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Engineering Design and Analysis

The Application of an Engineering Design Methodology – Industrial / Commercially Available Product

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Contents

1.0	Introduction	2
2.0	Design process fundamentals	3
2.1	Current Problem.....	4
2.2	The Design Specification.....	6
2.3	Research.....	10
2.4	Alternative Solutions.....	11
2.5	Selecting a Solution	14
2.6	Models and Prototypes.....	15
2.7	Testing and Evaluating.....	20
2.8	Manufacturing / Production & Commissioning.....	21
2.9	Conclusion.....	22
2.10	References	23

1.0 INTRODUCTION

This assignment looks at taking an industrial or commercially available part/ product and uses appropriate design methodology tools and techniques to re-design the product in line with the Design for 'X' drivers changed as highlighted below

- Manufacturing
- Assembly
- Disassembly
- Reliability
- Maintainability
- Serviceability
- Environment
- Life Cycle Cost

The assignment will highlight the current problem with the product following this a Design specification will be created and the process followed through to create numerous re-design options to selecting the most appropriate design and the manufacturing of the products as well as other considerations.

The suitable design will then be modelled on Solidworks with a model and a technical drawing created.

2.0 DESIGN PROCESS FUNDIMENTALS

The design process begins by highlighting what the current problem is. Defining the problem clearly and concisely is one of the most important stages in the design process. This has been highlighted by people such as Albert Einstein who stated, ‘If I had an hour to solve a problem I'd spend 55 minutes thinking about the problem and 5 minutes thinking about solutions.’

This has been further emphasised by the Harvard Business Review who state that well defined problems lead to breakthrough solutions, and critically analysing and clearly articulating a problem can yield a highly innovative solution (Spradlin, 2012).

Companies have used this technique and been very successful such as the Subarctic Oil problem where there was an oil spill in 1989 (Exxon Valdes Oil Spill) and clean up teams were still struggling to pump the oil from the low temperatures in the sea from the barrages to the onshore collection stations. After nearly 20 years the clean-up teams were still struggling. The problem was defined as material viscosity instead of oil spill clean-up and used language that was not targeted at the petroleum industry. This would attract suggestions from people in other fields.

The breakthrough was then found by a chemist in the cement industry who proposed a modification of commercially available construction equipment that would vibrate the frozen oil keeping it in its fluid form and making the clean-up process easier. (Spradlin, 2012).

Numerous companies have been successful using this process and seen new and innovative ideas coming from the process.

The following Design Methodology as shown in figure 2.0.1 will be used within the task to ensure a suitable solution is achieved.

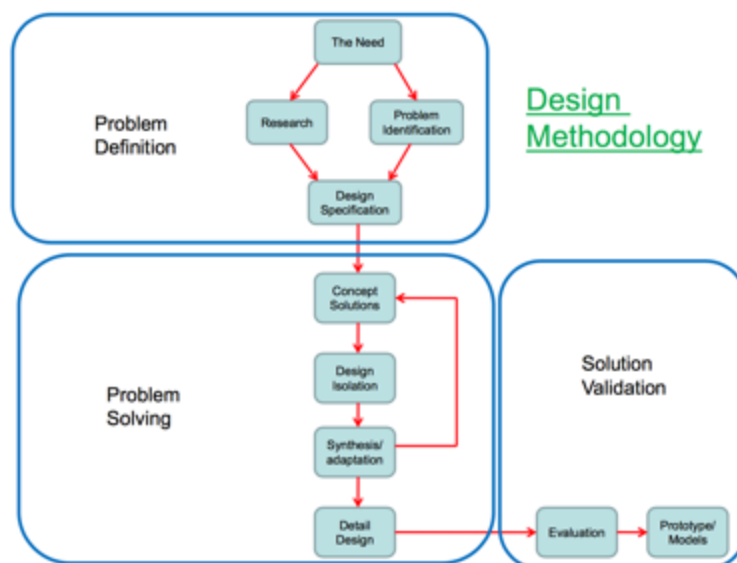


Figure 2.0.1 – Design Methodology format

2.1 – Current Problem

The current problem found within the RGH20/24 customisation cell of Renishaw is based around the cores used to build all of the readhead's. The main problems are;

1 - The toting currently used to transport cores can hold 120 cores. However, the maximum batch size on the line is 30, making the toting insufficient.



Figure 2.1.1 – Current Toting

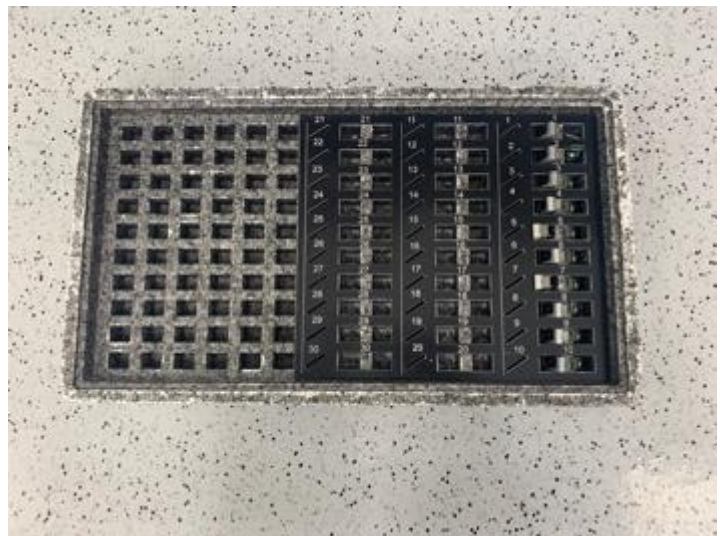


Figure 2.1.2 – Current Toting

2 - A new core design has recently been introduced which contains a new small PCB on the side of the sensor which is extremely delicate and susceptible to damage in the current toting.

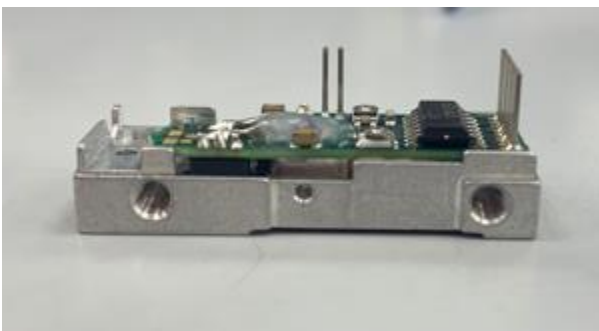


Figure 2.1.3 – Non ERiS Core



Figure 2.1.4 – New ERiS Core

3 - A new system on the line now consist of a front-loading picking system where all parts for the job are picked at the start of the line and transported down the line together ready for assembly. Using the current toting trays will mean that numerous trays will be required to carry the cores, PCB's, cables, labels and paperwork. The use of numerous trays increases the risk of mixing up batches and parts.

2.2 – The Design Specification

In order for the new design to be suitable it must have the following characteristics, functions, features and abilities to overcome the current problem facing the company.

The new design must be

- Stackable
- Fit on the rollers and shelves currently on the line
- Hold a maximum of 10 of each of the following parts:
New core, PCB, Cables, Labels, Paperwork
- ESD Safe
- RoHS compliant
- Durable
- Light Weight
- Not damage the new core with side PCB
- Be suitable for all variants of Readhead's across the whole of Renishaw

Life in Service Requirements

The new toting must last a minimum of 10 years in production to reduce the need for annual replenishment and reduce costs for the company.

Production Requirements

Simple Design which requires very little maintenance and is durable.

Can handle daily handling by people on the line.

Reduces the risk of parts being mixed up and customers receiving the incorrect part resulting in customer dissatisfaction.

Conformance Requirements

The largest conformance requirements for the product include;

- ESD safe
- RoSH compliant

QFD

Quality function deployment (QFD) is a methodology which is used to list the voice of the customer and effectively respond to those needs and expectations (ASQ, 2019).

A QFD matrix has been performed as show in in figure 2.2.1.

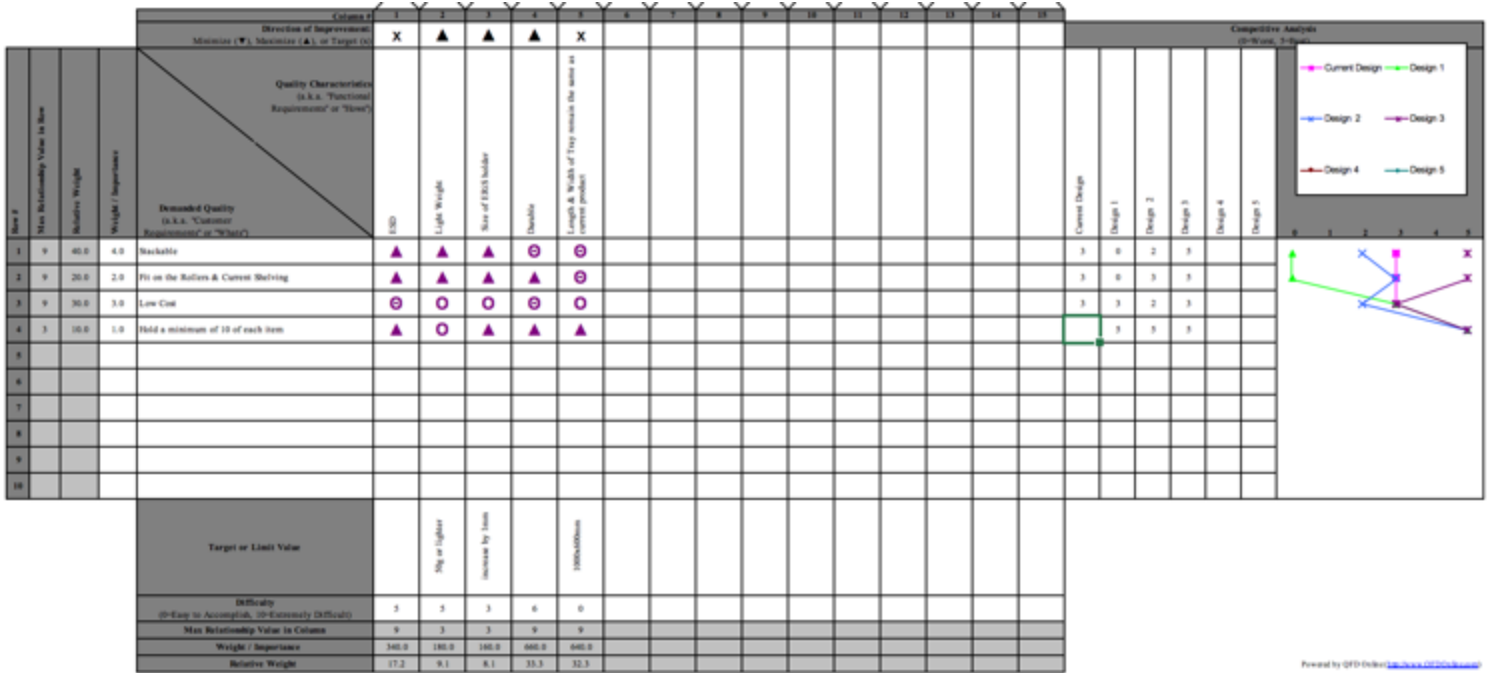


Figure 2.2.1 – QFD

FMEA

The FMEA process reviews the potential failures that may exist within the design process.

Table 2.2.1 shows the ratings for severity, occurrence and detection.

Severity			Occurrence			Detection		
Rating	Description	Potential Failure Rate	Rating	Description	Potential Failure Rate	Rating	Description	Potential Failure Rate
10	Hazardous	Detrimental consequences due to failure, would affect customer's product and use in industry	10	Very High	100% Failure Rate	10	Absolute Uncertainty	No chance of detection
9	Hazardous	Major consequences due to failure of product	9		90% Failure Rate	9	Very remote	Very remote chance of detection
8	Very High	Product is unusable	8	High	80% Failure Rate	8	Remote	Remote chance of detection
7	High	High failure rate, high customer dissatisfaction	7		70% Failure Rate	7	Very low	Very low chance of detection
6	Moderate	Frequent failure of product	6	Moderate	60% Failure Rate	6	Low	Low chance of detection
5	Low	Occasional failure of product	5		50% Failure Rate	5	Moderate	Moderate chance of detection
4	Very Low	Product will function, customer dissatisfaction expected	4	Low	40% Failure Rate	4	Moderately high	Moderately high chance of detection
3	Minor	Product still functions, customer dissatisfaction is unlikely	3		30% Failure Rate	3	High	High chance of detection
2	Very Minor	No observable failure noticeable to the customer	2	Failure is unlikely	20% Failure Rate	2	Very high	Very high likelihood of detection
1	None	Failure would have no effect on the customer	1		10% Failure Rate	1	Almost certain	Almost certain detection

Table 2.2.1 – FMEA Severity, Occurrence and detection ratings

Table 2.2.2 shows the FMEA conducted on the current and new toting trays. As shown in Figure 2.2.2 the re-design has resulted in a decrease in RPN which is desirable.

Process Function	Potential Failure Mode	Potential Effect(s) of Failure	S e v	Potential Cause(s)/ Mechanism(s) of Failure	O c c u r	Current Process Controls	D e t e c	R P N	Recommended Action(s)	Responsibility and Target Completion Date	Action Results				
											Actions Taken	S e v	O c c u r	D e t	R P N
Part Picking	Components knocked off of Core	Readhead does not function	10	Toting holding positions too small	9	Size of toting gaps large enough to hold the current parts	9	810	Increase the size of the ERS Core hole in the toting	Engineering Design Team	Dimensions increased by 1mm	10	7	8	560
Transportation	Mixing up parts and job sheets	Incorrect parts shipped to customers	7	Numerous toting boxes and only one piece of paperwork	6	Paperwork kept in toting	3	126	Include part labels at the start of the process, barcode includes job number and part number	Manufacturing Engineer	Re-organising the process so all parts including labels are generated at the start of the process	7	4	4	112
Transportation	Running out of the necessary toting	Different form of toting can be used and small parts can easily be lost if not in the correct toting	5	Toting is not standardised across the cell	5	None	1	25	Standardize toting trays so all parts can be transported in the same toting	Engineering Design Team	Quotation for new toting and cost benefit analysis	5	3	5	75
Part Picking	Using the incorrect cables for the job	Customer receives incorrect part	6	Selecting the wrong cable from the sheets due to numerous cables being kept togeth and part numbers only varyingby 1 digit	6	Buddy Check	3	108	Traceabilitysoftware put in place which checks the parts being used against the BOM to confirm theya re the correct parts	Software team - Development Manufacturing Engineering - Proveout	New softare designed	6	1	1	6
Part Picking	Using the incorrect core for the job	Customer receives incorrect part	6	Selecting the wrong core from the sheets due to numerous cables being kept togeth and part numbers only varyingby 1 digit	6	Buddy Check	3	108	Traceabilitysoftware put in place which checks the parts being used against the BOM to confirm theya re the correct parts	Software team - Development Manufacturing Engineering - Proveout	New softare designed	6	1	1	6
Part Picking	Using the incorrect top board	Customer receives incorrect part	6	Selecting the wrong top board from the sheets due to numerous cables being kept togeth and part numbers only varyingby 1 digit	6	Buddy Check	3	108	Traceabilitysoftware put in place which checks the parts being used against the BOM to confirm theya re the correct parts	Software team - Development Manufacturing Engineering - Proveout	New softare designed	6	1	1	6

Figure 2.2.2 - FMEA

2.3 – Research

Material Options

It is essential that a suitable material is selected as the products that will be transported in the toting are electrical components which will be subject to ESD damage which must be avoided.

Static electricity is the accumulation of positive or negative charges on insulators or conductors. Current flows from one item to the other where this transfer is known as electrostatic discharge (ESD). (EC&M, 2019)

As stated by EC&M all materials are sources of ESD. The human body can store a charge of 250 picofarads which equates to a stored charge of 25,000V (EC&M, 2019). As stated by Margaret Rouse some products are sensitive to as little as 10V and in some cases 25V can irreparably damage an integrated circuit. For this reason, preventing ESD damage is essential (Rouse, 2019)

As the parts are susceptible to damage due to Electrostatic discharge (ESD) it is essential to protect the parts during manufacturing not only by the use of wrist straps when being manufactured and tested by the operators to protect the parts, but it is also essential to use suitable transport toting when transporting the product down the production line.

There are numerous different types of ESD safe materials which can be considered for the use of the toting.

- SUSTAMID 6G ESD 90 (PA 6 G)
- SUSTARIN C ESD 90 (POM)
- SUSTARIN C ESD 90 PLUS (POM)

(ROCHLING, 2019)

A further alternative is to manufacture the toting out of standard material that is readily available and applying an antistatic liquid spray which allows the material to become ESD safe for a time period. Material such as staticcontrol AS 77 E10 (BOUSSEY CONTROL, 2019).

Although this could be a suitable alternative the parts would need to be regularly maintained and re-sprayed to ensure the material is always ESD safe. This could create more unnecessary work in the long run and cost more to the company than initially investing in an ESD safe material.

Alternatives to plastic materials include polystyrene which is light weight making it easier to carry as well as also being suitable to the injection moulding process. Material such as ESD A 400 Polystyrene (PS) offers ESD protection and static dissipation which is ideal for electrical components (RTP, 2019).

2.4 – Alternative Solutions

Solution 1

Using a 3 draw system all parts are transported together in a set of draws so the parts do not risk getting lost along the line. Each draw contains a different part of the encoder readhead.

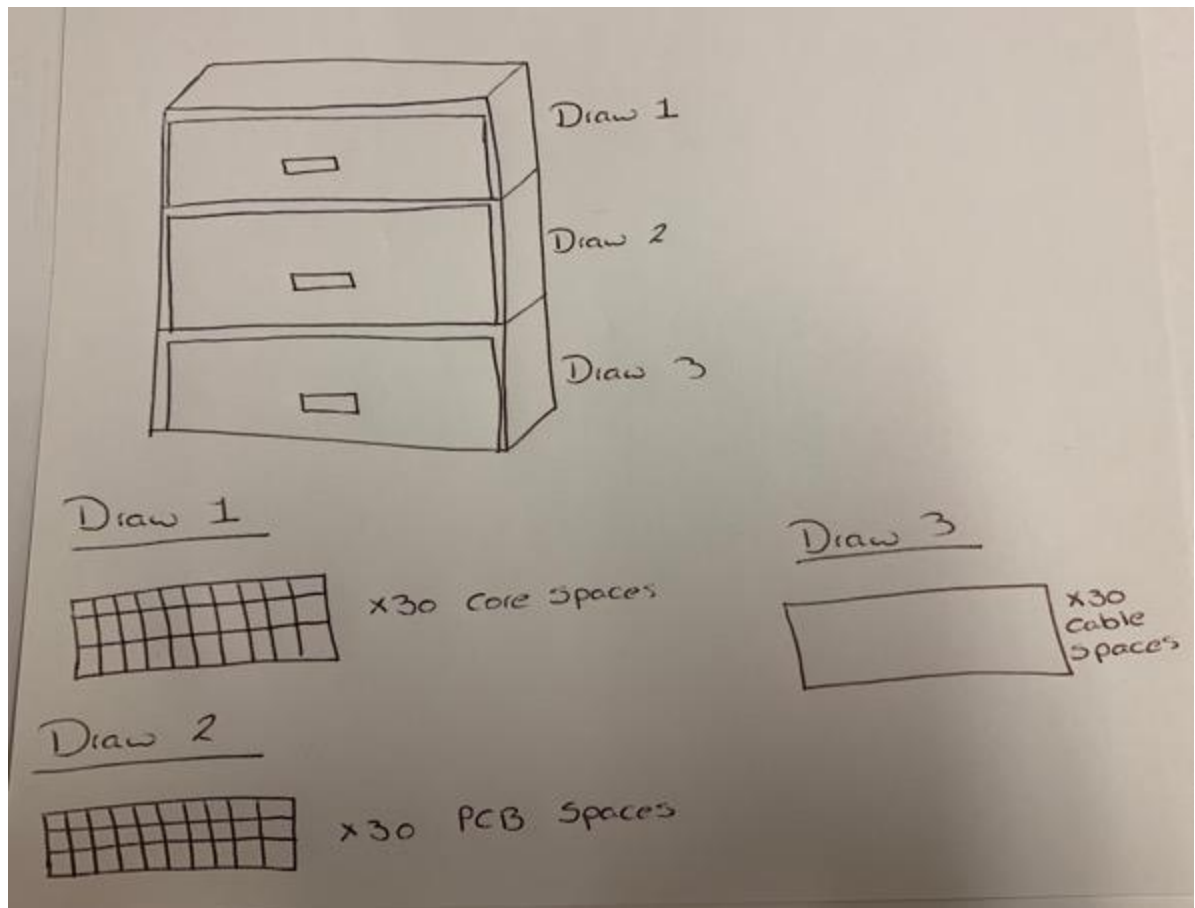


Figure 2.4.1 – Solution 1

Solution 2

Using a system of 3 different forms of toting. 1 will contain the cores, 1 will contain the PCB's and 1 will contain the cables.

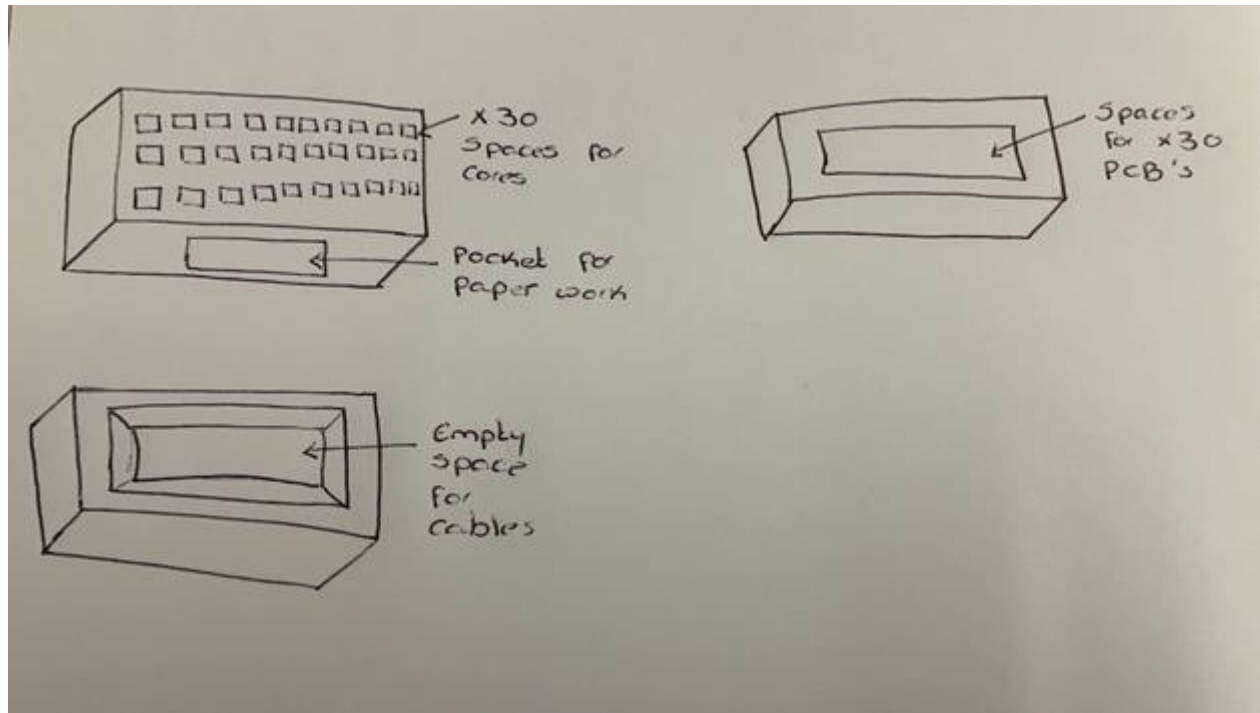


Figure 2.4.2 – Solution 2

Solution 3

Using a system of 1 toting tray which will contain all of the required parts to make 10 complete readhead's.

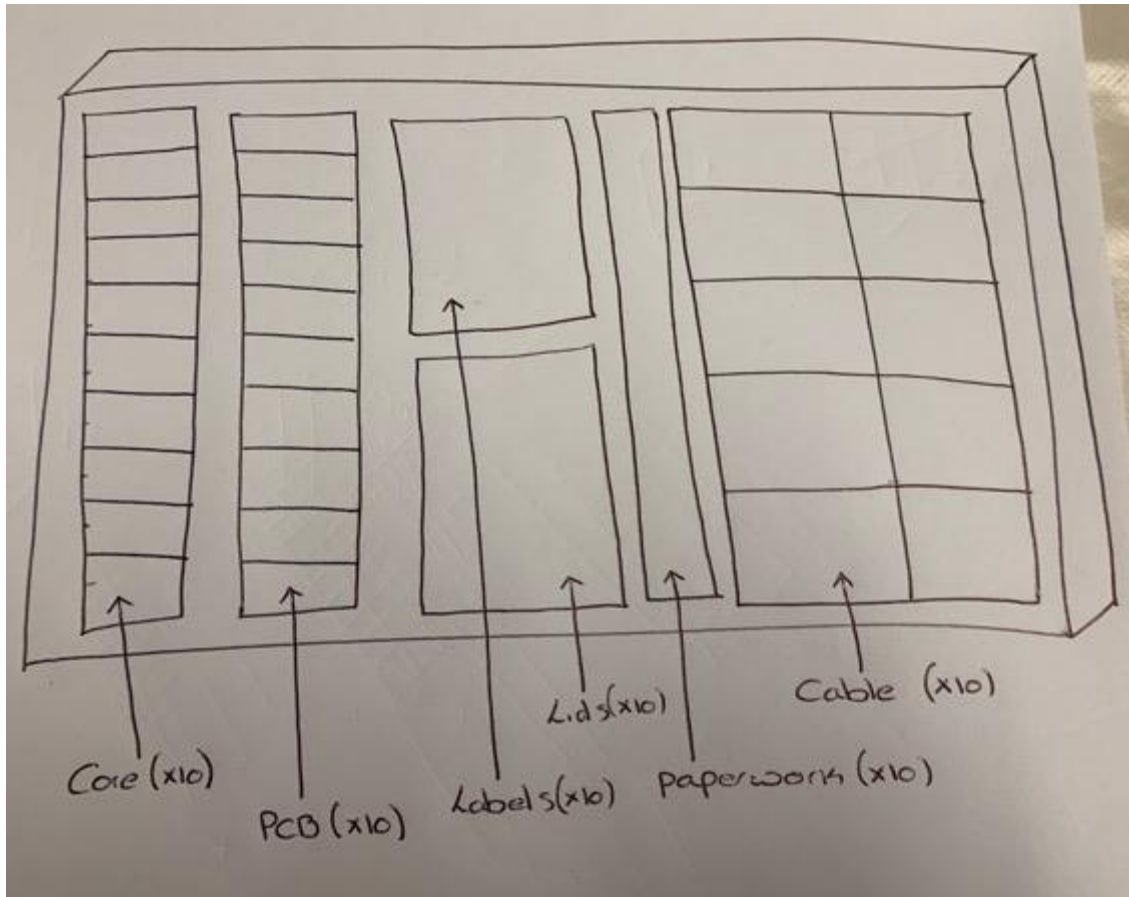


Figure 2.4.3 – Solution 3

2.5 – Selecting a Solution

A review of all the ideas is conducted with the Engineering Design Team, Manufacturing Engineering, Technicians, Cell Leaders and Operators on the line. This allows all users of the toting to be involved in the process and highlight any areas of concerns and also provide an opportunity for others to give suggestions for improvements to be considered before prototyping begins.

Based on the discussions with the entire team the most suitable solution to initially be trialled is solution 3. Solution 3 allows all parts to be put together in the same toting box. This will reduce the risk of parts being lost down the line or the mixing up of parts.

The toting will be light weight and stackable and ticks all the boxes with the design specifications initially set out.

2.6 – Models and Prototypes

A 3D CAD model of the most suitable design has been produced as shown in Figure 2.6.1 to 2.6.3.

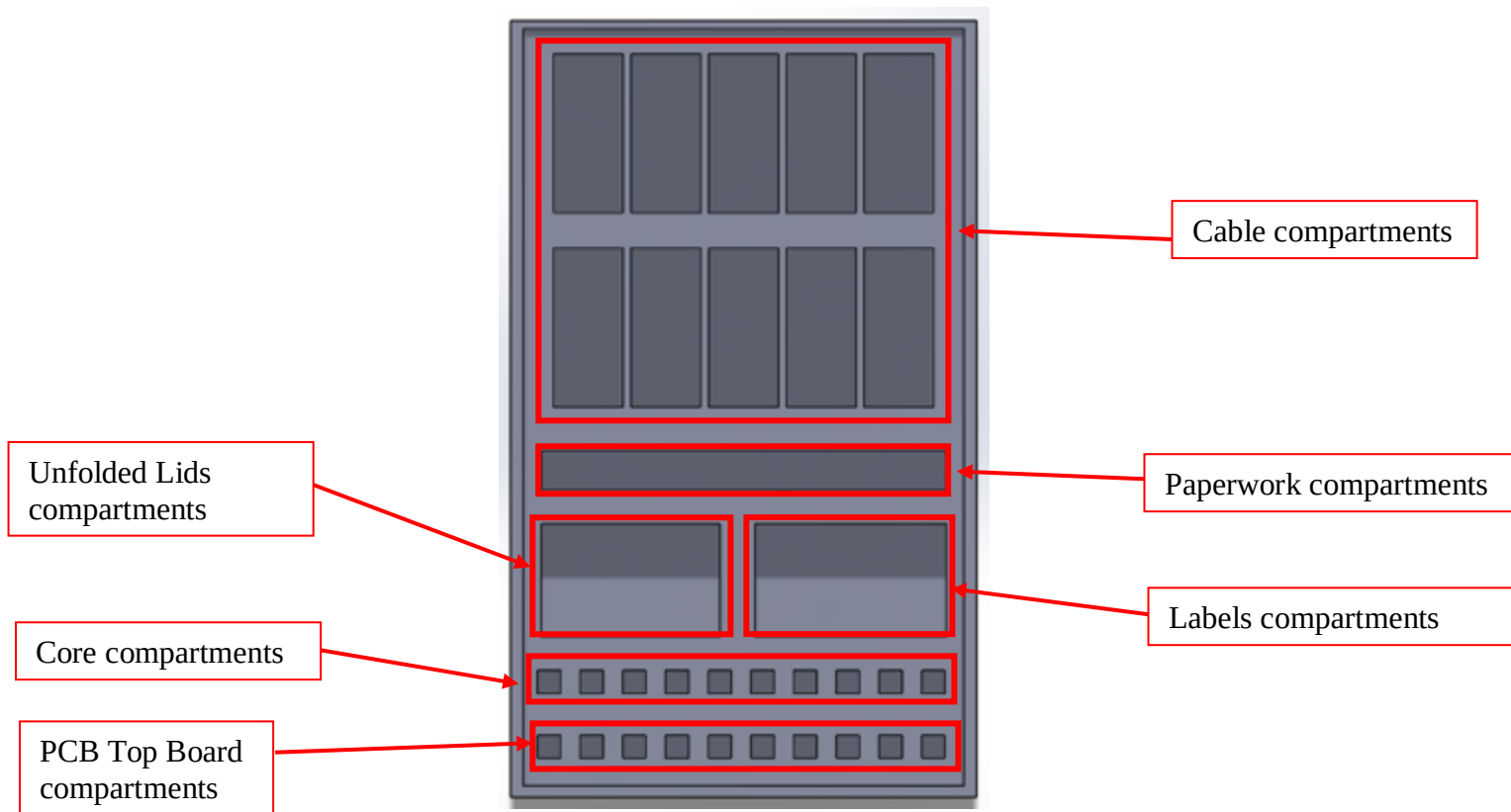


Figure 2.6.1 – 3D Model of Chosen Design

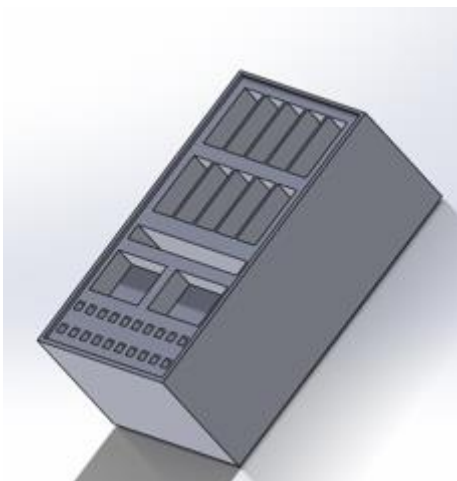


Figure 2.6.2 – 3D Model of Chosen Design

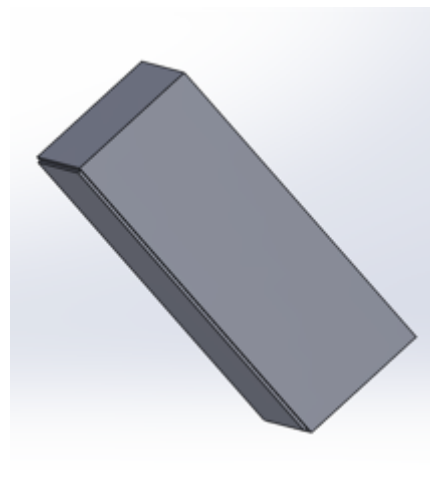


Figure 2.6.3 – 3D Model of Chosen Design

Based on the design spec it can be seen that the proposed design removes the need for numerous trays, each of which can only accommodate a particular part and incorporates all the different compartments required into one simple design. The proposed design will have the ability to hold all the parts required to build 10 complete read heads regardless of the part size/ variant.

The models consist of 6 compartments all of which will hold the cables, Lids, Core, PCB's, Labels and the paperwork for the job as shown in Figure 2.6.1.

The overall design can accommodate 10 completed read heads. The maximum order per job is 30 cores so for a job of 30, 3 lots of toting will be required, in order to prevent batches getting mixed up the toting has been designed so that it can be stacked. This allows all the parts for the job to be kept together and travel along the conveyor without getting lost.

However, it can be noted in the event of one of the toting boxes being removed and the paperwork not being with it the labels within the label compartment have a barcode on them which contains the part number, the job number and the serial number of the parts. This will allow the parts to be tracked back and re-united with the rest of the batch and the designated paperwork.

Having the toting stackable will not only help along the assembly line but also when storing the unused toting in the designated area. As the toting is light in weight it gives opportunity for any unused parts to be stored on top of one another therefore using up less space on the shop floor as shown in figure 2.6.4 and figure 2.6.5.

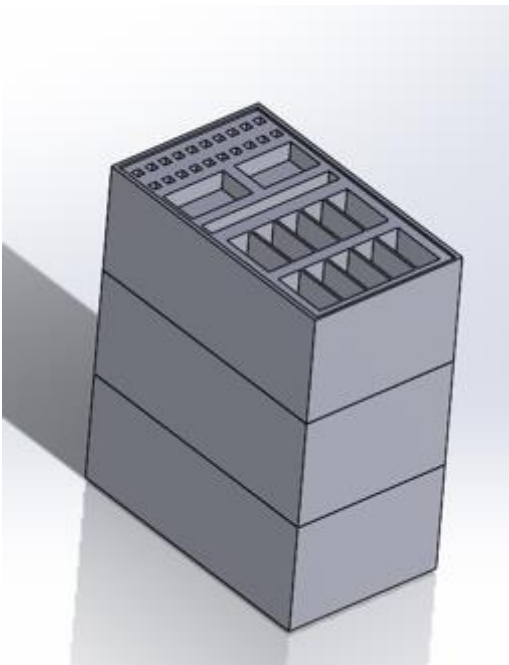


Figure 2.6.4 – 3D Model of Stacked Toting

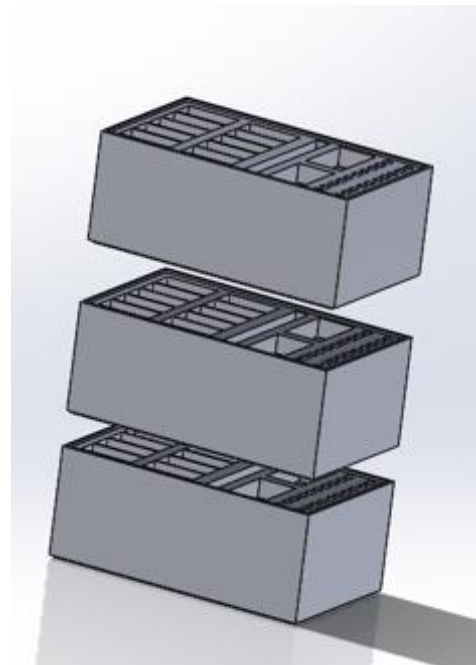


Figure 2.6.5 – Exploded View of Toting

To initially prove out the suitability of the design some prototypes will be required to trial putting the parts in and attempt stacking them both on the assembly line as well as off the line. As Renishaw have numerous 3D printing capabilities available on site the initial prototype would be 3D printed. Due to the size of each box 3 separate 3D printers would be required in order to print 3 separate boxes so stacking trails can be attempted.

Details of the drawing for the toting can be found in Figure 2.6.6

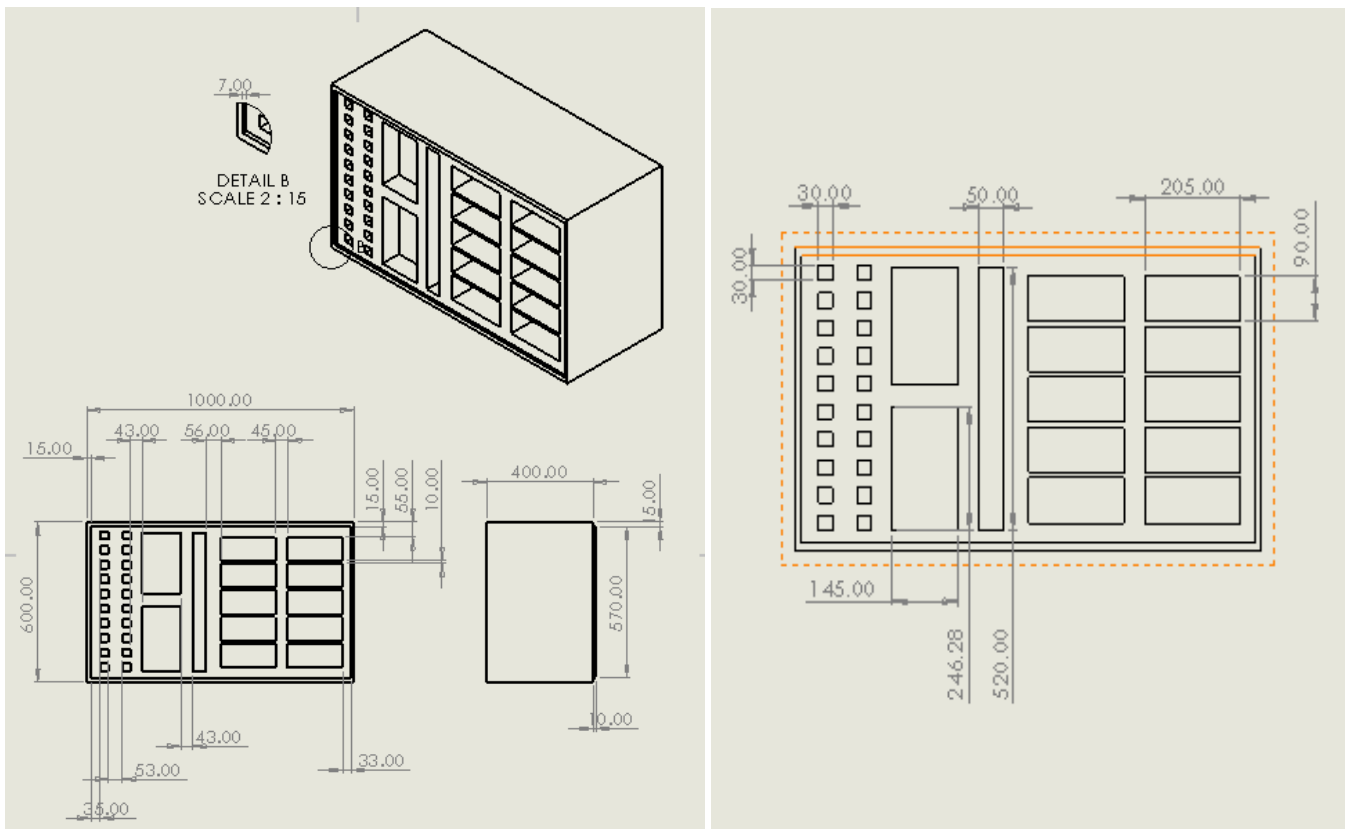


Figure 2.6.6 – Toting Drawing

Using the functions within Solid works an estimation of costings for the manufacturing of the parts can be conducted to give an idea to the company what the cost implications may be.

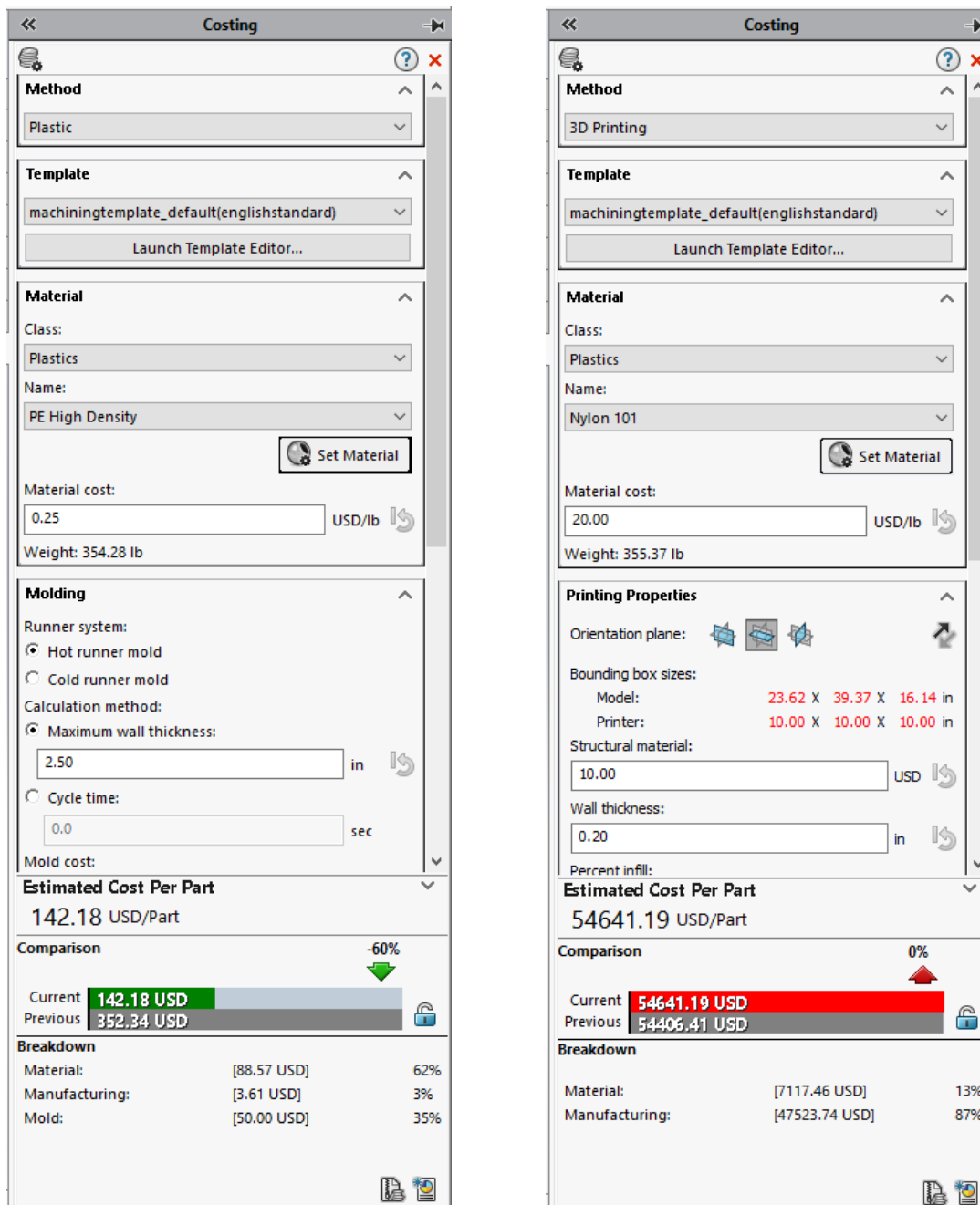


Figure 2.6.7 – Costing Comparison

As shown in figure 2.6.7 it can be seen that Solidworks gives an estimation of the cost for both a moulding process and the 3D printing process. As shown in Figure 2.6.7 the cheapest option would be to mould the parts rather than 3D print them. However, for the prototyping 3D printing the items would be the most suitable option as Renishaw have onsite 3D printers which will allow the rapid prototyping

process to begin immediately and within a couple of days the prototypes will be ready for use, this eliminates the need to request quotes and put purchase orders through.

However, for manufacturing of numerous parts the moulding process will be far more suitable and cost effective.

2.7 – Testing and Evaluating

Following the successful manufacturing of prototype parts these would then be trialled by numerous people involved with the manufacturing process from engineers through to technicians and operators to highlight any potential issues which may be found with the design.

It should be noted that as the prototype parts will be made through 3D printing these parts will not be ESD safe therefore the parts will need to be sprayed with an ESD coating which can be manually applied after the parts have been made. This will allow the prototypes to be used on the line and production parts used without the risk of damaging good parts. These parts can then be shipped to customers provided the ESD spray has been applied beforehand.

The testing procedure will initially consist of the following tests and steps:

Stacking

Can the toting items be easily stacked both on the floor and on the rollers on the line without falling over? Is the stability suitable.

Manual Use

Can the toting be easily carried by the users as well as the ease of use when putting the toting on the line and taking it off the line.

Keeping Track of Jobs

Using the new system are jobs going to be easily mixed up or do the preventative measures of the barcodes on the cables prevent this from happening.

ERiS

Are the new ERiS Cores protected from damage in the new toting, Trial to be run putting the ERiS cores in the new toting in different orientation by different operators and conducting standard build process and test the parts to ensure they are fully functioning after handling.

Timing Exercise

A timing exercise will be required to see if the total time of the process is reducing as the new toting no longer requires each individual person on the manufacturing line to go and collect the parts they need. Instead all items will be received in the toting which has been pre-populated at the start of the line. This should reduce unnecessary motion on the line and increase efficiencies.

2.8 – Manufacturing / Production & Commissioning

Batch Quantities

Based on the line being required to make 800 parts per day and each tray holding 10 completed parts at a time the minimum number of trays required are 80 trays. However, there are cases where some jobs will not require a job of 10 but may only consist of 1 item. This also needs to be accounted for. An additional 20 trays will be required for small batches. Additional spare trays will be required in case of an uptake in orders, as well as accounting for any WIP or items put into quarantines and any trays that are being transported between sites. It can be seen that a total of 250 trays will be required to accommodate the RGH24 customisation line.

Manufacturing Processes

The manufacturing of the parts will be conducted with the use of injection moulding based on the material selected. The material selected for the product is ESD safe polystyrene. ESD A 400 Polystyrene (PS) in foam form.

Design / Redesign for Manufacture

The design of product has been kept very simple so that it can accommodate all variants of the RGH24 readheads that are currently manufactured within Renishaw. However, as Renishaw are always striving to improve quality and be innovative, new designs of readheads are always released and replacing current ones to provide customers with superior parts for lower costs. Due to this it is essential that the toting does not just accommodate the RGH24 parts, but all read heads that are manufactured within Renishaw.

This will allow new designs produced in the future to be suitably transported down manufacturing lines without having to invest more money into new toting. It also allows the standardization of the toting trays across all sites and read head parts which means that the manufacturing batch size could potentially be increased reducing the manufacturing cost per part.

Finishing Processes

The most essential finishing process is to ensure all trays have been sprayed with ESD protective spray this will protect the electrical components that will be placed in the tray from getting damaged which will subsequently cause customer dissatisfaction.

Quality Control

To ensure the trays are always suitable for use and will not cause any damage to the products being shipped to customers a quarterly PMI will be put into place which will require all trays to be manually inspected and re-sprayed with ESD spray to ensure ESD damage to parts is limited.

2.9 Conclusion

Overall it can be seen that the design specifications have been met with the use of solution number 3. The new toting design ensures the ERiS PCB is protected and does not get damaged during transportation and handling. The design also allows all the required parts to be transported together along the assembly line reducing the risk of mixed up parts or incorrect parts being used due to other measures such as traceability software being put in place at the start of the production line.

Furthermore, it can be seen that by having all the parts in the toting the amount of motion operators needs to do will be drastically reduced as they no longer have to go and get the parts required for their job by moving from their station over to the storage area and select the desired part before returning to their station and begging the job. The reduction in motion and reduction in risk of using the incorrect parts will improve productivity and reduce re-work.

It is essential to trial the new toting design first and receive feedback from all users so additional changes/ improvements can be made before production of all parts is placed. This will reduce the chance of additional costs of re-work/ modification if issues are highlighted by users.

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