
| 61 | 22:58.0 - 23:20.4 | Perhaps you need to understand that as a company we are a research and product development company so we make -- other companies subcontract us to design their products for them. So the output for our perspective, it is not product in volume production. It’s the design product for somebody else to put into volume production, so we are in a slightly different position to a manufacturing company. | ID12 |
| 62 | 23:20.4 - 23:28.2 | We will always choose the best process for the project. You won’t choose from because we want to use it, but because it is the best for the client. | ID13 |
| 63 | 23:28.2 - 24:29.8 | I think the reasons that the numbers look very low in terms of on the market with products is that there are too many barriers to entry to using additive manufacturing to our clients to put the product on the market. The injection moulding rule is turn out even with the tooling cost to be cheaper that kind of volumes for the products we design for and there is often a request and a need for bespoke products so they want to offer unique anagraphics, finishes embossing, debossing that side of it but when put to the question of how much they are prepared to buy for that, that often then brings it back to small scale production. So the barrier is when asked what you are prepared to buy for the additional facility that you can get, as in bespoke parts often it drops back out again. | ID14 |
| 64 | 24:29.8 - 24:35.8 | It has to be real need for it like the hearing aid which has to fit your ear. This switch the one-off. | ID12 |
| 65 | 24:35.8 - 24:48.5 | Although in the aircraft industry they are using it for weight saving purposes, geometries you would not achieve with traditional manufacturing techniques so it might be a good area for you to, Jet and Boeing are doing it. | ID13 |
| 66 | 24:48.4 - 25:19.0 | Quite few of the large aircraft manufacturers in places like NASA and ESA are using it. Apparently it saves some weight and also to make it cheaper because instead of having say fifty more components or fifty all parts for a fuel injection system for a rocket, they might have just one or two now. This is particularly the case for NASA I believe, they are working on a couple of years ago now. | ID15 |
| 67 | 25:19.0 - 25:56.8 | Thank you. You told us before that there are at least three products in which you are using additive for production so in the shaver display, which you said some of the components are actually made in additive, the steering wheel and then this G-max device for horses and horses competitions. Could you show us some of the material you used to develop these products or components, like sketches, mock-ups? | Interviewer A |
| 68 | 25:56.8 - 26:10.4 | Yeah I’ve got a 3D printed mock-up of mechanism for the shave (unit) and there is also the actual unit out there as well in the marketing display area | ID13 |
| 69 | 26:10.4 - 26:17.7 | We can go and talk about these, the steering wheel and shavers are outside, we’ve got the G-max box if you go and get one of those | ID12 |
| 70 | 26:17.7 - 26:18.5 | Probably we have one | ID13 |
| 71 | 26:18.5 - 26:26.0 | It would be great if you can bring a couple of components here about this product, so we can have… | Interviewer A |
| 72 | 26:26.0 - 27:02.1 | You can take the iPhone with you. Let’s go outside and talk about these. | ID12 |
| 73 | 27:02.1 - 27:46.4 | This is the unit here, when it is plugged in, it opens up. These are shaver heads, they open out like a flower (tool soft) opening in a smooth motion and then you have the glow of the LEDs behind them from that diffused plate and then they move back in again. It is a continuous motion to kind of try to attract people to this product which is here. It actually won an award from the POPAI and one of the judges' comments was that something about seeing more 3D printing or additive manufacturing in these kind of displays in the future. It is on the website. | ID13 |
| 74 | 27:46.4 - 27:49.8 | This case works were 3D printed out, weren’t they? and covered. | ID14 |
| 75 | 27:49.8 - 28:05.2 | On this model itself this will be 3D printed, this was one of the early prototypes on display. We’ve got some Polyjet components and we’ve got an SLS case work and an FDM case work | ID13 |
| 76 | 28:05.3 - 28:10.1 | They are all primed and then painted to get the finishes on them. | ID14 |
| 77 | 28:10.1 - 28:17.6 | This finish is actually a chrome paint but I think the final ones they were vacuum metalized. | ID13 |
| 78 | 28:17.6 - 28:22.0 | How did you decide to produce this product with additive? | Interviewer A |
| 79 | 28:22.0 - 28:54.3 | We didn’t decide personally, we designed components for injection moulding but the quantity, we were doing they basically (wipe/wide up) the cost of the tooling for the components to the cost of producing so many hundreds as 3D prints and then they made a decision based on that I believe, so certain components they went with the injection moulding tooling because it was cheaper but of ones it worked out just financially better, due to the quantities, to just go with 3D printed finishing ones. | ID13 |
| 80 | 28:54.3 - 29:02.8 | And which additive manufacturing technology was used to produce this display? | Interviewer A |
| 81 | 29:02.8 - 29:21.9 | In this display we have SLS casework so SLS Nylon and we’ve got FDM ABS material. We also use Polyjet technology as well, so some Polyjet material there, what else is in there? I think that's it, but it is quite, three technologies are listed in one display, it is quite peculiar actually. | ID13 |
| 82 | 29:21.9 - 29:28.0 | How did you choose those specific technologies for each components? | Interviewer A |
| 83 | 29:28.0 - 29:40.1 | The Polyjet technology is great for the smaller components. It is quite slow comparatively and it is quite expensive on material cost as well. So large components they don’t really suit that technology so much . | ID13 |
| 84 | 29:40.1 - 29:40.5 | But cosmetic and | ID14 |
| 85 | 29:40.5 - 29:41.9 | Cosmetic it looks great | ID13 |
| 86 | 29:41.9 - 29:56.6 | Cosmetic without the need for taking stress or loads so anything that is just cosmetic and it is not under any load, it is good for things like this (that we find for), we the want the detail | ID14 |
| 87 | 29:56.6 - 30:00.1 | It is not really got the material properties for functional components so much | ID13 |
| 88 | 30:00.1 - 30:08.5 | The mechanism inside needs the strength of the FDM components and those have high durability and also SLS is great for that | ID14 |
| 89 | 30:08.5 - 30:17.0 | SLS is great for the larger components as well. They tend to have a larger bed on SLS machines so you get larger components on. | ID13 |
| 90 | 30:17.0 - 30:19.5 | But more difficult to finish | ID14 |
| 91 | 30:19.5 - 30:25.2 | And how about FDM? | Interviewer B |
| 92 | 30:25.2 - 30:36.7 | FDM has got a reasonable size bed and it is reasonably fast. You get the material properties of ABS, not quite as good due to the process | ID13 |
| 93 | 30:36.7 - 30:45.0 | With FDM, it is the resolution of the print that limits so it tends to be nom-cosmetic , functional parts that we are looking for | ID14 |
| 94 | 30:45.0 - 31:04.5 | Finishing the FDM is probably the hardest (so far as I had) to get good finish because you get the build lines they are really clear on them. I mean you can now vapour polish on those to speed the process up so if you just make polishing on them. I think some people tumble them as well but I have not done that myself. | ID13 |
| 95 | 31:04.5 - 31:15.5 | You said that you considered a commercial process right for this object, at the beginning, you considered injection moulding right? | Interviewer A |
| 96 | 31:15.5 - 31:26.6 | Yeah it tends to be the most standard approach especially when you start talking hundreds of or thousands of components then you look at injection moulding so you can imagine 3D printing them takes quite a long time. | ID13 |
| 97 | 31:26.6 - 31:46.7 | [ID14] I don’t think we’ve got any undercuts or anything like this that limited.  [ID13] No it is the same design, it’s got the draft angles for injection moulding. This is obviously the big downside of injection moulding. You have done the work designing draft angles and everything that you do whereas with additive manufacturing you are not limited by that anymore so it does open up more possibilities | ID14 |
| 98 | 31:46.7 - 32:01.0 | Why did you not only use SLS to make the all product because SLS can do cosmetic parts and also the small detail of the finishes. Why not just use SLS to make the whole product? | Interviewer B |
| 99 | 32:01.0 - 32:26.9 | Partially we’ve got the range of processes available to us so we can make a decision about which one we fed is the best fit rather than try to get all made in a single bed or whatever or using -- if we were limited to one technology then we might try to get down that way but if you’ve got the choice, then you balance up the decisions of which ones you think are the best. | ID14 |
| 100 | 32:26.9 - 32:49.0 | It does give you the options as well. If you say we wanted to make it overnight for the client because it had a presentation the next day, we could split the parts over our machines and we know which components will be better on certain machines so we put all the smaller ones on the Polyjet and the larger ones on the FDM that kind of thing so that allows for a fast turnaround as well (so below as it were) | ID13 |
| 101 | 32:49.0 - 33:38.8 | It is not (necessarily) applicable to this but on a lot of technologies we are looking at which one, is things like UV stability so SLA will be very difficult for parts we want to come outside and will be expose to the sun whereas SLS might be a better choice for that. Also things like a lot of them are not very good in moisture there is a lot of swell or degrade in moisture so we need to look at also the properties and the environments that they are going into to choose which one fits the best. So FDM for example would be a great choice for something that’s going outside in ABS but especially if there is in British weather where it might be exposed to the rain except I know we’ve got a sunny day today but where it might be exposed to rain or UV. | ID14 |
| 102 | 33:38.8 - 33:52.6 | Three four cycles as well. There has been some testing done with that and it’s been quite good with minimal delamination if the layers are all well together. | ID13 |
| 103 | 33:52.6 - 34:01.1 | Do you remember what were the main considerations for using additive manufacturing? | Interviewer A |
| 104 | 34:01.1 - 34:43.9 | Time and cost are always for any of the processes we choose are paramount so very quick turnaround projects which are becoming more and more common, then the advantage of being able to print overnight does come in and then cost would be the second consideration. And if it is for low volume, they tend to be less price sensitive to the part cost. A lot of the decisions are made about injection moulding may tent to only look at the part cost and not (notice) tooling cost in it which does make injection moulding come out as a high (front) runner. | ID14 |
| 105 | 34:43.9 - 35:16.7 | So you told us that you designed it first for injection moulding then a certain point you saw that injection moulding was not economically feasible and you decided to switch to additive, how did the design of the product change after you decided to make it with additive? | Interviewer A |
| 106 | 35:16.3 - 36:06.7 | It didn't massively because we knew we were designing for injection moulding but at the same time we had to -- we knew that the first opts would be 3D printed to test it, so it was originally designed with injection moulding in mind which means the geometry has the draft angles in place but it means also that it has got the thicker wall sections for the 3D print. So we kind of designed it for both at the same time so we were thinking about the limitations of the additive manufacturing technology. In this case, the material properties and we increased the wall thicknesses to allow for that. Whereas if we were going back to injection moulding what you do is reduce the wall section (to be better) one suited to injection moulding to not waste materials and take advantage of the material properties of injection moulding | ID13 |
| 107 | 36:06.6 - 36:11.7 | Did you remove the draft angles etc. when you decided to make it additively? | Interviewer B |
| 108 | 36:11.6 - 36:12.9 | No just keeping there | ID15 |
| 109 | 36:12.9 - 36:21.9 | So basically the same design that you used for additive, it could be use potentially for injection moulding without any changes? | Interviewer A |
| 110 | 36:21.9 - 36:28.3 | Yeah. When we started, at a point of the project, started designing that would’ve been to take it that way. | ID13 |
| 111 | 36:28.3 - 36:39.6 | What we will check is that the wall thicknesses, the minimum wall thicknesses in the product is not too small for 3D printing technology and then it will be good to go. | ID14 |
| 112 | 36:39.6 - 37:09.4 | Now I am going to use a metaphor... what did you do in order to arrive to this, what happened? | Interviewer A |
| 113 | 37:09.4 - 37:32.3 | So originally there was the client brief so what the client wanted and that was the space. They had their image in their head, their vision, and they shared that with us and it was our task to create that vision to make it come true. So that was our design brief really and then we had to kind of work out mechanically what was going on so there is sort of mechanical… | ID13 |
| 114 | 37:32.3 - 37:45.7 | The first stage was to work out the mechanism for getting the blades to come out and made several sort of basic mock-ups to test how we thought that would be done with various rods and runners. | ID14 |
| 115 | 37:45.7 - 37:52.9 | So sketching and there were some 3D CAD for that all and I was looking at the actual mechanism and movements, what sort of motion we wanted. | ID13 |
| 116 | 37:52.9 - 38:08.8 | And working out what profile movement was going to have as an (inlet), things like this. Was it coming out quite flat or was it coming out quite vertical. So working out the actual speeds and profile of the movements and then translate that into a mechanism. | ID14 |
| 117 | 38:08.8 - 38:32.2 | Yeah that's right and then we 3D printed that actually, the mechanism, so we took just the mechanism part and we 3D printed it just to test it and we actually. It was a manually driven instead of an electromechanical so actually you had a handle (in) turn that draws some cams. Although there are safety concerns as well so it can't have any finger traps so it would be dangerous because people or the public could touch it. So that would have to be designed as well. | ID13 |
| 118 | 38:32.3 - 38:37.7 | Yeah so it is driven on the way out and it is gravity on the way back again. | ID14 |
| 119 | 38:37.6 - 38:46.0 | So it is additive manufacturing to test the mechanics as well early on and then we took that in the CAD and developed it. | ID13 |
| 120 | 38:46.0 - 38:52.9 | Fit it inside the industrial design or the shell of it. | ID14 |
| 121 | 38:52.9 - 39:01.6 | What were the design considerations at the concept stage, during your idea generation? | Interviewer A |
| 122 | 39:01.5 - 39:48.2 | So obviously strength and robustness of the product comes in quite firmly for this. Once we worked out the mechanism, how we were gonna drive it and how the runners and the pins would work this. I think we did an FMEA study and then looked at the failure modes that we might predict. How we are gonna mitigate against those so that included the health aspects of it: not pitching fingers, where we might see breakages in the product, where it might need to be more robust and we looked at either thickening out wall sections (()). | ID14 |
| 123 | 39:48.1 - 40:00.9 | Oh I remember the risk assessment. There is a potential people dropping items into it. Try to post pencils in the (()) So this actually the LED diffuser plate acted as a shield as well, so people cannot harm themselves. | ID13 |
| 124 | 40:00.8 - 40:10.3 | What were the design considerations at the embodiment and the detail design stage?  So when you started to detail all the components and the assembly. | Interviewer A |
| 125 | 40:20.4 - 41:25.8 | Let’s say because that was done for -- it was originally designed for injection moulding in mind. It was obviously including all the draft angles and looking at good practices for moulding at that point so constant wall thicknesses looking where, you got a wall and another wall coming together, the ratio of those wall thicknesses and things like that. But all those, like I said, all those we can then check as long as the minimum wall thickness is suitable we can use additive manufacturing anyway even for something that is designed for injection moulding, but it does not necessary work the other way around. If we had initially done the design for additive, we would not have had the draft and we probably had more just constant and thicker wall thicknesses around the product anyway. Perhaps larger fillets in corners and things like that in order to, where walls come together to strengthen them in that point. Because it tends to be more brittle and you don't want it snapping at a T dimension so (try to fit that a lot more). | ID14 |
| 126 | 41:25.8 - 41:57.3 | Is there any specific, particular consideration for additive manufacturing in the conceptual design stage, because you mention: "you can see this strength and robustness of the product you suggest" I was told that for any manufacturing process you need to consider that those considerations. For additive manufacturing what other particular rule did you consider? | Interviewer B |
| 127 | 41:57.2 - 42:24.5 | The addition with additive manufacturing is that the properties can be a lot more time dependent than some of traditional techniques. So for example creep can be very quick in Polyjet components. So although initially the parts are very good since you put them under load they will deform and they will creep. | ID14 |
| 128 | 42:24.4 - 42:29.6 | Porosity as well. There is also water absorption can change the material properties. | ID13 |
| 129 | 42:29.6 - 42:49.8 | And like I said, they are very sensitive to UV light or some of the technics are very sensitive to UV light or moisture. So we tend to see them being quite time dependent as well as, maybe given the better accuracy, but they do deform under load. | ID14 |
| 130 | 42:49.8 - 42:59.3 | When you were designing this product or component did you follow any specific design rules or design guidelines? | Interviewer A |
| 131 | 42:59.3 - 43:11.5 | [ID13] What we would have been following injection?  [ID14] We would have been following injection moulding type of guidelines under the principle that it could still be made with additive. | ID14 |
| 132 | 43:11.4 - 43:16.4 | So it is the wall thickness again, draft angles and the usual. | ID13 |
| 133 | 43:16.4 - 43:34.3 | We do tend to try and keep the material to the minimum to keep the cost down on 3D printed parts as well. So more recently we have been looking at using hollow sections, so honeycomb inside rather than the complete material. | ID14 |
| 134 | 43:34.3 - 43:44.4 | Yes, especially the FDM technology. Looking at different types of infill. So different structures, different lattices to reduce material but maintain strength. | ID13 |
| 135 | 43:44.3 - 43:51.0 | And how did you learn about this rules? | Interviewer A |
| 136 | 43:52.2 - 44:48.7 | Trial and error for a lot of it. Learning what wall thicknesses are acceptable are down to just a number of parts we’ve made and the once we see that failed and the once that survived. For each technology you get a good idea of what wall thicknesses are required and if you look at what type of features (spell), like I said large fillets in the corners, quite often the parts we would have seen fail will be at sharp junctions due to the fact that they are built up in layers that tends to then propagate quite quickly. So the design guides come from trial and error and from just a number of parts that we made using additive manufacturing for the development process. The number that we’ve broken would be very high in that, but when you see how they break, you can then learn what the limits of those technologies are. | ID14 |
| 118 | 44:48.8 - 44:55.4 | Did you learn these rules in any other way? Did you use any books, any websites? | Interviewer A |
| 119 | 44:55.4 - 45:08.1 | We have looked up datasheets quite often to try and compare material strengths. For instance, on Polyjet, we have a whole range of materials, it's quite often that the question is asked is which is the strongest. | ID14 |
| 120 | 45:08.0 - 45:38.6 | Yeah, probably material datasheet is that kind of thing, but [ID14 is saying: we tend to mislead here] is to give us a book and materials, we tend to be sort of a little bit ahead of them. So if you go to read them out today, quite a time, like Mike said earlier about looking at actual 3D printed injection mould tools, I mean, this isn't something which you can buy books on. This is something which we are kind of leading the way on. So it's quite difficult to go, oh, which should we, or what should we read for this. We use our experiences and skills to kind of develop that. | ID13 |
| 121 | 45:38.6 - 46:22.4 | Yeah, for one product, we are using SLA, which is something we will buy from outside. And we did go and visit the supplier for that to discuss with them our design and how we might improve it. But the discussion tends to be on the build orientation that is best for that part. So one consideration might be that whether it needs to be built and then in a particular direction which might be more expensive. But they believe it gives us a better part. So to do that, we'll discuss with them what the function of it is and whether we'll require a good surface finish or whether we'll require strength and then they'll give us input in terms of direction of build. | ID14 |
| 122 | 46:22.4 - 46:35.9 | This discussion is about the build orientation and they have their () on strength and quality. Did it change your design? After that discussion, did you come back and change your design? | Interviewer A |
| 123 | 46:35.9 - 47:27.0 | So from that particular one, what it did change was the finishing that we used. So what we were finding was accuracy of the diameter, was not good enough from just the print. But when we looked at the process, they were cleaning up as a hand process, so they were blasting, sand blasting to remove support material. What we were finding was that (back) was a variable process, actually they just gave us a part out of machine and that was built in an orientation that it didn't need support material around the area, we needed, it actually got a better part from it. So in that case, it wasn't the design we changed. It was the process for making it. | ID14 |
| 124 | 47:27.0 - 47:53.9 | [ID13 is leaving and going to the workshop] | ID14 |
| 125 | 47:53.9 - 48:23.2 | Did the introduction of additive manufacturing knowledge change the design of other components of the product or the product itself? So, what I mean is, there are some specific components which are made in additive, and some other components which are not made in additive. Because some components you decided to make them in additive, did this change the design of other components which are made in other processes? | Interviewer A |
| 126 | 48:23.2 - 49:17.5 | I think, so taking this example, I don't think that was the case. They were not gonna affect. What we might've seen is that, because the mechanism was developed to using [should it be 'use'?] additive manufacturing, so the initial prototype was made or printed on the Polyjet machine here. The things like the wall thicknesses would've been developed, for strength, would've been developed actually as the additive manufactured parts. And that's what it'll be in this final product. We probably didn't need to do any further development in terms of changing that internal, the moulded part. I think the runners that are inside that would be thicker than required, because we were printing them rather than using injection moulding. | ID14 |
| 127 | 49:17.5 - 49:27.0 | Are there any drawbacks or limitation in this product by the fact some of the components were made in additive? | Interviewer A |
| 128 | 49:27.0 - 50:03.5 | Not what we've seen. But I'd say, we tend to notice that additive manufactured parts can be brittle. So maybe, but we haven’t heard of failure in the field for this. But I'm not sure we would've received that feedback. It would be interesting to see whether there were brittle failures in the field. Especially it's so constantly running mechanism, it would come under fatigue. And in general, I would expect additive manufacturing not to perform well on something that's a fatigue application. | ID14 |
| 129 | 50:03.5 - 51:06.6 | I think, certainly it's the issue in medical device or anything which is regulated product. We don't know the machine produces the same mechanical strength, part out of the part. Nobody's done the study that we know of. You know, making ten parts and seeing what the variability of mechanical strength is across those ten parts. We don't know the variability of all materials, process and characteristics why they said the machine is () important. I think there are a lot of, compared to other manufacturing processes, additive has been in a very early stage. A lot of this work hasn't been done. So it's tricky that we are not gonna use additive manufacture for structural parts which are very important to the function of the product until we have some confidence in processes and the control of the processes as well as the materials, strength being fundamentally ok as well. | ID12 |
| 130 | 51:06.6 - 51:12.8 | Did the use of additive manufacturing change your design process or practice? | Interviewer A |
| 131 | 51:12.9 - 52:18.7 | It does heavily in the development stage, yeah. We use much more iterative processes making and trying parts rather than going for the right first time approach, as in using FEA or (extensive you) [software name?] because the cost of people's time to do those reviews and to do those studies is a lot more than it would cost to make something and try, and in reality, a lot of those studies need to be calibrated against that tried and tested part anyway. So we do heavily use interaction in the design process. And 3D printing has been an essential part to that. If we couldn't make parts this quickly, then we would be using the right first time FEA analysis and (extensive you) approach more. | ID14 |
| 132 | 52:18.6 - 52:25.8 | For the design iteration, I think it's, additive manufacturing is used as the rapid prototyping tool? | Interviewer B |
| 133 | 52:25.8 - 53:15.7 | Yeah, for that, we do bear in mind the limitations that we see. So, some of the failures you will see would be down to prototyping. So a common course (conventionally) is high friction in the parts, because the way that build in layer, you don't tend to get smooth surfaces, and the materials tend to be quite sticking to each other. So friction properties are often not replicated, using that process. So quite often we have to use something like a PTFE (frame) to get parts to move against each other correctly. So we wouldn't be relying on it there that where friction was an important part to the design, but that's quite (rare) in my case, but () [voice too weak to hear] stop using it. | ID14 |
| 134 | 53:15.7 - 53:25.8 | So, if you would like to talk about, a little bit about the stirring wheel, then? | Interviewer A |
| 135 | 53:25.8 - 53:28.4 | Yeah, do you want to go downstairs? | ID14 |
| 136 | 53:28.4 - 53:29.5 | That would be fine. | Interviewer A |
| 137 | 53:29.5 - 53:38.0 | So this is an early mock-up of the stirring wheel. There is a final one which was made in Titanium. | ID14 |
| 138 | 53:38.0 - 53:41.3 | That's 3D printed in () [voice too weak to hear]? | ID12 |
| 139 | 53:41.3 - 53:51.8 | I think so, yes. It feels like S L S, yeah, haha. | ID14 |
| 140 | 53:51.7 - 53:52.6 | Do you want to explain a little bit about the background? | ID12 |
| 141 | 53:52.6 - 55:41.0 | If ID15 was available, he'd be better to explain it. But, uh, so this product was designed with 3D printing in mind, and specifically it was gonna be 3D printed in Titanium, make a strong but light stirring wheel. And the project was originally for () [company name], where they were trying to get to 1000 miles an hour. So you get the land speed, well crash the land speed ref I think. So what they were looking for was obviously to reduce, like an aircraft, reduce the weight but also you everything need to be very strong, 100% reliable, etc. So 3D printing in Titanium was chosen for it, we also could keep the weight down and maintain strength. But it needed to be designed to fit exactly to one person’s ergonomics, so to their hands and to help their arms move. And also things like thumb rotation to be able to get to the three sets of buttons there. They would be able to move their thumbs to press those buttons. So they were (worried) to work out from clay models, exactly with those hand () should be like in three dimensions and made it also work out exactly where those buttons should be for him to be able to press immediately. And in that date, it was scanned in and turned into a CAD model to get the final surfaces. And obviously then we had no limitations to what those surfaces needed to be like, you know, to worry about overhangs, draft angles and wall thickness changes and anything like that. So we could just design exactly what the geometry we needed to hold and then take the wall thicknesses from layers, and then that went on to be 3D printed in Titanium. | ID14 |
| 142 | 55:40.8 - 55:46.7 | How did you decide to produce this component using additive? | Interviewer A |
| 143 | 55:46.7 - 56:39.5 | Because it's one-off. The end cost was not such a big driver, but being able to get a part into his hands to try in a quick time was. The geometry would've been very difficult to do in most traditional methods, moulding or machining, especially we've been looking to get a hollow part in that. If we machined it, we would've probably ended up how to machine in sections and glue together or to fix together. So we would've ended up with additional interfaces which give us reliability problems. I think it was decided based on what they would expect the shape and what we tried to achieve, which didn't fit well with the traditional methods. 3D printing in Titanium was a good choice. | ID14 |
| 144 | 56:39.5 - 56:42.6 | Did you consider any way, any conventional process? | Interviewer A |
| 145 | 56:42.5 - 57:58.7 | We would've considered all processes. So machining certainly would've been talked about and discussed. Given that we would probably have selected metals and materials early on, I doubt we would've talked much about moulding, but I'd expect casting would've been considered as an investment cast. Yeah, so, we would've talked through all the processes we thought, some would've been easily eliminated, and then I would expect the () machining would've been discussed because of the one-off nature. Investment casting, because it can be used for that low volume, and can get that sort of net-shape product. But also the one another aim of the project is to promote engineering within the UK, within Britain. So to be able to promote things like additive manufacturing which is the, it seems as the future for engineering, is also a benefit. So to be able to talk about those kind of processes is part of this project, which is also important. It's their to inspire, it's to become engineers. | ID14 |
| 146 | 57:58.7 - 58:07.0 | Did you say the surface finish was not the primary consideration? You didn't need machining to? | Interviewer B |
| 147 | 58:07.0 - 59:04.6 | Yeah, the surface finish, so the finish would be a consideration in terms of the hand grips and where thumbs are going, because obviously it needs to be 100% reliable for his grip, you know, during the running he's making. So () of it, it's not a requirement, but it will also, because this is a promotional tool, the cosmetics of the part are, they are not functional in terms of meter and land speed record, but they are functional in terms of promoting engineering and making sure people are interested in what they are seeing when this car will be viewed a lot. So it's not to talk about function, but the visual I said are important because it's much about this way [strong background noise]. | ID14 |
| 148 | 59:04.6 - 59:18.4 | But for other additive manufacturing, post-processing will reduce anyway to get the surface finish, () and painting, it's really () as well. | ID14 |
| 149 | 59:18.4 - 59:25.1 | How did the design of the product change after you decided to make it in additive? | Interviewer A |
| 150 | 59:25.1 - 1:00:28.4 | So, firstly, we wouldn't have then had to consider how we would, we wouldn't have to look to how to split it up for, say machining had been chosen, we would've had to decide how split that product up to make it machinable, whereas, we found that bed was big enough to print that in one go, so I think that whole thing was just 3D printing in one go, so it didn't need to take that consideration. We didn't need to add fixing to reassemble it together. It's just fix and () [strong background noise] for the component to assemble inside it. So I think the advantage for us was we put all the features we wanted, where we wanted them without having to consider access for tooling, without having to consider how to split and reassemble the part. It could be done as a single part, with just the features where we wanted them for electronics to go inside (to connect to) the buttons. | ID14 |
| 151 | 1:00:28.4 - 1:00:45.0 | Now I'm asking you again, to immerse again in the metaphor, so I'm using the metaphor and a D V D recorder again. So, how did you come about with this design? How did you design the way it is? | Interviewer A |
| 152 | 1:00:45.0 - 1:00:49.3 | It's a more difficult task because I wasn't involved in this project. | ID14 |
| 153 | 1:00:49.3 - 1:01:13.1 | It's started off the economics study to get the shape for hand. So obviously these constraints from (), which a bit was taken into account. The certain size we can fit it in. So we started with that information, and then we built on top of that. The aesthetics of the design is important because it's sort of, uh. | ID12 |
| 154 | 1:01:13.1 - 1:01:22.2 | I think it was the competition to design the look, this wheel. | ID14 |
| 155 | 1:01:22.2 - 1:01:43.5 | It's sort of, it's a key part of the, when you look at the () the car, it's the () [voice too weak to hear]. So aesthetics were important. And then obviously the manufacturing processes had to match the ergonomics of the aesthetics. That came one after another in that tool, I think. | ID12 |
| 156 | 1:01:43.5 - 1:01:58.8 | Do you remember what were the design considerations at the concept stage, so when generating the ideas about this stirring wheel? Do you remember which considerations, what considerations? | Interviewer A |
| 157 | 1:01:58.8 - 1:02:27.5 | Usability was the primary consideration. So for a one-off used by one person, so it's how do we exploit that to the best, which basically involved getting the person that was gonna use the wheel and to do the testing during the development stage to make sure these grips were comfortable that he sat in the car with the mock-up of this wheel to check everything was gonna go. | ID14 |
| 158 | 1:02:27.5 - 1:02:38.0 | Do you remember some more specific consideration when you were trying to design the details of the stirring wheel? | Interviewer A |
| 159 | 1:02:38.0 - 1:03:39.3 | I don't remember but I'm assuming we would've done some FEA, some finite element analysis study to ensure the strength. Because I think one of the advantages we were able to utilise that organic shape and to do this stress analysis and then to optimise that organic shape rather than using straight section struts etc. We might've done, we've gone more traditional manufacture, so this was one while we were looking to exploit the benefits of getting the material in the right place with strength without having to worry about whether we can manufacture material in that shape. So I'm sure it went fast topological studies, but I think it was done using finite element analysis and looking at this organic shapes and where did we use material to make it stronger. | ID14 |
| 160 | 1:03:39.3 - 1:04:02.2 | Where were the considerations towards production? So when you actually started to produce the actual components, did you have some considerations, did you change something after the design? | Interviewer A |
| 161 | 1:04:02.2 - 1:04:10.0 | I don't think so. Maybe with design for 3D printing in mind, so don't think there were any changes. | ID12 |
| 162 | 1:04:10.0 - 1:04:19.1 | There were a lot of iterations made. That would've been done to testing. | ID14 |
| 163 | 1:04:19.1 - 1:04:32.8 | When you were designing this product, did you follow any specific design guidelines or principles? It was designed with 3D printing in mind, what do you mean? | Interviewer A |
| 164 | 1:04:32.8 - 1:05:00.1 | It was always going to be Titanium SLS, so I guess, I don't know, I wasn't in the design but I guess... [chatting. Mike and ID14 are trying to find ID13 to explain the design of the stirring wheel] | ID12 |
| 165 | 1:05:00.0 - 1:05:07.3 | I see also that you changed the fixture from 3 to 4. | Interviewer A |
| 166 | 1:05:07.3 - 1:05:45.9 | Yes, I don't remember why that, yes, maybe it went from 4 to 3, and we went back, because this is an early prototype. This was definitely done through iteration as well, for parts being made for the guy to test them. And then made very small changes that would make a difference to his performance. | ID14 |
| 167 | 1:05:45.9 - 1:06:06.0 | [people are going upstairs back to the meeting room to continue the interview] | Everyone |
| 168 | 1:06:06.0 - 1:06:14.7 | So what are your general views on additive manufacturing as a production process for end user products or components? | Interviewer A |
| 169 | 1:06:14.7 - 1:07:12.3 | I think at the moment there is a novelty requirement for it. So for example, the clothing industry, I've seen it used for glass etc., where it's been specifically used for is the novelty and the fact that it's been promoted quite heavily as a new technology. So for people in the fashion industry, that's a great thing. In engineering, because of the functional requirements and costs, we are not really seeing it take off the production process. There is lots of discussion on how to overcome those barriers. So for example, how do you made a lot of parts rather than a few one-off parts? And how do you bring the cost of it down to match traditional processes like moulding and casting? | ID14 |
| 170 | 1:07:12.2 - 1:07:42.7 | I think it'll first come in medical devices and stuff which is very high added value and very unusual requirements and the requirements of one-off customisation to the patient. So there are likely to be the first areas. But, as I said before, we () overcome materials and compatibility. It's (use) process (qualification), it's (use) EP grade materials or those requirements. | ID12 |
| 171 | 1:07:42.7 - 1:08:20.8 | The biggest issue with mass manufacturing with additive manufacturing is the point being how slow it is. So you need a lot of printers or machines to in order to say, replace injection moulding machine or CNC milling machine. And it can be quite variable how the quality gets out with the other end. So I personally don't know what quality control is for say printer filament, but pressure on the hobby grade one is not gonna be particularly good. I don't know whether the quality is there for the more advanced materials yet. | ID15 |
| 172 | 1:08:20.8 - 1:08:22.8 | Quality is an issue. | ID12 |
| 173 | 1:08:22.6 - 1:09:17.1 | Yeah, for what we see, the reliability of the machines isn't high enough either for production environment or to downtime machines for any production line is one of the biggest considerations. We see the machines go down for a 5 to 10% of the time. They have high maintenance requirements. If you are looking at, I mean, we use Polyjet for instance, so you have to keep the heads clean in order to keep (judging) as you would for any home printer. It's got the same sort of head technology in there. On the FDM, we see the filament breaks or snaps at some point. So you would need the downtime of putting that right. So the maintenance and the downtime of the machine is relatively high compared to traditional production methods at the moment as well. | ID14 |
| 174 | 1:09:17.1 - 1:09:30.6 | Now I want to ask you, for us it's a quite important question, so what do you think designers need to know for designing effective parts for additive? | Interviewer A |
| 175 | 1:09:30.6 - 1:09:44.5 | We need to know all about material properties and that's it. As the raw material, and then the material as in that process' study. | ID12 |
| 176 | 1:09:44.4 - 1:10:53.3 | I also think we need to know the differences in different types of additive manufacturing, 'cause there are quite a lot out there now. For example, FDM printing isn't particularly good if you have overhang, 'cause you'll have to print a lot of support material where it not only increases the build time and build cost, it can be difficult removing that material, especially it's the same as the part, which is quite common with a lot of printers, () extruder, dual head extruders, help with that 'cause you can a completely different build material, which makes removing the supports a lot easier, but you need to take sort of thing into account during the design stage and when you are laying it out for actual print, especially given that the strength of the F D M part changes depending on which orientation it's in. So in one direction, it might be stronger but more likely to delaminate if you have a vertical force on it. So you need to take that as well as the overhang into account. | ID15 |
| 177 | 1:10:53.3 - 1:11:21.1 | Yeah, tolerance is another very important issue and it's difficult to get information at the moment on what tolerance you have on the parts. So that has caused problems. We have an 'O' ring fit to go onto the 3D printed part and that gave very variable results and then we discovered the tolerance of those parts was not as high as expected. So actually knowing what tolerance we can get on the parts, which is true for any design, is very important. | ID14 |
| 178 | 1:11:21.1 - 1:11:42.4 | At the moment, we standardise the clean-up processes. At the moment, your part quality depends on a lot on post processes and there is not standardised approach. It's called out post-process and then what you are going to get, you are not getting anything. | ID12 |
| 179 | 1:11:42.4 - 1:12:01.0 | In some cases, the sizes of features, so minimum sizes of features you can make, a lot of stuff we do has some small features in there and it's often not clear whether they will print correctly, and what we'll get from 3D print on features of those size. | ID14 |
| 180 | 1:12:01.0 - 1:12:07.2 | FDM tends to, I think, that's about half a millimetre, feature wise. | ID15 |
| 181 | 1:12:07.2 - 1:12:11.9 | Yeah, we trial and error to whether it's ok or not. | ID14 |
| 182 | 1:12:11.9 - 1:12:18.3 | I think the best part goes about 0.3mm and that was pushing things. | ID15 |
| 183 | 1:12:18.3 - 1:12:23.6 | How did you learn how to design for additive? | Interviewer A |
| 184 | 1:12:23.6 - 1:12:25.8 | Experiment. | ID12 |
| 185 | 1:12:25.7 - 1:12:29.6 | Yeah, buying machines and trying. | ID14 |
| 186 | 1:12:29.6 - 1:12:33.8 | Did you come up with your own rules? | Interviewer A |
| 187 | 1:12:33.8 - 1:12:45.8 | Knowhow, knowhow within the company, people. So if somebody's designing a part, they'll go to speak to somebody who's designed the part using that technology and get advice. | ID12 |
| 188 | 1:12:45.8 - 1:12:49.2 | Do you have any document? | Interviewer A |
| 189 | 1:12:49.2 - 1:12:49.7 | No. | ID12 |
| 190 | 1:12:49.7 - 1:12:54.7 | It's just the informal () [background noise]. | Interviewer A |
| 191 | 1:12:54.7 - 1:13:23.2 | We've got a couple of guidelines written on the, we have a wiki, which is sort of our record of company knowledge and advice. And there are a couple of guidelines; they will be only along the lines of wall thicknesses you can print in the different technologies. We do have material datasheets available but we don't tend to rely on that. | ID14 |
| 192 | 1:13:23.2 - 1:13:27.4 | Can you show us that wiki? Is it part of? | Interviewer A |
| 193 | 1:13:27.4 - 1:13:30.3 | Company confidential. | ID14 |
| 194 | 1:13:30.3 - 1:13:34.4 | How did you develop those rules, the internal wiki? | Interviewer A |
| 195 | 1:13:34.1 - 1:13:36.5 | Trial and error. Experience. | Mike and ID14 |
| 196 | 1:13:36.4 - 1:13:39.3 | Did you prove them? | Interviewer A |
| 197 | 1:13:39.3 - 1:14:05.8 | No, I think it's just the experience. As I was saying, coming back to the point of that qualification, it is a big opportunity. Nobody has really done that. If somebody's got a published study with all the different technologies, you know, the variability you can get from different material properties and tolerances by set up a machine and buying it, material, variations, that'd be very interesting study. | ID12 |
| 198 | 1:14:05.8 - 1:14:52.5 | It'd be interesting if the machines that we've got here, they don't provide, for instance, a standard part to print to check that your machine is still in tolerance. So when they come and they do the maintenance, they just print a part and make, they have some standard parts like a spanner or there are some bits. But they don't tend to provide a STL file, you can print this and measure the wall thickness on this and then you know whether your machine is in calibration or not. So we don't see the effort coming from the machine manufacturer at the moment to help with that kind of calibration of the machine and to promote the understanding of what's acceptable and what's not in terms of wall thickness, radius, [interrupted by Mike] | ID14 |
| 199 | 1:14:52.5 - 1:14:55.5 | They don't wanna do that, otherwise customers will send the machines [interrupted by ID14] | ID12 |
| 200 | 1:14:55.5 - 1:14:58.5 | We start to noticing that machines are wrong. | ID14 |
| 201 | 1:14:58.5 - 1:15:03.6 | You are talking specifically about Polyjet, right? | Interviewer A |
| 202 | 1:15:03.6 - 1:15:54.2 | It does apply to Polyjet. The reason we came across really is that SLA tend to be calibrated. I think they have a scaling fact that they can change according to the calibration of their machine. So it's not something we experience directly. But having talked to those manufacturers, we would be looking at whether we can apply similar principles on our machine and for example, for us to come up with something we would print and measure, so that we would understand better what tolerances when we print a part that we can actually expect to see. Because if you're using those parts for testing, it's good to know, when you need to know really, what size of the features are in fact important, what they inspect and how would they affect the test result, if they are not. | ID14 |
| 203 | 1:15:54.2 - 1:16:01.3 | About the internal wiki, what processes do you have? | Interviewer B |
| 204 | 1:16:01.3 - 1:17:14.0 | So, predominantly, it is listing people that run the various machines and then secondly giving advice on choosing which technology to use. So at the moment, we have the Object material, the Polyjet, and we have FDM, so the advice is along the lines of checking for, if the part is suitable for FDM, then we use that, it's the cheap technology. Also to check that the parts are reviewed before we print, although we have () process, there is a tendency to rely on it and some print can be obsolete before they finished. So there is also advice on ensuring what's printed is reviewed and checked to be suitable. So we have a core team of people that run the printers and we will help review for people giving advice to people on their design. | ID14 |
| 205 | 1:17:14.3 - 1:17:29.7 | In the next 10 to 5 years, how do you think additive as a production process will influence design? How do you think design will be influenced by additive as a production process? | Interviewer A |
| 206 | 1:17:29.7 - 1:18:51.8 | Customisation, I would think, will be one of the key drivers. There are a lot of products we've been asked to design where customisation is something that has been dropped into importance due to the difficulty in cost. It's nice to have but not an essential part of a product. A lot of people would like to move towards that. So additive manufacturing would give that ability. And again, we put that for () tailored or individuals, so in medical for heat () etc. For dental work, obviously that's matched to individual. Wearables is a growing market and obviously ergonomics is very important to that. So things that could be designed and made, maybe a template, I know for example, I think glasses, they've been template design, you can then scale and fit an individual. So each set of () can be made to fit individual space with limited () making a model to do that. | ID14 |
| 207 | 1:18:51.8 - 1:20:00.2 | I think simplifying parts and reducing the weight in them. There is new software which places much more sort of natural looking structures where it uses a finite element analysis to work out where () or a force against () on the model and where, and then it works out where I can remove material from. There is some quite natural looking structures on this which is also way a lot less but you would have absolutely no chance to making a conventional tooling kit. You can also simplify large parts. So you might break it down maybe 10 if you are using a conventional tooling. You can now make it in one component so that will also reduce, like something failing, you've got a few joints from different parts. I think it might be of use in that probably. Cover everything. | ID15 |
| 208 | 1:20:00.1 - 1:20:59.3 | I think another thing that might need to be addressed then, specially if the home market does develop, is ownership of the design and how you control and sell a particular design. So obviously the 3D model is a extensive bit of work, if you are gonna put that on the market, that's very easy for someone to copy and replicate. So I think, longer term, in terms of protections and understanding how to design and how to sell in market to a design for 3D printing will also be becoming important. If the home market does take off, or if small scale production takes off in terms of you going to a small factory that's making parts to a S T L that you asked for, so I think that will become important at some point as well. | ID14 |
| 209 | 1:20:59.3 - 1:21:13.4 | Thank you very much. I just want to you some a few details about your educational background. So what is your educational background, if I may ask? | Interviewer A |
| 210 | 1:21:13.4 - 1:21:27.8 | I got a degree in mechanical engineering from IfM under the manufacturing engineering course. | ID12 |
| 211 | 1:21:27.8 - 1:21:36.6 | Physics at the University of Bath. | ID15 |
| 212 | 1:21:36.6 - 1:21:50.9 | Degree in Mechanical Engineering from the University of Surrey. All the people in the interview I think are degree qualified like Physics or Mechanical Engineering. | ID14 |
| 213 | 1:21:50.9 - 1:21:55.6 | How long have you been working as a professional designer? | Interviewer A |
| 214 | 1:21:55.6 - 1:22:04.7 | That's a good question. 26 years. | ID12 |
| 215 | 1:22:04.7 - 1:22:10.2 | I can only approximate to 20 years. | ID14 |
| 216 | 1:22:10.2 - 1:22:16.4 | Nine and a half. | ID15 |
| 217 | 1:22:16.4 - 1:22:21.2 | Ok, so, we cover the range. | ID14 |
| 218 | 1:22:21.2 - 1:22:28.4 | My experience with 3D printing is more from a personal project. | ID15 |
| 219 | 1:22:28.3 - 1:22:36.4 | Can I confirm it is ok for me to take some pictures of the objects you showed me? | Interviewer A |
| 220 | 1:22:36.4 - 1:22:38.6 | Yes. | ID14 |
| 221 | 1:22:38.6 - 1:22:41.4 | Are the projects in the public domain? | Interviewer A |
| 222 | 1:22:41.3 - 1:22:42.5 | Yes. | ID14 |
| 223 | 1:22:42.4 - 1:22:44.5 | Can we use them as the case study? | Interviewer A |
| 224 | 1:22:44.5 - 1:22:51.1 | I would think so, yes. I think probably we would like to know what you are going to say. | ID12 |
| 225 | 1:22:51.1 - 1:22:59.2 | For (blood handling), we can provide our case study and then you might be able to work from that. | ID14 |
| 226 | 1:22:59.2 - 1:23:28.4 | Ok, so, in the following weeks, we'll transcribe the interview and send you a copy in order to see if we understood you correctly. At that time, you are completely free to change, delete anything that are in the transcript. Just one last question, in the case we are going to publish the results of this interview and the case study, would you prefer to be named or be anonymised? | Interviewer A |
| 227 | 1:23:28.4 - 1:23:31.3 | You mean the company or the individuals? | ID12 |
| 228 | 1:23:31.7 - 1:23:41.1 | Both. Can I use your names or can I use the company? | Interviewer A |
| 229 | 1:23:41.0 - 1:23:43.6 | Both. | ID12 |
| 230 | 1:23:43.5 - 1:23:47.0 | Ok, so that's everything. | Interviewer A |
| 231 | 1:23:46.9 - 1:23:48.3 | Good, thank you very much. | ID12 |
| 232 | 1:23:48.3 - 1:29:34.4 | [chatting] | All |