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DFMA – PROCESS DEVELOPMENT IN SASKEN FINLAND OY

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Master’s Thesis
Autumn 2010
Degree Programme in Industrial
Management
Oulu University of Applied Sciences

ABSTRACT

Oulu University of Applied Sciences
Degree Programme in Industrial Management

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Title of thesis: DFMA – Process Development in Sasken Finland Oy
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Term and year when the thesis was submitted: Autumn 2010 Number of pages: 37

ABSTRACT

The objective of this research was to develop the DFMA process for mechanics engineers and to link it into the product development (PD) process of the Sasken Finland Oy. To develop guidelines, checklist, etc. tools for mechanics engineers to help them in their design work, documentation and reporting. One of the big objectives was to create the DFMA process required by one of the main customers.

This research addresses on DFM (Design for Manufacturability) and DFA (Design for Assembly) engineering theories and implementing these theories in practice. DFM takes into consideration possibilities and limits of certain manufacturing processes and aims at designing parts which are easy to fabricate and produce. DFA takes into consideration possibilities and limits of assembly processes and aims at designing assemblies or products that are easy to assemble and produce.

This research was done and the future development will be done at the Sasken Finland site. The research was done in a group of seven mechanics engineers. The research method was the so called Action Method.

As a result of this research DFMA process for mechanics, design guidelines, design checklists and DFMA analyze template will be taken into use at least at the Beijing and Bangalore sites.

The DFMA process and documentation will be yearly updated and developed under the Sasken Finland Research and Capability management.

Keywords: Product Design, Design for Manufacturability / Assembly, Concurrent Engineering

1 INTRODUCTION

1.1 Subject Matter

This research was commissioned by my employee Sasken Finland Oy and is part of the global HW Resource and Capability development.

Sasken Finland Oy is a subsidiary of Sasken Communication Technologies Ltd., a global leader in R&D and support services to companies across the communications value chain. Sasken provides products and services to leading semiconductor, terminal device, network equipment and test and measurement companies, and service providers globally. Established in 1989, the company has over 3,500 associates, and operates out of offices in India, China, France, Finland, Germany, Japan, Mexico, UK and the U.S.

Sasken Finland Group is a service provider for companies wishing to generate winning products and services in the rapidly growing wireless technology area.

Sasken Finland's vision is to be a leading product and solution design company for wireless applications. The employees are highly trained experts. Most of them have advanced degrees and are experienced in their field. They are continuously developing their knowledge. The driving force is to be innovative and solution oriented.

HW Business Line is a division specializing in wireless technology products offering hardware and mechanical design services and solutions with a particular strength in RF-design know-how. It also includes testing services and, therefore, offers a one stop shop method for testing and is capable of testing whole products with the main focus on R&D testing of wireless technology products.

SW Business Line is a division focusing on software engineering, integration & consulting. It represents the top knowledge of the industry in mobile software development. SW Business Line is continuously involved in several demanding software projects - that ensures durable competence, which can be leveraged for your benefit. (http://www.sasken.fi/company_profile.htm 27 Oct. 2009)

The research addresses on DFM (Design for Manufacturability) and DFA (Design for Assembly) engineering theories and implementing these theories in practice. DFM takes into consideration possibilities and limits of certain manufacturing processes and aims at designing parts which are easy to fabricate and produce. DFA takes into consideration possibilities and limits of assembly processes and aims at designing assemblies or products that are easy to assemble and produce.

These two definitions are very narrow and simple explanations of quite complex issues. These two philosophies or theories are more or less mixed, and go side by side and are very much connected to each other. Because of this, in many contexts, these two issues are under the letters DFM, DFA or DFMA. There are also some letter combinations to describe some special processes like DFBA, Design for Board Assembly. Or DFFA Design For Final Assembly.

In my research I have decided to use letters DFMA, which I think, is the best way of describing the issues. Dr. David M. Anderson describes in his book:

DFM is the process of proactively designing products to: (a) optimize all the manufacturing functions: fabrication, assembly, test, procurement, shipping, service and repair; and (b) assure the best cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction; and (c) ensure that lack of manufacturability doesn’t compromise functionality, styling, new product introductions, product delivery, improvement programs, strategic initiatives and unexpected surges in product demand. (Anderson 2008)

In my opinion it is alright to talk about DFMA as “Design for all”. DFMA is not a new invention but it is a thing that rarely is focused systematically on product development processes. This was also one of my basic assumptions at the very beginning of the study and also was confirmed later on by interviews with designers.

1.2 Objective

The objective of this research was to develop a DFMA process for a mechanics engineering group and link it into the product development (PD) process, as were as, to develop guidelines, checklists, etc. tools for mechanics engineers to help them with design work, documentation and reporting.

One of the main objectives was to create a DFMA process required by one of the main customers. They were developing their own DFM capabilities and competencies and were also setting requirements for suppliers. The customer was committed to the DFMA process development, giving their support and arranged DFMA training to the company's management and mechanics team.

1.3 Definition

Issues included in this research are as follows:

1. To get knowledge from DFMA issues

2. To get understanding of the level of DFMA capabilities and competencies among mechanics engineers, by means of interviews

3. To find out a way to join the DFMA process part of the PD process

4. To develop guidelines, checklists, etc. to ease DFMA design work and documentation for mechanics engineers

6. To arrange an internal DFMA course for mechanics engineers, containing use of documents created during this development process and how to join DFM issues in the PD process

1.4 Theoretical Background

The literatures mainly used in this research are as follows:

Dr. David M. Anderson; Design for Manufacturability & Concurrent Engineering, 2008

Boothroyd and Dewhurst DFM methods, 1983

1.5 Research Method

1.5.1 Research Scope

This research was carried out at the company's site here in Finland, in a mechanics engineering group consisting of seven mechanics engineers. The Research method is the so called Action Method. Future development work will be done together with the company's sites in Finland, Bangalore and Beijing. Sasken Finland has already had some co-operation with the Bangalore site.

The outputs from this research are as follows: DFMA process for mechanics, DFMA Guideline for Mechanics document, DFMA Appendix 1 Assembly Check List document, DFMA Appendix 2 Part Design Check List document, DFMA Analyze Template document and DFMA Analyze lecture material and lesson from the DFMA process and new tools for Mechanics Engineers.

In the future the DFMA process and documents will be employed and used at least at the Beijing and Bangalore sites.

1.5.2 Methods of Data Collection

There were two interview rounds among the mechanics engineers. The first round was arranged to get understanding of what the level of DFMA capabilities and competencies among the mechanics engineers was. How they saw the DFMA issues were taken care of and what kind of ideas they had to improve the situation. In my opinion this was one of the most important phases of this research. This way the engineers were involved in this development process, their ideas were listened and recorded. They got an opportunity to affect the coming process. The second round was to track the situation after they had participated in the customer's DFM course, they had been familiarized with the guidelines, checklist, etc. tools, and they had participated in an internal course. The interviews were open conversations in person between the author and a mechanics engineer. In the interviews a few open questions were used to keep the conversation in track and to have comments to the same issues from everyone. (Appendix 1) Conversations were recorded and analyzed. The records are in the hands of the author.

As a member of the mechanics engineering group I had a very good position to make observations about the following: How DFMA is understood, how it was taken care of in practice and what happened during the process. Many times during this study I ended up in a situation where someone pointed out some DFMA related issue to me, or I got an opportunity to point out some issues that were related to DFMA.

Theoretic data was collected from literature, different kinds of publications, the internet and the customer's training material.

2 DFMA AND CONCURRENT ENGINEERING

2.1 DFM / DFA

Engineers are generally not taught DFM or concurrent engineering at college – the focus is usually on how to design for functionality. Further, they are typically trained to design parts, not products or systems. Most design courses do not even talk about how the parts are to be manufactured. And engineering students rarely follow through designs to completion to get feedback on the manufacturability of their designs. (Anderson 2008)

This is one of the main problems that were also found out in this research. Based on the interviews and my own experience I can agree with Dr. Anderson. The first interview round showed that new engineers did not seem to have so much knowledge about DFM or DFA as more experienced engineers had. It was also noticed that the engineers who had been actively working in R&D programs with the customer, had good or very good knowledge about DFM/A issues. This tells that these issues are learnt in working life and real product development tasks. It was also noticed that all the engineers had more understanding about DFM than DFA. This way that can be understood easily. It is more common that DFM issues are taken care of in R&D projects than DFA issues. I think it is more natural to take care of DFM with the part supplier, maybe not under DFM letters but as some kind of “Design Feedback”.

Because DFMA knowledge seemed to be very much dependent on the persons` working history, some of them knew more than the others, and because the company was not having a certain process for DFMA, these DFMA issues were more or less taken care of by individual engineers, handled and based on the persons` “gray information”, if they were. According to my experience DFMA issues were not the first thoughts in mind when a new product was designed, but functionality, reliability, and demand for marketing and industrial design and keeping schedules. It happened many times that all constrains were already locked when a production engineer and/or a part supplier gave feedback of manufacturability or assembly. As we all know in this phase, maybe just before the file release, it is a bit too late to start thinking about DFMA.

On the other hand, when the DFMA issues are not in a systematic process, product development managers usually stress schedule and cost, but, if not measured right, may further reinforce the suboptimal behavior described above. Pressuring engineers to complete tasks “on schedule” is really telling them to “throw it over the wall on-time”. In reality, the most important measure of schedule is the time within the product has ramped up to stable production and is satisfying all the customers who want to buy the product. (Anderson 2008)

2.2 Concurrent Engineering

“Throw over the wall” effect can be caused either by schedule oriented design process, lack of systematic DFMA work or cultural fact, “we are designing the product, DFMA is the supplier’s problem”. Here we come to another very important thing; Concurrent Engineering. Concurrent Engineering is the proactive practice of designing products to be built in standard processes, or concurrently developing new processes while concurrently developing new products. If existing processes are to be utilized, then the product must be designed for the processes. If new processes are to be utilized, then the product and the process must be developed concurrently. This requires a lot of knowledge about manufacturing processes and one of the best ways of doing so is to develop products in multifunctional teams. The most critical factor in the success of Concurrent Engineering is the availability of resources to form multifunctional teams with all specialties present and active early. (Anderson 2008)

I would like to open this Concurrent Engineering a little bit more. When we talk about Concurrent Engineering at a single part design level, we can either design the part for existing technology, e.g. a plastic part for injection molding, just following the design guidelines and having a discussion with the part supplier. In this case the DFM and Concurrent Engineering would be at the simplest level. Or we can design the part and develop the new a technology to make the part. In this case Design House and Part supplier work together as a team; concurrently. Still we can only say that DFM is done concurrently, not yet DFA. When we go into a more wider perspective, not just designing a part, but designing a product, we need a more wider range of expertise, e.g. in a handset we need: mechanics designers, PWB layout designers, RF designers, audio designers, HW designers, industrial designers, marketing, management, graphical designers, etc, all this from a design house and when we go further we need tool designers from part suppliers, production engineers and operators, preproduction, etc. When all of them are working together as a team, we can speak about high level Concurrent Engineering.

During the interviews the engineers often mentioned co-operation, co-operation with part suppliers and material suppliers. The engineers seem to know and understand DFM and the importance of DFM. Often, when they were asked to describe DFMA, they were actually describing DFM, which, in my opinion, is only a half of DFMA. Also our customer highlighted this issue, they have had situations when they have arranged DFA training for their part suppliers and they have asked part suppliers to describe DFA, part suppliers have actually described DFM issues. In the interviews the engineers often were also talking about concurrent engineering inside the design house, many times concurrent engineering was limited in the design house and did not reach the part suppliers or other partners.

2.3 DFX Design for Everything

Engineers are trained to design for functionality and their CAD tool predominantly designs for functionality. However, really good product development comes from designing for everything, which is sometimes called DFX. Here is a list of design considerations for Design for Everything. The key here is to consider all goals & constrains at the early stage of the PD process.

Function. Of course the product has to work properly, but it must be kept in mind that, although, function is the most obvious consideration, it is far from being the only one.

Cost. Cost has been the battlefield of competition for decades now. Design determines more than three fourths of cost of a product.

Delivery. Delivery is greatly affected by the product design, because the design determines how difficult it is to build and assemble. The choice and the design of parts determine how hard it is to produce the parts and how vulnerable production is when supplying glitches. Standardization and staying within well-known materials and technologies affect the effectiveness of lean production, which is the key of a fast factory throughput.

Quality and reliability. Like cost, quality and reliability are determined more by design than is commonly realized. Designers specify the parts and, thus, the quality of the parts. Designers determine the number of parts and this way determine the cumulative effect of part quality on product quality, which is especially important for complex products. Designers are responsible for tolerance sensitivity. The processes specified by designers determine the inherent quality of the parts. Designers are responsible for ensuring that parts are designed so that they cannot be assembled wrong, which in Japan is called poka-yoke, or what we would call mistake-proofing. These are very much DFM issues since quality problems must be consistently corrected at plants before products can be shipped.

Ease of assembly. Ease of assembly is one of the main targets of DFMA, and also one of the main focus areas of this research. There is a method developed by Boothroyd and Dewhurst; Boothroyd and Dewhurst DFM methods, 1983. Also software to analyze designs to look for opportunities to improve the assembly of high volume products. More about this later in chapter 3.3.

Ability to test. Test strategy is very much affected by the company quality “culture”. In companies with good quality culture, quality is everyone’s responsibility, including designers. The TQM (Total Quality management) philosophy is that, instead of being tested in, quality should be designed in and then built in by using process controls. Theoretically, products need not to be tested if all processes are 100% in control. However, few factories are that confident and in real life designers are responsible for devising ways of not only testing products but, also diagnosing them if needed by the factory. As to complex products, test development costs can exceed product development costs and even take more calendar time.

Ease of service and repair. Being able to repair a defective product is a DFMA issue because any product failing any test will have to be repaired, thus consuming valuable manufacturing resources. Service and repair in the field can be more troublesome because field service centers usually have less sophisticated equipment than factories. In extreme cases, field failures may be sent back to the factory for repair, thus diluting manufacturing recourses.

Supply Chain management. Supply chain management can be greatly simplified by the standardization of parts and raw materials, by part selection based on adequate availability over time, and by product line rationalization to eliminate or outsource the, low volume, unusual products that have the most unusual parts. In many cases, this simplification, performed in product portfolio planning and product development, is essential to the success of supply chain management initiatives as well as programs to implement lean production, build-to-order, and mass customization.

Shipping and distribution. The distribution of products will be revolutionized by build-to-order, which is capable of building products on-demand and shipping them directly to customers, stores, or other factories instead of the mass production tradition of building huge batches and then shipping them through warehouses and distribution centers. Packaging considerations should not be left a side until the first manufactured product reaches the shipping dock. Packaging variety and its logistics can be reduced with standard packaging that can be used for many products. Unique information can be added by printing on-demand labels or directly onto the boxes. Environmentally friendly packaging materials and recycled packages are now becoming more important.

Human factors. Human factors and ergonomics are social considerations that should be considered in the very beginning, since ergonomic changes would be difficult to implement after the design has been complete. Good human factors in the design of a product and a process will reduce errors and accidents in use and during manufacture. In some industries e.g. the electronics industry, many service calls are made to correct customer setup and operation errors.

Appearance and style. Appearance and style should be considered an integral part of the design, not something that is added later. Sometimes, the style dictated by an early industrial design study. This can really hamper incorporating DFMA principles if these were not considered in the "styling" design. All factors of design, including styling, need to be considered simultaneously throughout the design.

Safety. Safety should not be considered after the recall of the first law suit. Careful design and simulation should be utilized to prevent safety problems before they would manifest. If a safety issue appears, the root of the problem must be determined and remedied immediately. This can be a major disruption to Engineering, Manufacturing, and Sales, in addition to jeopardizing the reputation of the product and the company. Designers should make all they can to design safe products from the start as their moral and legal obligation.

Customer's needs. The ultimate goal in designing a product is to meet the needs of the customer. In order to do that, designers must thoroughly identify and understand customer needs and then systematically develop the product to meet those needs. Engineers must be beware of the "next bench syndrome" and avoid designing products for themselves or their peers.

Breadth of product line. When the principles of lean production and build-to-order are used, products can be designed with standard parts and produced on flexible manufacturing lines or cells. Common parts, standard design features, modular subassemblies, and flexible manufacturing can be combined to satisfy more customers.

Product customization. Customized products can be built as quickly and efficiently as in mass production if products and processes are designed for mass customization.

Time-to-market. Time-to-market is a major source of competitive advantage. In fast moving markets, being the first to the market can be a major market share implication.

Expansion and upgrading. Designers should design their products so that they are easy to expand or upgrade by the plant or by the customer. This possibility may allow the company to increase profits by extending the lifetime of each product. Marketing and finance representatives should be involved at an early stage to help formulate the product upgrading strategy and calculate its value.

Future designs. Similarly, current products should be designed so that subsequent products can be based largely on current designs. This would save much time and cost in the next design if the maximum use can be reached by employing current engineering, parts, modules, and software.

Product pollution. Environmental design considerations should not be left aside when a product or its process is fired up for the first time. Problems discovered at this stage may require major changes or a redesign to be corrected. Designers should anticipate environmental trends and design products clean enough for future environmental standards.

Processing pollution. Product designers specify the process whether they realize it or not. Even if a usual process is specified, it may continue with a process causing pollution from solvents, combustion products, chemical waist, and so forth. Designers of new products have the opportunity of optimizingg the environmental cleanliness of processes. This is much easier to do at the early stages of design than later. Do not wait until environmental activists or a regulatory agency force your company to change your processes, which would result in disruptive changes in the factory, costly penalties, engineering change orders, and maybe a product redesign.

3M Corporation formulated an environmental strategy called the 3P program: “Pollution Prevention Pays”. The theme is prevention of pollution at its source. The three elements of the program are: 1 Recycling, 2 Redesign products and equipment for less pollution and 3 Create products that do not pollute in the first place.

Note that two out of three methods depend on the design to reduce pollution.

Ease of recycling the products. Similarly, companies should be concerned about what happens to the product after its useful lifetime is over. Can it be recycled into a new product? Can it be upgraded for extended lifetime?

All these DFXs should be emphasized early enough by product development teams since redesigns or major product design changes consume a great deal of design and manufacturing resources to implement the changes. Remember that changes and redesigns consume the engineering time and money that should be invested in new product development.

3 OUTCOME

One of the main targets of this research was to develop, as an outcome, guidelines, checklists, etc. documents to ease DFMA design work and documentation of mechanics engineers. During the interviews the engineers got an opportunity to share their ideas and thoughts for future documents and processes. DFMA Guideline for Mechanics (appendix 3) includes three appendixes: DFMA Appendix 1 Assembly Check List, DFMA Appendix 2 Part Design Check List and DFMA Analyze Template were developed to serve four purposes. First to work as a short introduction into DFMA issues. Secondly to help Mechanics Engineers during a product development process to design and to optimize the product design for manufacturability and assembly. Thirdly, finalized documents DFMA Appendix 1 Assembly Check List, DFMA Appendix 2 Part Design Check List are part of the Product Development process documentation. Fourthly, DFMA Analyze template (appendix 3) is used to evaluate, compare and develop a certain assembly or product and collect data for DFMA metrics.

3.1 DFMA Guideline for Mechanics

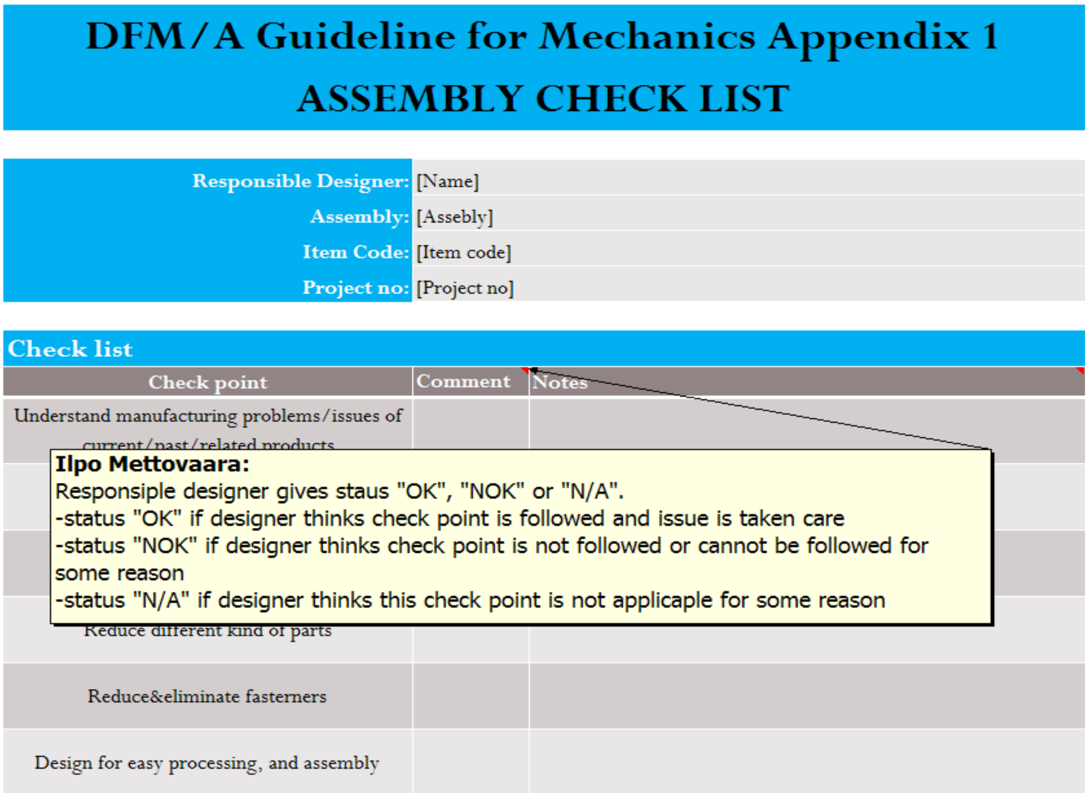
DFMA Guideline for Mechanics document (appendix 3) works as a short introduction into DFMA issues, this is something that especially young engineers need. To help mechanics engineer during the product development process to design and to optimize the product design for manufacturability and assembly. In the document there is shortly explained what DFMA is and what it is not. In the document there are key principles of DFMA and the generic guidelines of DFMA for a product development process. Short and simple examples, how you can optimize the design from the point of view of DFMA. The document also includes chapters for the different phases of the PD process. What should be considered in the concept/architecture phase? What should be considered in product design, integration and verification phases? Type approval and certification phase? Volume production phase?

The DFMA Guideline for Mechanics document including current and coming appendixes is authored, reviewed and updated every year under HW Recourse and Capability Management.

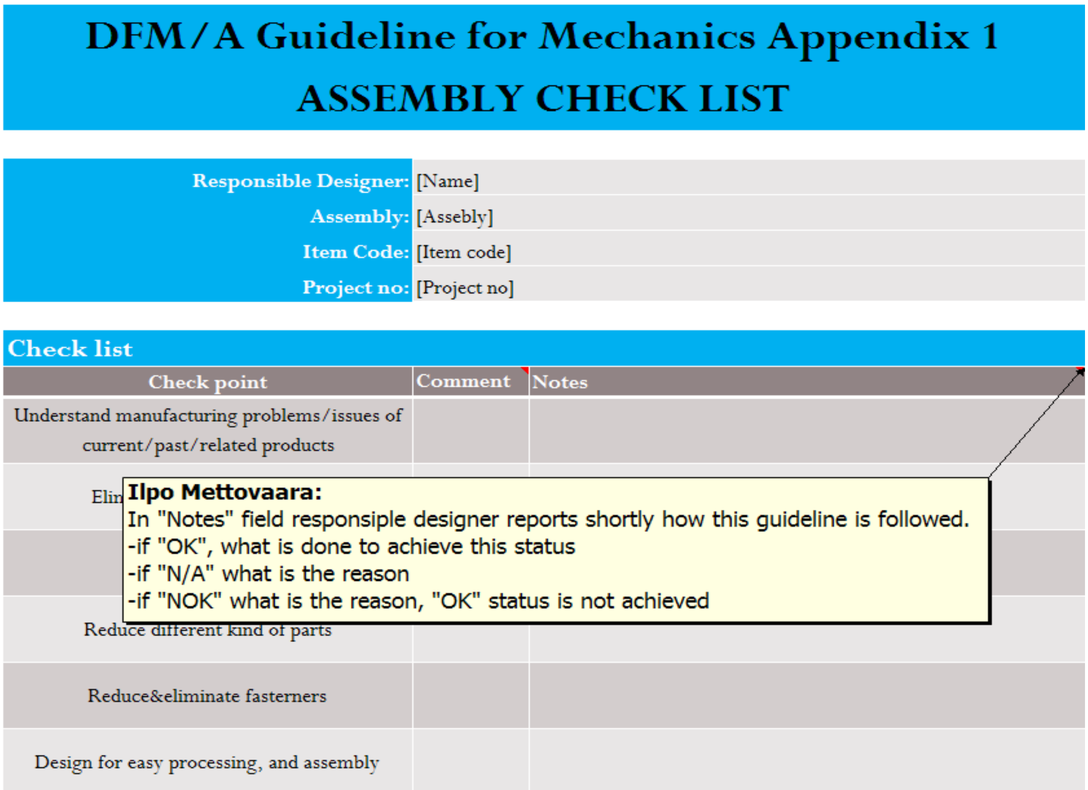
3.2 DFMA Check Lists

As part of the DFMA Guideline for Mechanics, there are DFMA Appendix 1 Assembly Check List and DFMA Appendix 2 Part Design Check List documents which were developed to work as check lists for mechanics designers during the PD process, to give some very practical check points, in the question form, not to control too tightly the design but more likely to work as an inspiration to the right direction.

These check lists also work as documents from the DFMA work done. In the check list a responsible designer gives comments OK, NOK or N/A based on how the designer sees the current check point is fulfilled. The designer also gives short comments on every check point, how the OK stage is exceeded or why some check point is in NOK or N/A stage. (pictures 1 and 2)



PICTURE 1



PICTURE 2

3.3 DFMA Analysis

The DFMA Analysis template document (appendix 4) is used to evaluate, compare and develop a certain assembly or product and collect data for DFMA metrics and lessons learned documentation. A short description of the document and instructions for it are located on the cover page of the document. (picture 3)

Description:
This DFMA analysis is based on Bootroy's and Dewhurst's DFMA Analyse theory. Theory offers eight rules or guidelines which are important during design of assembly.
1. Reduce part count and variations of parts
2. Attempt to eliminate adjustments
3. Design self-aligning and self-locating parts
4. Ensure easy access and unrestrivted vision
5. Ensure ease of handling parts from bulk, tray etc.
6. Minimize the need of re-orientations during assembly
7. Design parts that cannot be installed incorretly
8. Maximize part symmetry if possible or make parts obviosly asymmetrical

Instructions:
Analysis is given at architecture or concept phase of the PD process. Early before detailt product design phase begins. Analysis can be given also to a redy made product.
1. Obtain all the possible information about the product, assembly or part from 3D models, drawings, samples etc.
2. Disassemle the product or assembly, or imagine, and assign an identification number to each item as it is remowed.
3. Begin to reassemble the product begining whit the highest identification number and add remaining parts one-by-one.
-Complete one row of the DFMA worksheet for each part
-Newer assume that parts are grasped one in each hand and the assembled together before placing them in a partically-completed assembly
4. Gave an estimation of theoretical number of parts
5. Complete DFMA worksheet , computing total assembly time, cost and design effiency.
6. Go trough the design and try to find ways to improwe the design efficiency.
7. Complete the DFMA worksheet , computing the total assembly time, cost and design effiency for the new assembly.

PICTURE 3

On the summary page there is the a field (picture 4) including all the important numerical information needed to evaluate and to compare one assembly with another. This information is used to support decision making, and to collect numerical information. The idea is to minimize the number of parts and subassemblies in the main assembly, in this way to minimize assembly and operating time and operating costs.

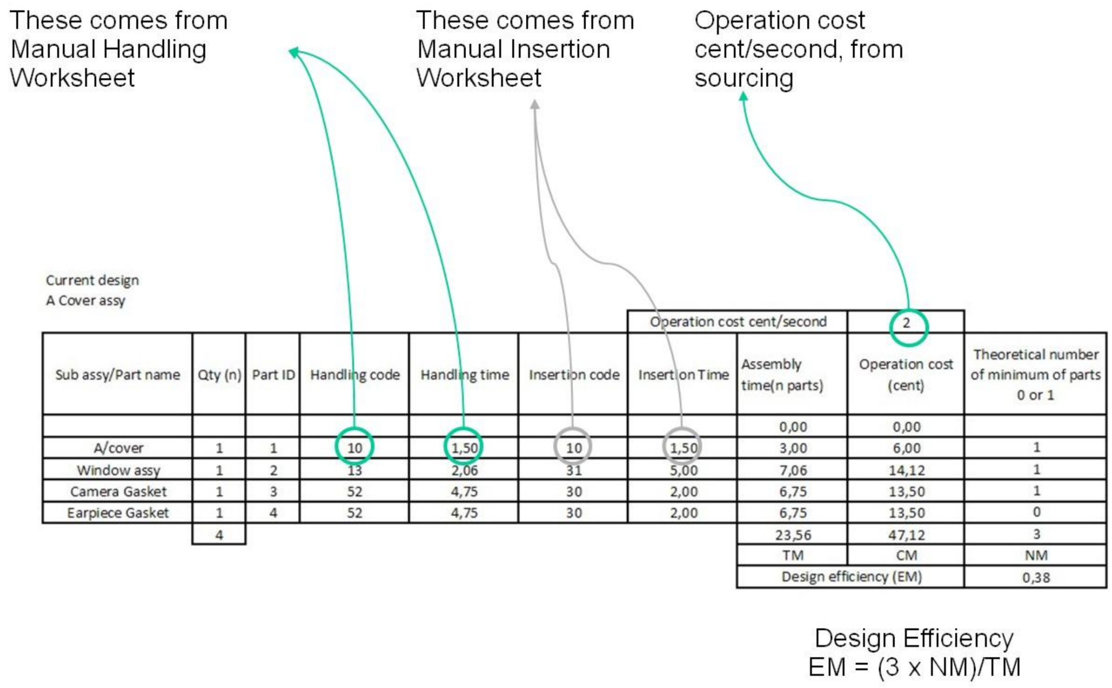
Project number / Name 770002
Assembly A Cover Assembly
Date 2.12.2009

	Number of parts	Assembly time (seconds)	Operatin costs (cents)	Design efficiency
Current design	4	23,56	47,12	0,38
Proposal	3	16,81	33,62	0,54
Change	1	6,75	13,5	0,15
Change %	25,0	28,7	28,7	28,7

Convert to milliminutes

PICTURE 4

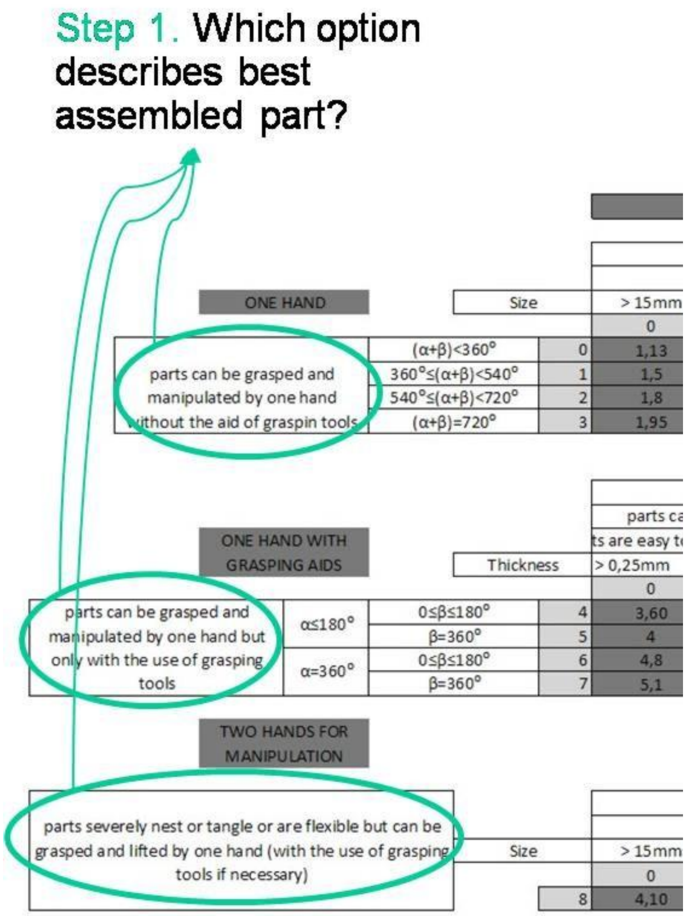
On the analysis page (picture 5) all parts and/or subassemblies are listed and identified with Part ID. Handling code and Handling time are generated from Manual Handling Worksheet in five steps. The operation cost/second information is fed into the Analysis worksheet. The Analysis Worksheet counts the assembly time (n parts), operation cost, total assembly time (TM) and total operation cost (CM).



						Operation cost cent/second		2	
Sub assy/Part name	Qty (n)	Part ID	Handling code	Handling time	Insertion code	Insertion Time	Assembly time(n parts)	Operation cost (cent)	Theoretical number of minimum of parts 0 or 1
							0,00	0,00	
A/cover	1	1	10	1,50	10	1,50	3,00	6,00	1
Window assy	1	2	13	2,06	31	5,00	7,06	14,12	1
Camera Gasket	1	3	52	4,75	30	2,00	6,75	13,50	1
Earpiece Gasket	1	4	52	4,75	30	2,00	6,75	13,50	0
	4						23,56	47,12	3
							TM	CM	NM
							Design efficiency (EM)		0,38

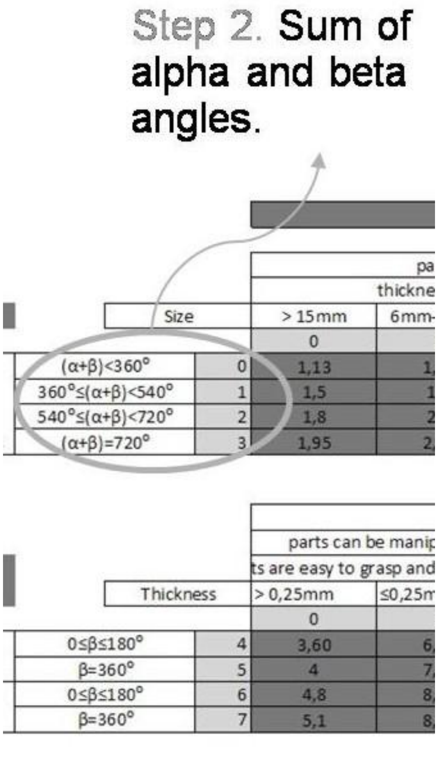
PICTURE 5

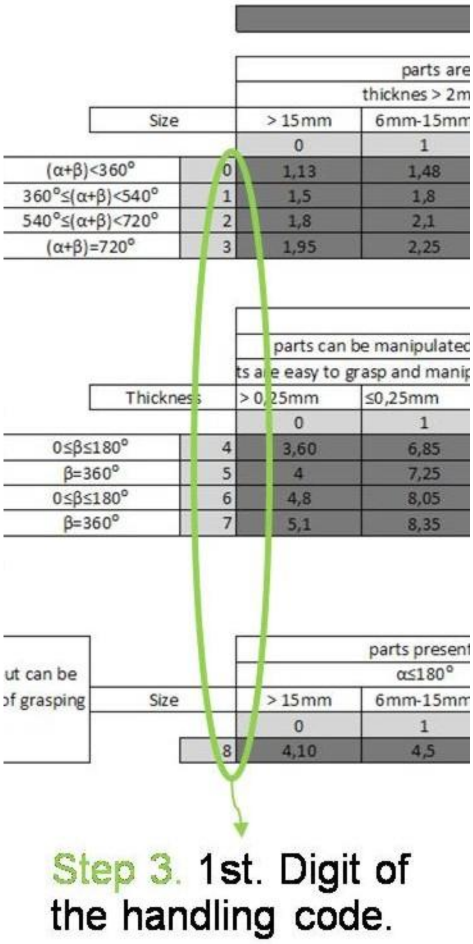
In the first step you need to pick up an option which describes best assembled part. (picture 6).



PICTURE 6

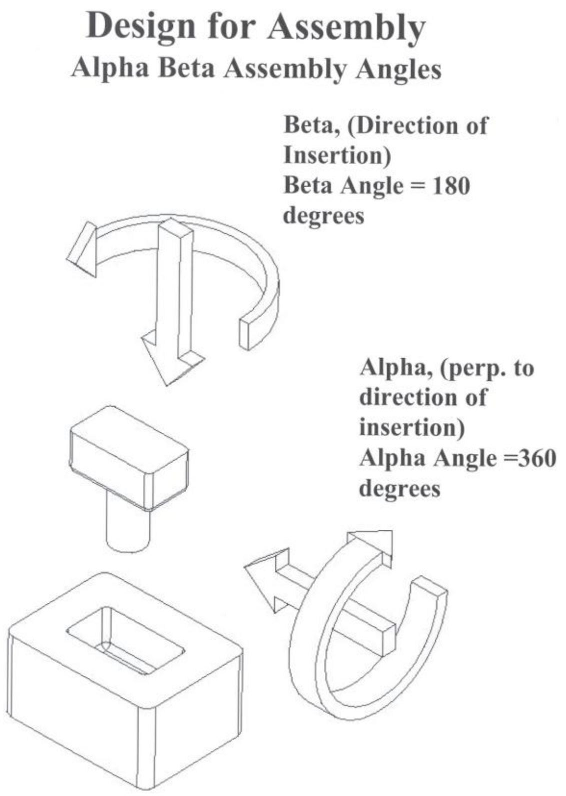
In the second step the sum of Alpha and Beta angles are counted and picked up from the Manual Handling Worksheet. (picture 7) In the third step you get the first digit of handling code. (picture 8)





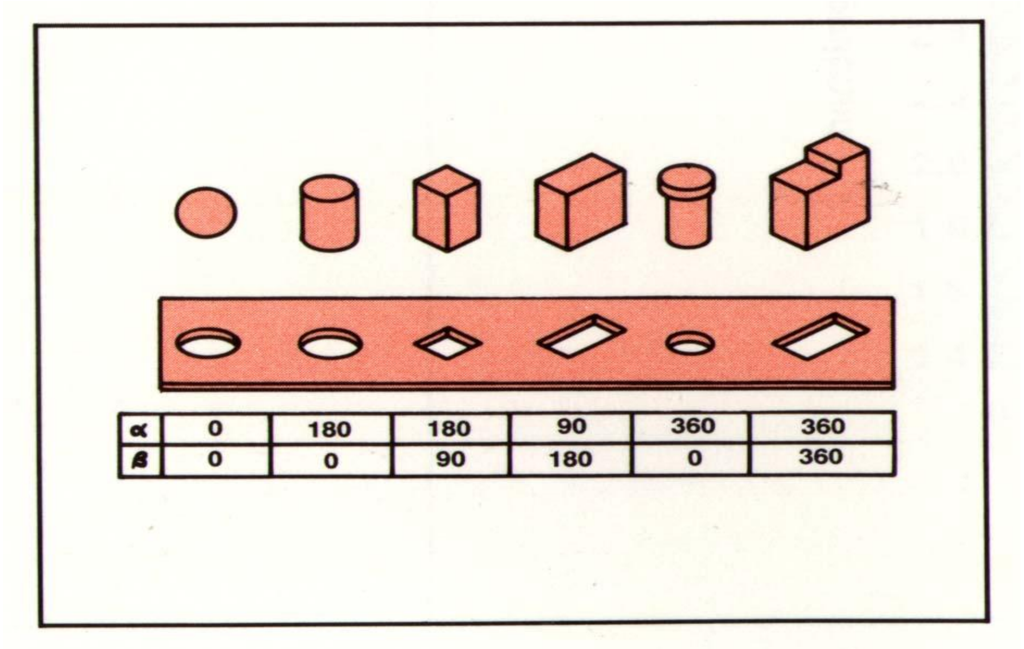
PICTURE 7 *PICTURE 8*

The theory of the Alpha and Beta angles can be found from Help of the DFMA Analysis Template. In the theory there are two part symmetries. Primary alpha symmetry: Rotational symmetry perpendicular to the axis of insertion, and Beta symmetry: Rotational symmetry about the axis of insertion. Pictures 9 and 10 explain the part symmetry of alpha and beta.



PICTURE 9

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

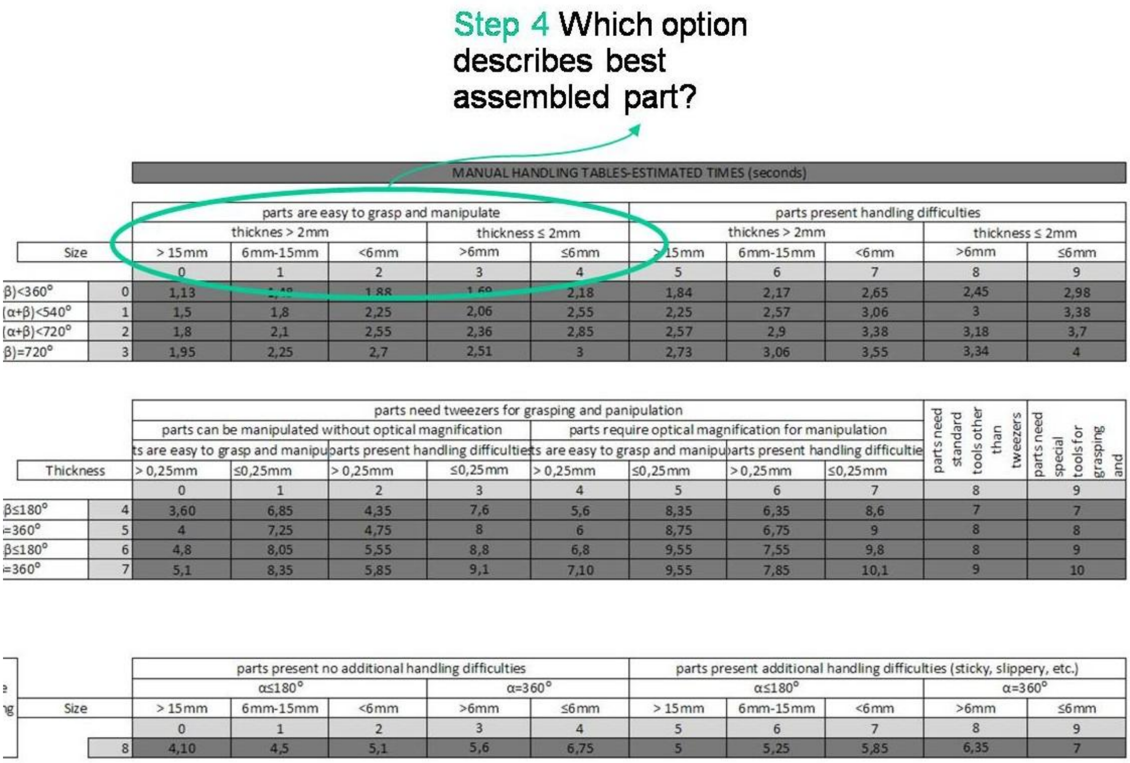


α	0	180	180	90	360	360
β	0	0	90	180	0	360

PICTURE 10

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

In the fourth step you pick up an option that describes the best assembled part. (picture 11)



MANUAL HANDLING TABLES-ESTIMATED TIMES (seconds)

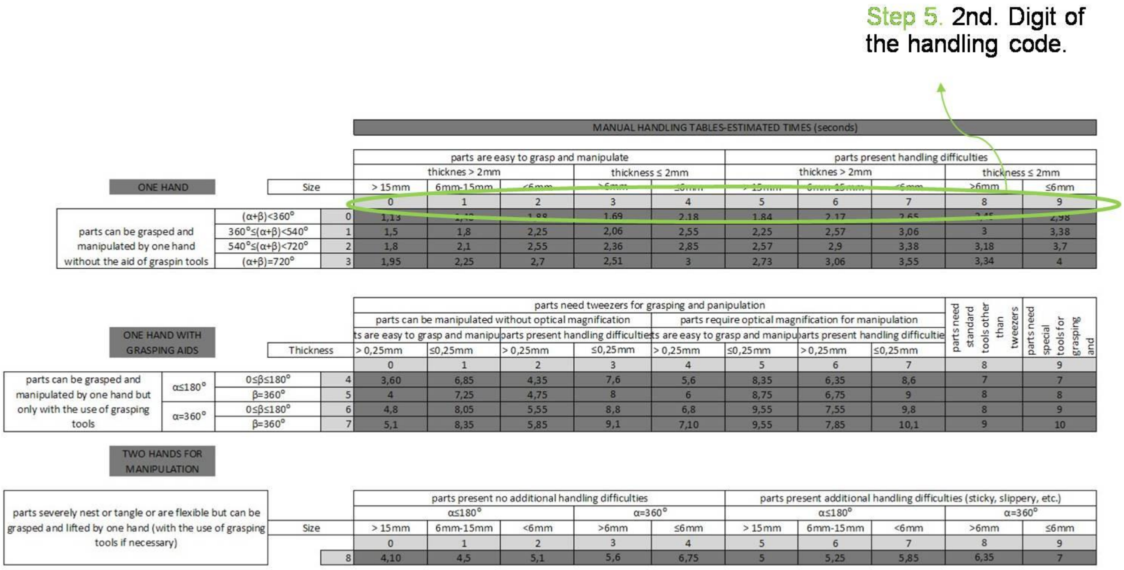
		parts are easy to grasp and manipulate					parts present handling difficulties				
		thicknes > 2mm			thickness ≤ 2mm		thicknes > 2mm			thickness ≤ 2mm	
Size		> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
		0	1	2	3	4	5	6	7	8	9
β)<360°	0	1,13	[illegible]	1,88	[illegible]	2,18	1,84	2,17	2,65	2,45	2,98
(α+β)<540°	1	1,5	1,8	2,25	2,06	2,55	2,25	2,57	3,06	3	3,38
(α+β)<720°	2	1,8	2,1	2,55	2,36	2,85	2,57	2,9	3,38	3,18	3,7
β)=720°	3	1,95	2,25	2,7	2,51	3	2,73	3,06	3,55	3,34	4

		parts need tweezers for grasping and panipulation								parts need standard tools other than tweezers	parts need special tools for grasping and
		parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
		ts are easy to grasp and manipu		parts present handling difficulties		ts are easy to grasp and manipu		parts present handling difficultie			
Thickness		> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm		
		0	1	2	3	4	5	6	7	8	9
β≤180°	4	3,60	6,85	4,35	7,6	5,6	8,35	6,35	8,6	7	7
=360°	5	4	7,25	4,75	8	6	8,75	6,75	9	8	8
β≤180°	6	4,8	8,05	5,55	8,8	6,8	9,55	7,55	9,8	8	9
=360°	7	5,1	8,35	5,85	9,1	7,10	9,55	7,85	10,1	9	10

		parts present no additional handling difficulties					parts present additional handling difficulties (sticky, slippery, etc.)				
		α≤180°			α=360°		α≤180°			α=360°	
Size		> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
		0	1	2	3	4	5	6	7	8	9
	8	4,10	4,5	5,1	5,6	6,75	5	5,25	5,85	6,35	7

PICTURE 11

In the fifth step you get the second digit of the handling code. (picture 12)



MANUAL HANDLING TABLES-ESTIMATED TIMES (seconds)

ONE HAND		Size	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
			parts are easy to grasp and manipulate: thicknes > 2mm			thickness ≤ 2mm		parts present handling difficulties: thicknes > 2mm			thickness ≤ 2mm	
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of graspin tools	(α+β)<360°	0	1,13	[illegible]	1,88	1,69	2,18	1,84	2,17	2,65	[illegible]	2,98
	360°≤(α+β)<540°	1	1,5	1,8	2,25	2,06	2,55	2,25	2,57	3,06	3	3,38
	540°≤(α+β)<720°	2	1,8	2,1	2,55	2,36	2,85	2,57	2,9	3,38	3,18	3,7
	(α+β)=720°	3	1,95	2,25	2,7	2,51	3	2,73	3,06	3,55	3,34	4

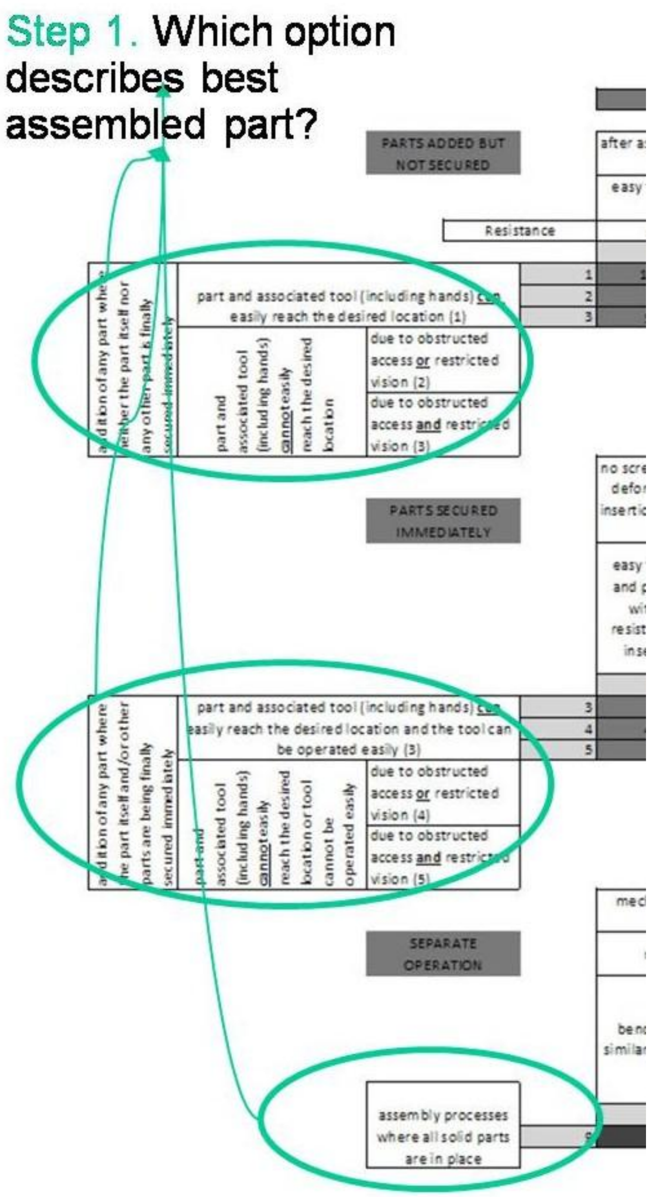
ONE HAND WITH GRASPING AIDS				parts need tweezers for grasping and panipulation								parts need standard tools other than tweezers	parts need special tools for grasping and
				parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
				ts are easy to grasp and manipu		parts present handling difficultie		ts are easy to grasp and manipu		arts present handling difficultie			
		Thickness		> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm		
				0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand but only with the use of grasping tools	α≤180°	0≤β≤180°	4	3,60	6,85	4,35	7,6	5,6	8,35	6,35	8,6	7	7
		β=360°	5	4	7,25	4,75	8	6	8,75	6,75	9	8	8
	α=360°	0≤β≤180°	6	4,8	8,05	5,55	8,8	6,8	9,55	7,55	9,8	8	9
		β=360°	7	5,1	8,35	5,85	9,1	7,10	9,55	7,85	10,1	9	10

TWO HANDS FOR MANIPULATION

parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary)		parts present no additional handling difficulties					parts present additional handling difficulties (sticky, slippery, etc.)				
		α≤180°			α=360°		α≤180°			α=360°	
	Size	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
		0	1	2	3	4	5	6	7	8	9
	8	4,10	4,5	5,1	5,6	6,75	5	5,25	5,85	6,35	7

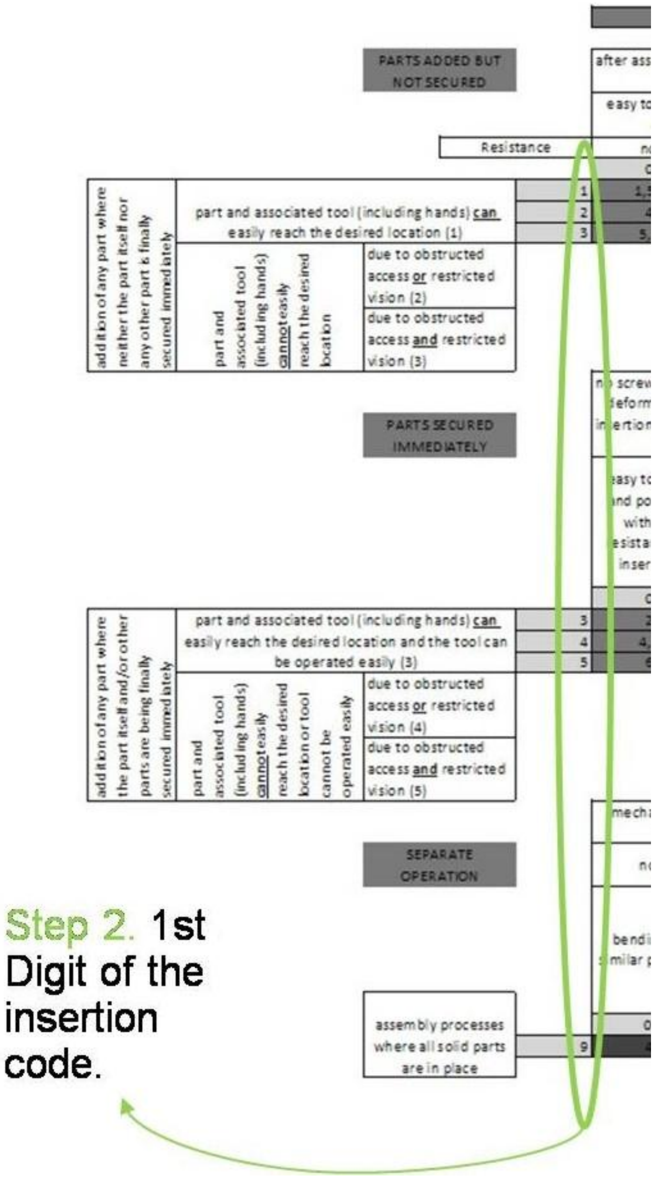
PICTURE 12

Insertion code and insertion time are generated from Manual Insertion Worksheet in four steps. In the first step (picture 13) you need to pick up the option which describes the best assembled part.



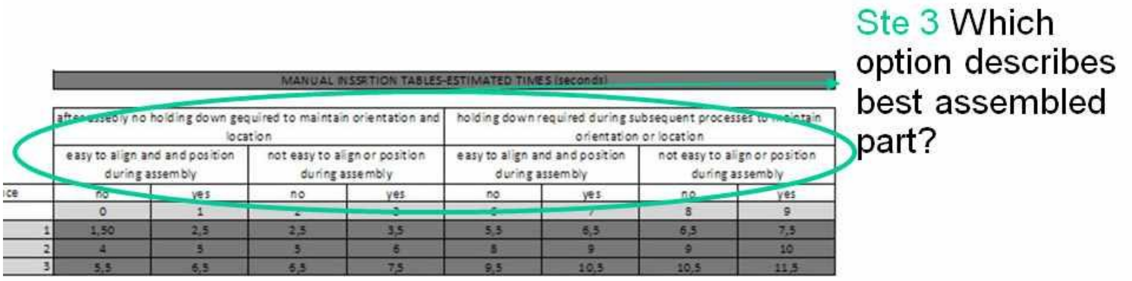
PICTURE 13

In the second step (picture 14) you get the first digit of the insertion code.



PICTURE 14

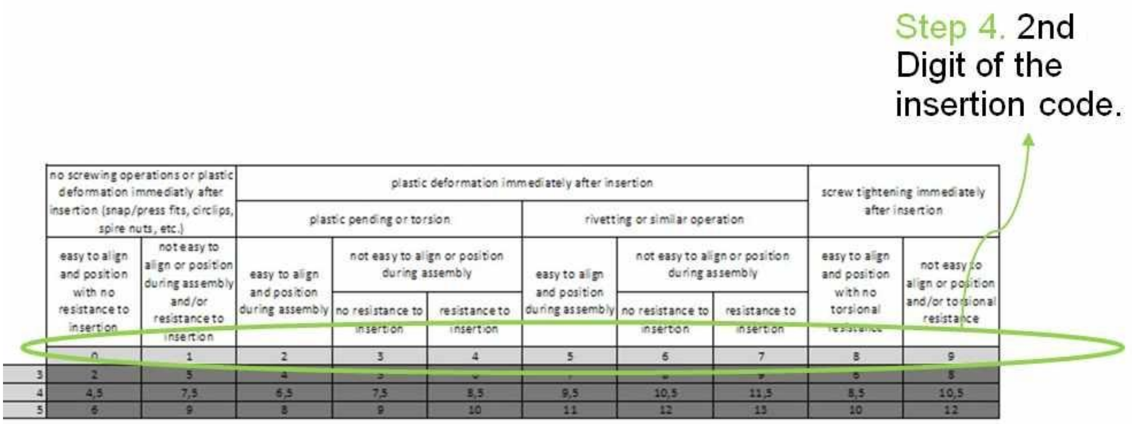
In the third step (picture 15) you need to pick the option which best describes the assembled part.



MANUAL INSSRTION TABLES-ESTIMATED TIMES (seconds)									
	after assebly no holding down gequired to maintain orientation and location				holding down required during subsequent processes to maintain orientation or location				
	easy to align and and position during assembly		not easy to align or position during assembly		easy to align and and position during assembly		not easy to align or position during assembly	
ice	no	yes	no	yes	no	yes	no	yes
	0	1	[illegible]	[illegible]	[illegible]	[illegible]	8	9
1	1,50	2,5	2,5	3,5	5,5	6,5	6,5	7,5
2	4	5	5	6	8	9	9	10
3	5,5	6,5	6,5	7,5	9,5	10,5	10,5	11,5

PICTURE 15

In the fourth step (picture 16) you get the second digit of the insertion code.



	no screwing operations or plastic deformation immediatly after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion	
			plastic pending or torsion			rivetting or similar operation				
	easy to align and position with no resistance to insertion	not easy to align or position during assembly and/or resistance to insertion	easy to align and position during assembly	not easy to align or position during assembly		easy to align and position during assembly	not easy to align or position during assembly		easy to align and position with no torsional resistance	not easy to align or position and/or torsional resistance
				no resistance to insertion	resistance to insertion		no resistance to insertion	resistance to insertion		
	0	1	2	3	4	5	6	7	8	9
3	2	5	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6	8
4	4,5	7,5	6,5	7,5	8,5	9,5	10,5	11,5	8,5	10,5
5	6	9	8	9	10	11	12	13	10	12

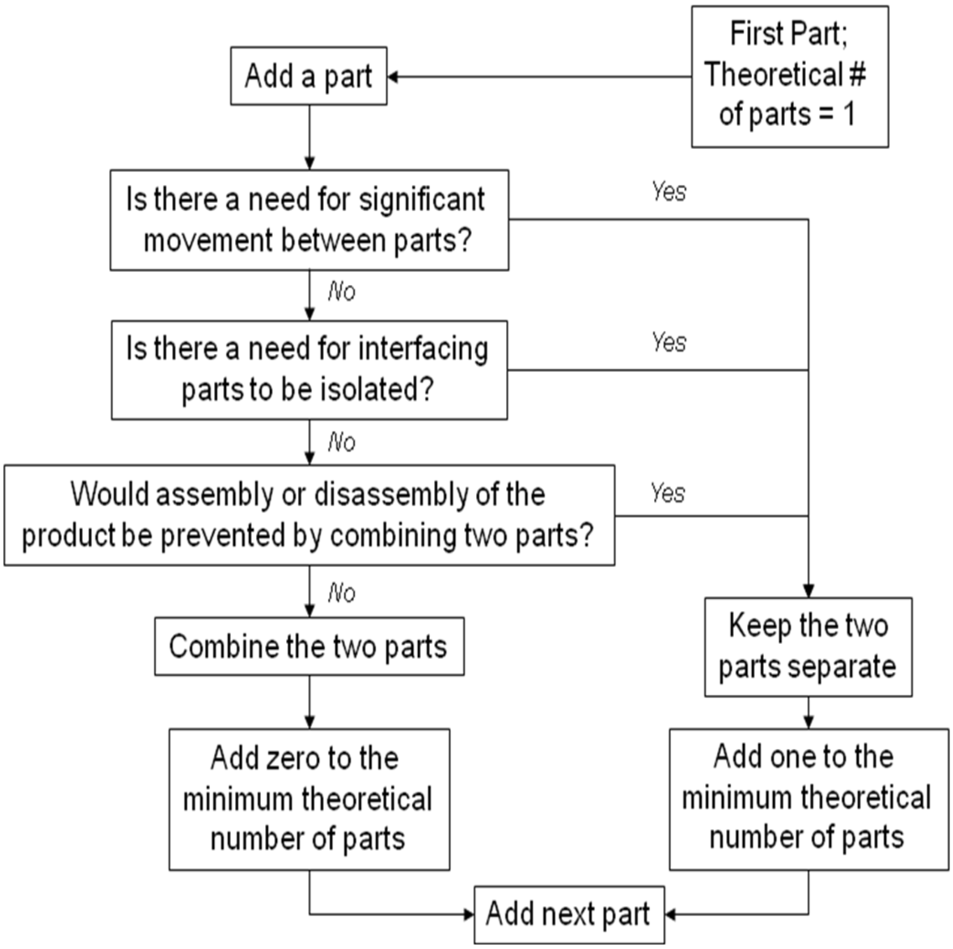
PICTURE 16

Now you have the first and the second digits of the handling code and the first and the second digits of the insertion code, you can get the estimated theoretical handling and insertion times for the part or assembly. Now you need to insert these times in DFMA Analysis worksheet (picture 5). Next you need to get operation cost cent/second information. This information can be provided by the sourcing organization. With this information you can actually convert the design change proposals into Euros. The theoretical number of the minimum of parts is a theory which handles the single part or subassembly by three questions. If any of these three questions is answered "yes", you should keep the parts independent, separated parts. If all the questions are answered "no", you should combine the parts with the others (picture 17). The engineering solution of course in real life is not this straight and simple. We need to keep in mind that this is a theoretical and very simplified solution to minimize the number of parts. In real life you need to compromise.

1. Does the part have to be moved in relation to the rest of the assembly?

2. Must the part be made of a different material from the rest of the assembly for fundamentally physical reasons?

3. Does the part have to be separated from the assembly for assembly access, replacement or repair?



PICTURE 17

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

3.4 DFMA Lecture

One of the outcomes of this research was to have a lecture for our mechanical engineers about DFMA issues. I also had to introduce the DFMA Guideline for mechanics document, DFMA checklists and DFMA Analysis documents and how DFM issues are joined in our PD process. I created the lecture material (appendix 4), arranged and gave the lecture to our engineers. With the same content I had a second round of interviews to track how the DFMA knowledge was increased during the process and how the engineers thought about the outcomes of this research. At the same time I introduced my Master Thesis to our mechanical engineers.

4 CONCLUSION

This research and development was done under our company's HW capability & resource development. At the very beginning of this research one of the main objectives was to create a DFMA process, required by one of our main customers. They were developing their own DFM capabilities and competencies and were also setting requirements for suppliers. The customer was especially interested in the question: At what level our DFM competences were, and whether we had systematic processes and tools to implement the DFM theory in design work.

The outcomes of this thesis with Sasken Finland are as follows:

Got understanding of the level of DFMA capabilities and competencies among mechanics engineers

Improved the knowledge level of DFMA issues among mechanics engineers

Found out and introduced a way of joining the DFMA process part of the PD process

Developed guidelines, checklists, etc. tools to ease the DFMA design work and documentation for mechanics engineers

Arranged an internal DFMA course to mechanics engineers, containing use of documents that were created during this development process and how to join DFM issues in our PD process

5 CONTEMPLATION

I can say that in the organization there was an actual need for the subject of this master's thesis. This fact gave me motivation to carry out the thesis work to the very end. The thesis work was done in schedule, but I have to admit that completing the master's report took more time than I had expected. I think that the outcomes match what is defined at the beginning of this thesis work. Yet there are some things which I think should be further developed. For example, the DFMA Analyze template should be transformed into a more usable format, for example, with a more interactive web based tool. I also think that Design check lists should be created more, for example, based on different kinds of production technologies.

I got feedback from the mechanics team mainly after the internal course and it was mainly positive. The engineers felt that this kind of tools would help them in their design work especially at the beginning of their career. With this kind of tools DFMA work is systematic, proven and documented it is not like it was before.

REFERENCES

(1). Boothroyd and Dewhurst, DFM methods 1983

(2). Dr. David M. Andersons, Design for Manufacturability & Concurrent Engineering, 2008

(3). http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

(4). http://www.sasken.fi/company_profile.htm 27 Oct. 2009

APPENDIXES

1. Interview Check List
2. DFMA Guideline for Mechanics
3. DFMA Analysis Template
4. DFMA Analysis Lecture

APPENDIX 1 Interview Check List

Interview Check List

Interviewee: [Name]
Date: [Date]

1st Interview, Survey

Issue	Comment
What is DFM/A?	
Good example of DFM/A?	
Bad example of DFM/A?	
Consequence of good DFM/A?	
Consequence of bad DFM/A?	
Who takes care of the DFM/A?	
How DFM/A shows in our PD process?	
Who is responsible that DFM/A issues are taken care of?	
At which state of the PD process DFM/A issues should be considered?	
Where can you get information/support in DFM/A issues?	
How well do you think DFM/A issues are taken care of in our company?	
Do you think the company should do some corrections?	
Do you think you should do something different?	

Date: [Date]

2nd Interview, Follow-Up

Issue	Comment
What is DFM/A?	
Good example of DFM/A?	
Bad example of DFM/A?	
Consequence of good DFM/A?	
Consequence of bad DFM/A?	
Who takes care of the DFM/A?	
How DFM/A shows in our PD process?	
Who is responsible that DFM/A issues are taken care of?	
At which state of the PD process DFM/A issues should be considered?	
Where can you get information/support in DFM/A issues?	
How well do you think DFM/A issues are taken care of in our company?	
Do you think the company should do some corrections?	
Do you think you should do something different?	

15 April 2009

DFMA Guideline for Mechanics
DFMA Process Development
Ilpo Mettovaara

DFMA Guideline for Mechanics

15 April 2009

DFMA Guideline for Mechanics
DFMA Process Development
Ilpo Mettovaara

Change History:

Version	State	Date	Author	Description
0.1	Draft	28.04.2009	Mikko Keskilammi	Reviewed
0.2	Draft	12.05.2009	Mikko Keskilammi	Reviewed
0.3	Draft	19.08.2009	Mikko Keskilammi	Reviewed
0.4	Draft	15.10.2009	Mikko Keskilammi	Reviewed
1.0		19.11.2010	Ilpo Mettovaara	

15 April 2009

DFMA Guideline for Mechanics
DFMA Process Development
Ilpo Mettovaara

CONTENTS

15 April 2009

DFMA Guideline for Mechanics
DFMA Process Development
Ilpo Mettovaara

1 Purpose of this document

The purpose of this document is to help Mechanics Engineers during the Product Development process to design and to optimize the product design for manufacturability and assembly. The purpose of this document is to act as a short introduction and guideline in DFMA. In the appendix there are several guidelines which act as checklists and documentation of DFMA issues during the whole Product Development process. The final document is part of the Product Development process documentation. DFMA Analysis template (appendix 3) is used to evaluate, compare and develop certain assembly or product and collect data for DFMA metrics.
This document is authored, reviewed and updated every year under HW Recourse and Capability Management.

1.1 DFM/DFA

Design For Manufacturability/Assembly is the theory or process of proactively designing product to: a) optimize all the manufacturing functions: fabrication, assembly test, procurement, shipping, service and repair; b)assure the best cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction; and c) ensure that lack of manufacturability doesn't compromise functionality, styling, new product introductions, product delivery, improvement programs, strategic initiatives and unexpected surges in product demand.

1.2 Key DFM/A Principles

- Do it right first time; you can't afford to do it over. No arbitrary decisions.
- It's everyone's responsibility to consider all the goals and constraints early. Don't throuw it over the wall.
- Define the product well to satisfy the "voice of the customer".
- The most important time-to-market measurement is the time to stable, trouble-free production. No energy and time wasted on firefighting in mass production phase.
- The further into a design, harder it is to start satisfying additional needs. No late engineering changes.
- The most effective way to achieve quality is to design it in and then build it in.
- Cost is designed into the product, especially by early concept decisions, and is difficult to remove later.
- Design to optimize the system, not just many parts that are hard to integrate together. The team should be designing the product concurrently as a team.
- Break down the walls by working together, in multifunctional design teams, all members are expected to jointly design the product.
- Make sure all the specialties are present to confront all the difficult tradeoffs and resolve the issues early.

- Early Vendor involvement, one of the main strengths of Concurrent Engineering is **early** and **active** participation of vendors. Past relationships and proven record of performance.
- Use proven features and modules from previous designs to avoid reinventing the wheel. Use standard parts for New Designs. Optimize the Utilization of Off-the-Shelf Parts. ”Never design a part you can buy out of a catalog”
- Use methodical approaches to specifying tolerances for an optimal balance of performance, cost, quality, and safety.
- Work with other projects to design product families to maximize synergies and avoid duplication of effort.
- Proactively manage product variety by designing for lean production, build-to- order, and mass customization.

1.3 What DFM/A is not

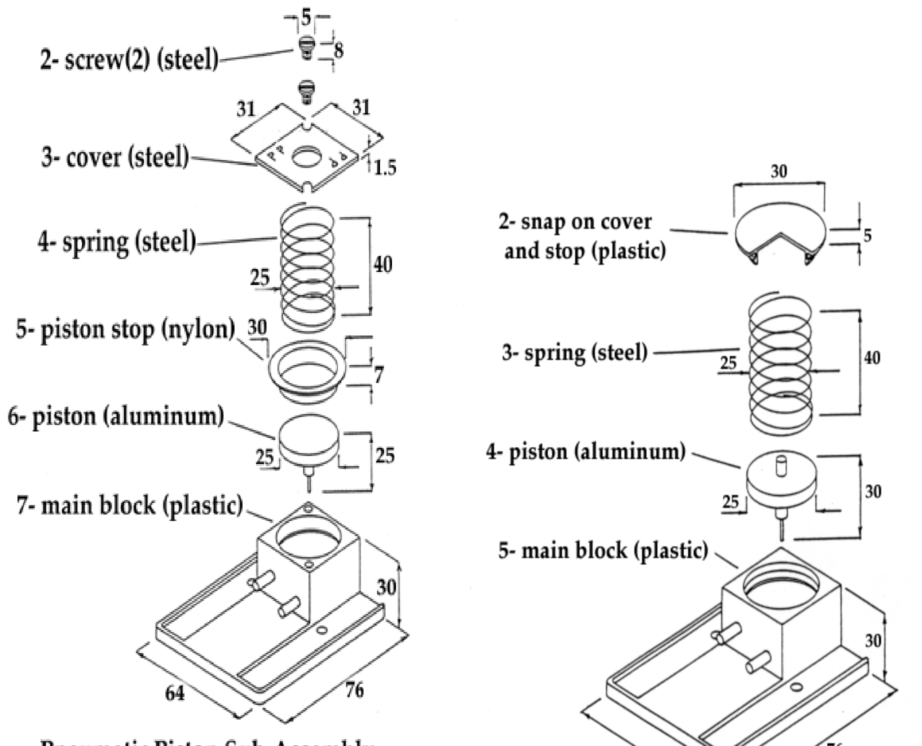
- DFM/A is not a late step that, once checked off, gets you trough a design review or gate
- DFM/A is not done by the "DFM/A Engineer"
- DFM/A is not done by a "tool"
- DFM/A is not just done at the parts level; most opportunities are at the system level
- DFM/A is not an afterthought
- DFM/A is not to be "caught" later in design reviews
- DFM/A is not to be accomplished by changes
- DFM/A is not thrown over the wall to Vendor or production engineers

2 Generic Guidelines

Following list is meant to followed trough during the Product Development process. Following list is generic and should be used together with part/assembly based checklists, shown in appendix of this document.

2.1 Simplify the design and reduce the number of parts

”The best part is the undone part”
Because of each part, there is an opportunity for a defective part an assembly error. As the number of parts goes up, the total cost of fabricating and assembling goes up. The designer should go through the assembly part by part and evaluate whether the part can be eliminated, combined with another part, or the function can be performed in another way.



Pneumatic Piston Sub-Assembly
(dimensions in mm)

2.2 Standardize and use common parts and materials

To facilitate design activities, to minimize the amount of inventory in the system, and to standardize handling and assembly operations. Operator learning is simplified and there is a great opportunity for automation. Limit exotic or unique components, materials or processes. Use similar designs and common material.

2.3 Design for ease of fabrication

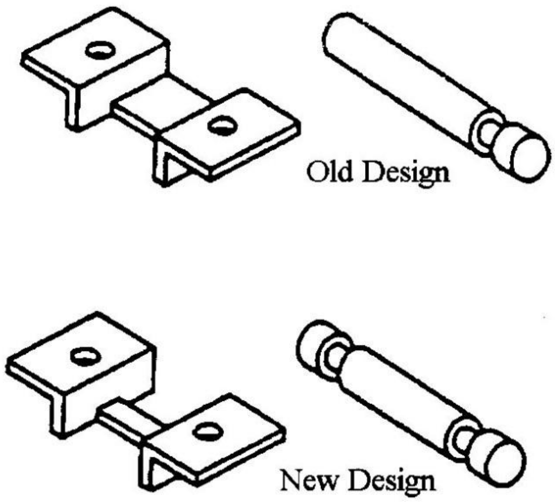
Select process compatible with material and production volumes. Avoid unnecessary part features because they involve extra processing effort and/or more complex tooling. Apply specific guidelines for the fabrication process. Work closely together with part supplier as early as possible.

2.4 Design within process capabilities and avoid unneeded surface finish requirements

Know the production process capabilities of equipment and establish controlled process. Avoid unnecessarily tight tolerances that are beyond the natural capability of the manufacturing processes. Also avoid tight tolerances on multiple, connected parts. Design in the center of a components parameter range to improve reliability and limit the range of variance around the parameter objective. Surface finish requirements likewise may be established based on standard practices and may be applied to interior surfaces resulting in additional costs where these requirements may not be needed.

2.5 Design Mistake-proof product design and assembly (poka-yoke)

So that assembly process in unambiguous. Components should be designed so that they can only be assembled in one way; they cannot be reserved. Notches, asymmetrical holes and stops can be used to mistake-proof proof the assembly process. For mechanics products, verifiability can be achieved with simple go/no go tools. Products should be designed to avoid or simplify adjustment.



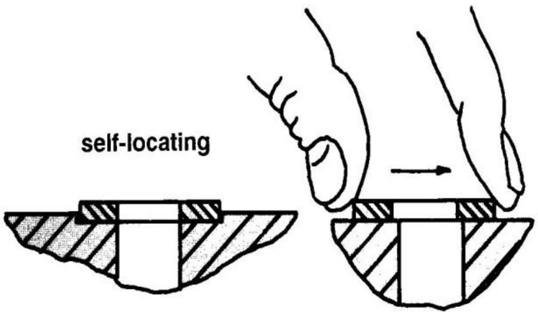
2.6 Design for part orientation and handling

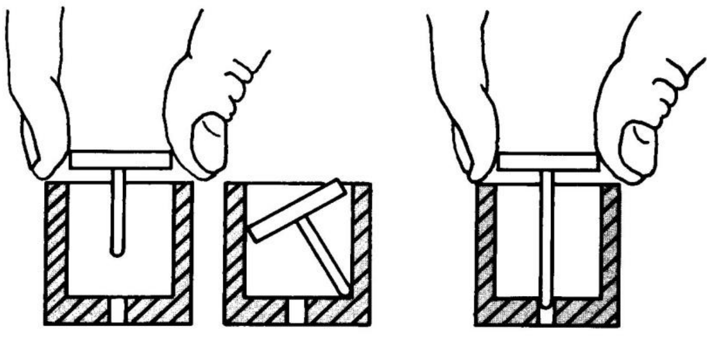
To minimize non-value-added manual effort and ambiguity in orienting and merging parts. Basic principles to facilitate parts handling and orienting are:

- Parts must be designed to consistently orient themselves when fed into a process.
- Product design must avoid parts which can become tangled, wedged or disoriented. Avoid holes and tabs and designed "closed" parts. This type of design will allow the use of automation in parts handling and assembly such as vibratory bowls, tubes, magazines, etc.
- Part design should incorporate symmetry around both axes of insertion wherever possible. Where parts cannot be symmetrical, the asymmetry should be emphasized to assure correct insertion or easily identifiable feature should be provided.
- With hidden features that require a particular orientation, provide an external feature or guide surface to correctly orient the part.
- Guide surfaces should be provided to facilitate insertion.
- Parts should be designed with surfaces so that they can be easily grasped, placed and fixed. Ideally this means flat, parallel surfaces that would allow a

part to picked-up by a person or a gripper with a pick and place robot and then easily fixed.

- Minimize thin, flat parts that are more difficult to pick up. Avoid very small parts that are difficult to pick-up or require a tool such as a tweezers to pick-up. This will increase handling and orientation time.
- Avoid parts with sharp edges, burrs or points. These parts can injure workers or customers, they require more careful handling, they can damage product finishes, and they may be more susceptible to damage themselves if the sharp edge is an intended feature.
- Avoid parts that can be easily damaged or broken.
- Avoid parts that are sticky or slippery (thin oily plates, oily parts, adhesive backed parts, small plastic parts with smooth surfaces, etc.).
- Avoid heavy parts that will increase worker fatigue, increase risk of worker injury, and slow the assembly process.
- Design the work station area to minimize the distance to access and move a part.



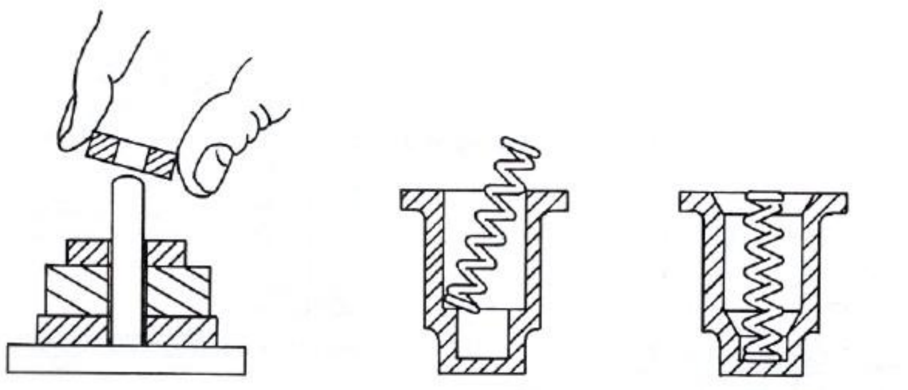


2.7 Minimize flexible parts and interconnections

Avoid flexible and flimsy parts such as belts, gaskets, tubing, cables and wire harnesses. Their flexibility makes material handling and assembly more difficult and these parts are more susceptible to damage.

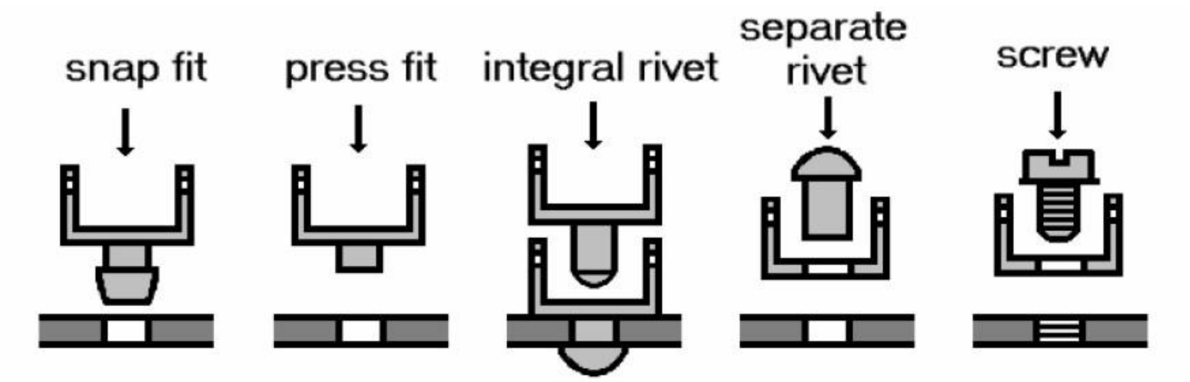
2.8 Design for ease of assembly

By utilizing simple patterns of movement and minimizing the axes of assembly. Complex orientation and assembly movements in various directions should be avoided. Assembly should proceed vertically with other parts added on top and positioned with the aid of gravity.



2.9 Design for efficient joining and fastening

Threaded fasteners (screws, bolts, nuts and washers) are time-consuming to assemble and difficult to automate. Where they must be used, standardize to minimize variety and use fasteners such as self threading screws and captured washers. Consider the use of integral attachment methods (snap-fit). Evaluate other bonding techniques with adhesives. Match fastening techniques to materials, product functional requirements, and disassembly/servicing requirements.



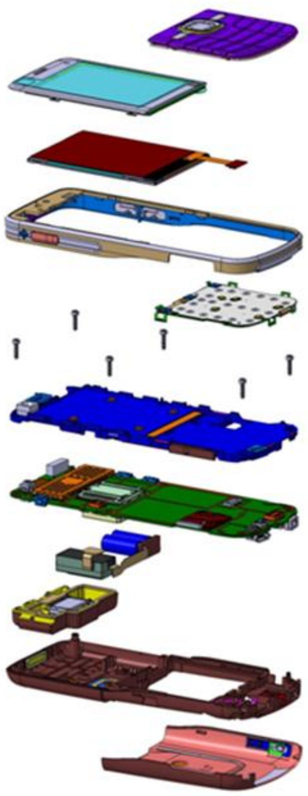
2.10 Design modular products

To facilitate assembly with building block components and subassemblies. This modular or building block design should minimize the number of part or assembly variants early in the manufacturing process while allowing for greater product variation late in the process during final assembly. The short final assembly lead-time can result in a wide variety of products being made to a customer's order in a short period of time without having to stock a significant level of inventory.

Production of standard modules can be leveled and repetitive schedules established.

FA1 Assemblies:
1. UI assembly
2. Front camera gasket
3. Display
4. Screws 6pcs
5. Deck assembly
6. Engine
7. Flash module assembly
8. Audio box assembly
9. B-cover assembly

FA2 Assemblies:
10. Keymat
11. Window assembly
12. A-cover assembly
13. Type Label
14. Battery cover assembly



2.11 Design for automated production

Automated production involves less flexibility than manual production. The product must be designed in a way that can be handled with automation.

2.12 Design printed circuit boards for assembly

Design together with HW designer and PWB lay out designer the coming interfaces between mechanics and PWB.

3 DFM/A through concept/architecture

- Voice of the customer captured and documented
- Lessons learned from previous projects understood with respect to manufacturability, quality and so forth
- Concept simplification at the product/process level
- Architecture optimization for product, product families, processes and supply chain
- All issues raised and resolved early
- Optimal utilization of off-the-shelf parts
- Modular strategy determined early
- Outsourcing/integration strategy optimizes concurrent engineering, manufacturability, cost, quality, and responsiveness
- Strategy is determined for variety, options, customizations, extensions, and derivatives
- DFMA Analysis done and documented

4 DFM/A through product design, integration & Verification

- DFMA Analysis, if not done yet
- The product is designed as a system, not just a collection of parts
- Vendors are on the team early to help design parts for their processes
- Products are designed for existing processes or concurrently designed new processes
- DFM guidelines are obeyed for all relevant processes
- Quality and reliability targets are achieved by design
- Mistake proofing by design
- Robust design ensures optimal tolerances and compatibility with process capabilities
- Arbitrary decisions are avoided by early participation of complete teams and early inclusion of all design considerations
- Standard parts lists are determined and used for new designs
- Parts are selected for quality, availability, and supply chain management optimization
- Cost is computed by total cost measurements
- Time is measured to stable, trouble-free production
- Documentation is complete and unambiguous

5 DFM/A through Type approval & certification

- Assembly and testing of the construction is analyzed
- Actual assembly times of each part or assembly is compared with target values
- Unidentified problems are mapped and improvements in construction details are made.

6 DFM through Volume production phase

- Follow-up and reporting of DFM metrics, MFR and assembly and testing process improvement
- Reviewing and finalizing DFM documentation
- Identifying improvements in construction design, manufacturing, assembly or testing processes.
- Creating DFM part of Project’s Lessons Learned Report

7 APPENDIXES

|1|	Document name:	Assembly Check List
	Storage:	
	Author:	Ilpo Mettovaara
|2|	Document name:	Part Design Check List
	Storage:	
	Author:	Ilpo Mettovaara
|3|	Document name:	DFMA Analysis template
	Storage:	
	Author:	Ilpo Mettovaara

8 REFERENCES

1. Dr. David M. Andersons, Design for Manufacturability & Concurrent Engineering, 2008
2. http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

DFM/A Guideline for Mechanics Appendix 1
ASSEMBLY CHECK LIST

Responsible Designer:	[Name]
Assembly:	[Assembly]
Item Code:	[Item code]
Project no:	[Project no]

Check list

Check point	Comment	Notes
Understand manufacturing problems/issues of current/past/related products		
Eliminate unnecessary parts		
Combine parts		
Reduce different kind of parts		
Reduce & eliminate fasteners		
Design for easy processing, and assembly		
Design for Top/Down layered assembly		
Enhance self-locating and & alignment capability		
Eliminate over constrains to minimize tolerance demands		
Provide unobstructed access for parts and tools		
Make parts independently replaceable		
Order assembly so that the most reliable goes in first; the most likely to fail goes in last		
Make sure options can be added easily		
Ensure the products life can be extended with future upgrades		
Structure the product into modules and subassemblies, as appropriate		

Make sure the wrong part cannot go in the intended position		
Make sure the part cannot go in the wrong position		
Design so that parts cannot be installed in the wrong orientation		
Revisions to the product design are clearly conveyed to manufacturing and implemented		
Design so that omissions cannot happen		
Design so that subsequent part installation will sense previous part omission		
Design so that omissions would be visually obvious		
Design so that omissions would be easy to see during inspection		
Eliminate process steps that depend on operator's memory		

DFM/A Guideline for Mechanics Appendix 2

PART DESIGN CHECK LIST

Responsible Designer:	[Name]
Assembly:	[Assembly Name]
Part:	[Part Name]
Item Code:	[Item code]
Project no:	[Project no]

Check list

Guideline	Comment	Notes
Understand manufacturing problems/issues of current/past/related parts		
For critical parts, the part designer should be an early and active participant in concept phase		
Understand the purpose of the part		
First consider off-the-shelf parts. Thoroughly investigate available candidates		
Explore all the ways to design and make the part. Don't just jump at the first idea that comes to mind		
Keep thinking about how the part is to be made throughout the design process		
Design for easy fabrication and processing		
Eliminate over constrains to minimize tolerance demands		
Obey all the specific guidelines for part design		
Design with help of the vendor working with the team		
Design the part keeping in mind the optimal balance of design considerations		
Choose raw materials commonly used		
Make sure the part cannot go in the wrong position in assembly		

Design so that parts cannot be installed in the wrong orientation		
Avoid right/left hand parts; use paired parts		
Design parts with symmetry		
If part symmetry is not possible, make parts very asymmetrical		
Design for fixturing; concurrently design fixtures		

APPENDIX 3 DFMA Analysis Template

Confidential
11 Aug 2009

DFMA Analysis Template
DFMA Process Development
Ilpo Mettovaara

Version	State	Date	Author	Description
0.1	Draft	11 Aug.2009	Mikko Keskilammi	1st Draft
0.2	Draft	17 Sept.2009	Mikko Keskilammi	Draft, Reviewed
0.3	Draft	12 Oct.2009	Mikko Keskilammi	Draft
0.4	Draft	18 Feb. 2010	Mikko Keskilammi	Draft
1.0		21.Now.2010	Ilpo Mettovaara	

Description:
This DFMA analysis is based on Bootroy's and Dewhurst's DFMA Analyse theory.
Theory offers eight rules or guidelines which are important during design of assembly.
1. Reduce part count and variations of parts
2. Attempt to eliminate adjustments
3. Design self-aligning and self-locating parts
4. Ensure easy access and unrestrivted vision
5. Ensure ease of handling parts from bulk, tray etc.
6. Minimize the need of re-orientations during assembly
7. Design parts that cannot be installed incorretly
8. Maximize part symmetry if possible or make parts obviosly asymmetrical

Instructions:
Analysis is done in architecture or concept phase of the PD process. Early before detailt product design phase begins. Analysis can be done also to redy made product.
1. Obtain all the possible information about the product, assembly or part from 3D models, drawings, samples etc.
2. Disassemle the product or assembly, or imagine, and assign an identification number to each items as it is removed.
3. Begin to reassemble the product begining whit highest identification number and add remaining parts one-by-one.
-Complete one row of the DFMA worksheet for each part
-Newer assume that parts are grasped one in each hand and the assembled together before placing them in a partically-completed assembly
4. Do the estimation of theoretical number of parts
5. Complete DFMA worksheet , computing total assembly time, cost and design effiency.
6. Go trough the design and try to find ways to improwe design efficiency.
7. Complete DFMA worksheet , computing total assembly time, cost and design effiency for the new assembly.

DFMA Analyze Summary

Project number / Name 0
Assembly Name
Date DD.MM.YYYY

	Number of parts	Assembly time (seconds)	Operatin costs (cents)	Design efficiency
Current design	0	0	0,00	#DIV/0!
Proposal	0	0	0,00	#DIV/0!
Change	0	0	0	#DIV/0!
Change %	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Convert to milliminutes

Action proposals

Here you can give written action proposal.

sasken

DFMA Analyze worksheet

Current design
A Cover assy

						Operation cost cent/second		2	
Sub assy/Part name	Qty (n)	Part ID	Handling code	Handling time(seconds)	Insertion code	Insertion Time (seconds)	Assembly time(nparts)(seconds)	Operation cost (cent)	Theoretical number of minimum of parts 0 or 1
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0						0	0,00	0
							TM	CM	NM
							Design efficiency (EM)		#DIV/0!

Proposa design
A Cover assy

						Operation cost cent/second		2,00	
Sub assy/Part name	Qty (n)	Part ID	Handling code	Handling time (seconds)	Insertion code	Insertion Time (seconds)	Assembly time(n parts) (seconds)	Operation cost (cent)	Theoretical number of minimum of parts 0 or 1
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0	0	0	0,00	0	0,00	0,00	0,00	0
	0						0	0,00	0
							TM	CM	NM
							Design efficiency (EM)		#DIV/0!

MANUAL HANDLING TABLES-ESTIMATED TIMES (seconds)

ONE HAND

			parts are easy to grasp and manipulate					parts present handling difficulties				
			thicknes > 2mm			thickness ≤ 2mm		thicknes > 2mm			thickness ≤ 2mm	
	Size		> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of graspin tools	(α+β)<360º	0	1,13	1,48	1,88	1,69	2,18	1,84	2,17	2,65	2,45	2,98
	360º≤(α+β)<540º	1	1,5	1,8	2,25	2,06	2,55	2,25	2,57	3,06	3	3,38
	540º≤(α+β)<720º	2	1,8	2,1	2,55	2,36	2,85	2,57	2,9	3,38	3,18	3,7
	(α+β)=720º	3	1,95	2,25	2,7	2,51	3	2,73	3,06	3,55	3,34	4

ONE HAND WITH GRASPING AIDS

				parts need tweezers for grasping and panipulation								parts need standard tools other than tweezers	parts need special tools for grasping and manipulation
				parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
				easy to grasp and manipulate		resent handling difficulties		easy to grasp and manipulate		present handling difficulties			
		Thickness		> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm		
				0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand but only with the use of grasping tools	α≤180º	0≤β≤180º	4	3,60	6,85	4,35	7,6	5,6	8,35	6,35	8,6	7	7
		β=360º	5	4	7,25	4,75	8	6	8,75	6,75	9	8	8
	α=360º	0≤β≤180º	6	4,8	8,05	5,55	8,8	6,8	9,55	7,55	9,8	8	9
		β=360º	7	5,1	8,35	5,85	9,1	7,10	9,55	7,85	10,1	9	10

TWO HANDS FOR MANIPULATION

			parts present no additional handling difficulties					parts present additional handling difficulties (sticky, slippery, etc.)				
			α≤180º			α=360º		α≤180º			α=360º	
	Size		> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
			0	1	2	3	4	5	6	7	8	9
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary)		8	4,10	4,5	5,1	5,6	6,75	5	5,25	5,85	6,35	7

MANUAL INSSRTION TABLES-ESTIMATED TIMES (seconds)

PARTS ADDED BUT NOT SECURED

				after assebly no holding down gequired to maintain orientation and location				holding down required during subsequent processes to maintain orientation or location			
				easy to align and position during assembly		not easy to align or position during assembly		easy to align and position during assembly		not easy to align or position during assembly	
		Resistance		no	yes	no	yes	no	yes	no	yes
				0	1	2	3	6	7	8	9
addition of any part where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) **can** easily reach the desired location (1)		1	1,50	2,5	2,5	3,5	5,5	6,5	6,5	7,5
	part and associated tool (including hands) **cannot** easily reach the desired location	due to obstructed access **or** restricted vision (2)	2	4	5	5	6	8	9	9	10
		due to obstructed access **and** restricted vision (3)	3	5,5	6,5	6,5	7,5	9,5	10,5	10,5	11,5

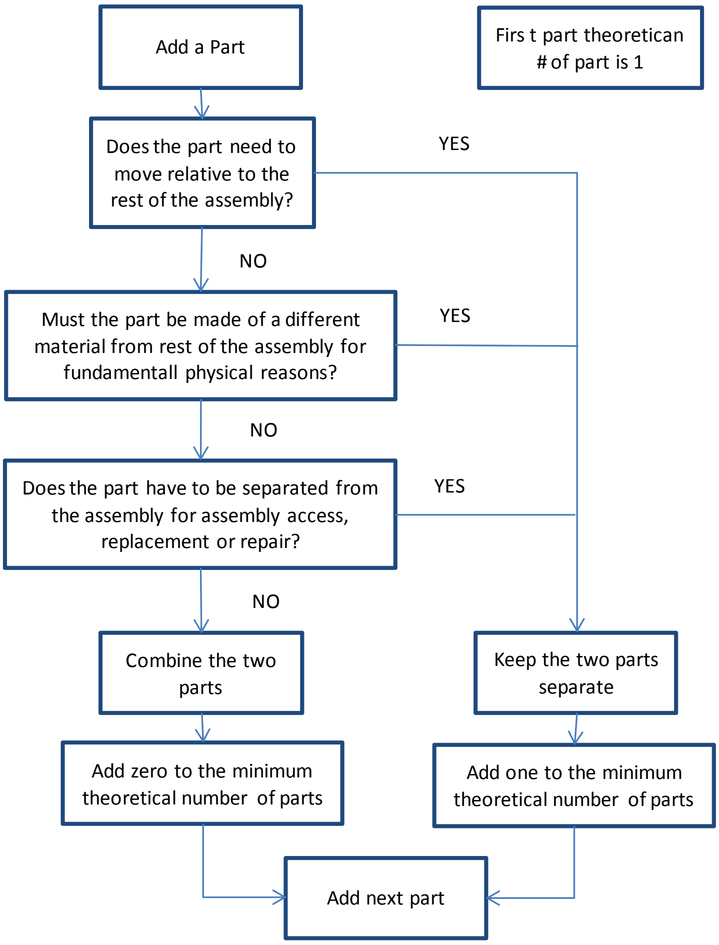
PARTS SECURED IMMEDIATELY

				no screwing operations or plastic deformation immediatly after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion								screw tightening immediately after insertion	
						plastic pending or torsion			rivetting or similar operation						
				easy to align and position with no resistance to insertion	not easy to align or position during assembly and/or resistance to	easy to align and position during assembly	not easy to align or position during assembly		easy to align and position during assembly	not easy to align or position during assembly		easy to align and position with no torsional resistance	not easy to align or position and/or torsional resistance
							no resistance to insertion	resistance to insertion		no resistance to insertion	resistance to insertion		
				0	1	2	3	4	5	6	7	8	9
addition of any part where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) **can** easily reach the desired location and the tool can be operated easily (3)		3	2	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) **cannot** easily reach the desired location or tool cannot be operated easily	due to obstructed access **or** restricted vision (4)	4	4,5	7,5	6,5	7,5	8,5	9,5	10,5	11,5	8,5	10,5
		due to obstructed access **and** restricted vision (5)	5	6	9	8	9	10	11	12	13	10	12

SEPARATE OPERATION

		mechanical fastening processes(part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) alredy in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation			snap fit, snap clip, press fit, etc.	metallurgical processes			chemical processes (e.g. Adhesive bonding, etc.)	manipulation of parts or sub-assembly (e.g. Orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. Liquid insertion, etc.)
		bending or similar process	rivetting or similar process	screw tightening or other process		no additional material required (e.g. Resistance, friction welding, etc.)	additional material required				
							soldering process	eld/braze proces			
		0	1	2	3	4	5	6	7	8	9
assembly processes where all solid parts are in place	9	4	7	5	3,5	7	8	12	12	9	12

ESTIMATING THEORETICAL NUMBER OF PARTS



APPENDIX 4 DFMA Analysis Lecture

DFMA

DFMA

- Design For Manufacturability/Assembly is theory or process of proactively designing product to: a) optimize all the manufacturing functions: fabrication, assembly test, procurement, shipping, service and repair; b)assure the best cost, quality, reliability, regulatory compliance, safety, time-to-market, and customer satisfaction; and c) ensure that lack of manufacturability doesn't compromise functionality, styling, new product introductions, product delivery, improvement programs, strategic initiatives and unexpected surges in product demand.

"Design for all"

What DFMA is not

- DFM/A is not a late step that, once checked off, gets you trough a design review or gate
- DFM/A is not done by the "DFM/A Engineer"
- DFM/A is not done by a "tool" (http://www.dfma.com/index.html)
- DFM/A is not just done at the parts level; most opportunities are at the system level
- DFM/A is not an afterthought
- DFM/A is not to be "caught" later in design reviews
- DFM/A is not to be accomplished by changes
- DFM/A is not thrown over the wall to Vendor or production engineers

Tools for DFMA

- DFMA Guideline for Mechanics

To give you short introduction to DFMA

To give you basic DFMA guidelines for design work

To introduce you to SASKEN DFMA process

- DFMA Assembly Check list

To give you DFMA guidelines for designing assembly

To work as a follow up list during the design process

To work as a input to lessons learned reporting

Tools for DFMA

- DFMA Part Design Check List

To give you DFMA guidelines for designing assembly

To work as a follow up list during the design process

To work as a input to lessons learned reporting

- DFMA Analyze template

To work as analyzing and optimizing tool for existing product or product under development.

To collect data for DFMA metrics

To work as a report template when reporting DFMA analyze to customer

To work as a input to lessons learned reporting

DFMA Analyze

- There are eight rules or guidelines which are important during design for manual assembly (listed in decreasing order of importance):

1. Reduce part count and part types
2. Strive to eliminate adjustments
3. Design parts to be self-aligning and self-locating
4. Ensure adequate access and unrestricted vision
5. Ensure the ease of handling parts from bulk
6. Minimize the need for re-orientations during assembly
7. Design parts that cannot be installed incorrectly
8. Maximize part symmetry if possible or make parts obviously asymmetrical (http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro)

DFMA Analyze

Step 1: Obtain information about the product or assembly from drawings, prototypes, or an existing product

Step 2: Take the product or assembly apart and assign an identification number to each item as it is removed

Step 3: Begin to reassemble the product beginning with the highest identification number and add the remaining parts one-by-one

- Complete one row of the DFMA worksheet for each part
- Never assume that parts are grasped one in each hand and then assembled together before placing them in a partially-completed assembly

- **Step 4:** Complete DFMA worksheet, computing total manual assembly time, cost, and design efficiency

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

DFMA Analyze Worksheet

These comes from Manual Handling Worksheet

These comes from Manual Insertion Worksheet

Operation cost cent/second, from sourcing

Current design
A Cover assy

						Operation cost cent/second		2	
Sub assy/Part name	Qty (n)	Part ID	Handling code	Handling time	Insertion code	Insertion Time	Assembly time(n parts)	Operation cost (cent)	Theoretical number of minimum of parts 0 or 1
							0,00	0,00	
A/cover	1	1	10	1,50	10	1,50	3,00	6,00	1
Window assy	1	2	13	2,06	31	5,00	7,06	14,12	1
Camera Gasket	1	3	52	4,75	30	2,00	6,75	13,50	1
Earpiece Gasket	1	4	52	4,75	30	2,00	6,75	13,50	0
	4						23,56	47,12	3
							TM	CM	NM
							Design efficiency (EM)		0,38

Design Efficiency
EM = (3 x NM)/TM

Manual handling Worksheet

Step 1. Which option describes best assembled part?

Step 2. Sum of alpha and beta angles. Theory in slides 11-17

Step 4 Which option describes best assembled part?

Step 5. 2nd. Digit of the handling code.

MANUAL HANDLING TABLES-ESTIMATED TIMES (seconds)

ONE HAND

			parts are easy to grasp and manipulate					parts present handling difficulties				
			thicknes > 2mm			thickness ≤ 2mm		thicknes > 2mm			thickness ≤ 2mm	
	Size		> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
			0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand without the aid of graspin tools	(α+β)<360°	0	1,13	[illegible]	1,88	1,69	2,18	1,84	2,17	2,65	2,45	2,98
	360°≤(α+β)<540°	1	1,5	[illegible]	2,25	2,06	2,55	2,25	2,57	3,06	3	3,38
	540°≤(α+β)<720°	2	1,8	2,1	2,55	[illegible]	[illegible]	[illegible]	[illegible]	3,38	3,18	3,7
	(α+β)=720°	3	1,95	2,25	2,7	2,51	3	2,73	3,06	3,55	3,34	4

ONE HAND WITH GRASPING AIDS

				parts need tweezers for grasping and panipulation								parts need standard tools other than tweezers	parts need special tools for grasping and
				parts can be manipulated without optical magnification				parts require optical magnification for manipulation					
				ts are easy to grasp and manipu		parts present handling difficulties		ts are easy to grasp and manipu		parts present handling difficultie			
		Thickness		> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm	> 0,25mm	≤0,25mm		
				0	1	2	3	4	5	6	7	8	9
parts can be grasped and manipulated by one hand but only with the use of grasping tools	α≤180°	0≤β≤180°	4	3,60	6,85	4,35	7,6	5,6	8,35	6,35	8,6	7	7
		β=360°	5	4	7,25	4,75	8	6	8,75	6,75	9	8	8
	α=360°	0≤β≤180°	6	4,8	8,05	5,55	8,8	6,8	9,55	7,55	9,8	8	9
		β=360°	7	5,1	8,35	5,85	9,1	7,10	9,55	7,85	10,1	9	10

TWO HANDS FOR MANIPULATION

			parts present no additional handling difficulties					parts present additional handling difficulties (sticky, slippery, etc.)				
			α≤180°			α=360°		α≤180°			α=360°	
parts severely nest or tangle or are flexible but can be grasped and lifted by one hand (with the use of grasping tools if necessary)	Size		> 15mm	6mm-15mm	<6mm	>6mm	≤6mm	> 15mm	6mm-15mm	<6mm	>6mm	≤6mm
			0	1	2	3	4	5	6	7	8	9
		8	4,10	4,5	5,1	5,6	6,75	5	5,25	5,85	6,35	7

Step 3. 1st. Digit of the handling code.

Manual insertion Worksheet

Step 1. Which option describes best assembled part?

Step 3 Which option describes best assembled part?

MANUAL INSRTION TABLES-ESTIMATED TIMES (seconds)

PARTS ADDED BUT NOT SECURED

				after assembly no holding down gequired to maintain orientation and location				holding down required during subsequent processes to maintain orientation or location			
				easy to align and and position during assembly		not easy to align or position during assembly		easy to align and and position during assembly		not easy to align or position during assembly	
		Resistance		no	yes	no	yes	no	yes	no	yes
				0	1	2	3	4	5	8	9
addition of any part where neither the part itself nor any other part is finally secured immediately	part and associated tool (including hands) **can** easily reach the desired location (1)		1	1,50	2,5	2,5	3,5	5,5	6,5	6,5	7,5
	part and associated tool (including hands) **cannot** easily reach the desired location	due to obstructed access **or** restricted vision (2)	2	4	5	5	6	8	9	9	10
		due to obstructed access **and** restricted vision (3)	3	5,5	6,5	6,5	7,5	9,5	10,5	10,5	11,5

Step 4. 2nd. Digit of the insertion code.

PARTS SECURED IMMEDIATELY

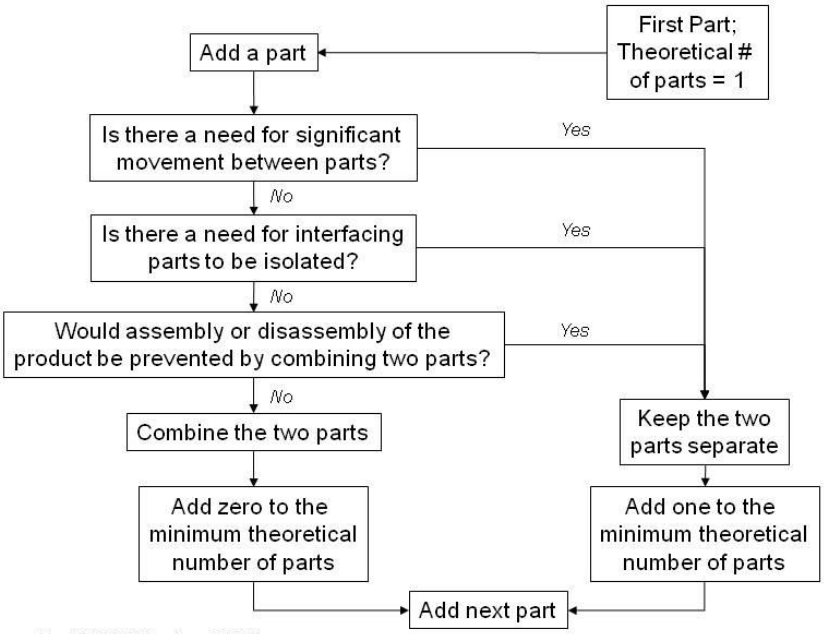
				no screwing operations or plastic deformation immediatly after insertion (snap/press fits, circlips, spire nuts, etc.)		plastic deformation immediately after insertion						screw tightening immediately after insertion	
						plastic pending or torsion			rivetting or similar operation				
				easy to align and position with no resistance to insertion	not easy to align or position during assembly and/or resistance to insertion	easy to align and position during assembly	not easy to align or position during assembly: no resistance to insertion	not easy to align or position during assembly: resistance to insertion	easy to align and position during assembly	not easy to align or position during assembly: no resistance to insertion	not easy to align or position during assembly: resistance to insertion	easy to align and position with no torsional resistance	not easy to align or position and/or torsional resistance
				0	1	2	3	4	5	6	7	8	9
addition of any part where the part itself and/or other parts are being finally secured immediately	part and associated tool (including hands) **can** easily reach the desired location and the tool can be operated easily (3)		3	[illegible]	5	4	5	6	7	8	9	6	8
	part and associated tool (including hands) **cannot** easily reach the desired location or tool cannot be operated easily	due to obstructed access **or** restricted vision (4)	4	4,5	[illegible]	6,5	7,5	8,5	9,5	10,5	11,5	8,5	[illegible]
		due to obstructed access **and** restricted vision (5)	5	6	9	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	12

SEPARATE OPERATION

		mechanical fastening processes(part(s) already in place but not secured immediately after insertion)				non-mechanical fastening processes (part(s) alredy in place but not secured immediately after insertion)				non-fastening processes	
		none or localized plastic deformation			snap fit, snap clip, press fit, etc.	metallurgical processes			chemical processes (e.g. Adhesive bonding, etc.)	manipulation of parts or sub assembly (e.g. Orienting, fitting or adjustment of part(s), etc.)	other processes (e.g. liquid insertion, etc.)
		bending or similar process	rivetting or similar process	screw tightening or other process		no additional material required (e.g. Resistance, friction welding, etc.)	additional material required: soldering process	additional material required: weld/braze proces			
assembly processes where all solid parts are in place		0	1	2	3	4	5	6	7	8	9
	9	4	7	5	3,5	7	8	12	12	9	12

Step 2. 1st. Digit of the insertion code.

Estimating Theoretical Minimum Number of Parts



http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

Assumptions for DFMA

- Parts are provided in bulk and randomly oriented in a bin.
- Parts are handled and inserted one at a time.
- Products weigh a few grams to a few tens of kilograms and are electro-mechanical in nature.
- Assembly sequence is optimized for one operator.

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

Assembly Time Estimate

Estimate assembly time:
- Time to assemble a part:
  - »Time to handle a part
  - »Time to insert a part
- Time to assemble all parts, one at a time

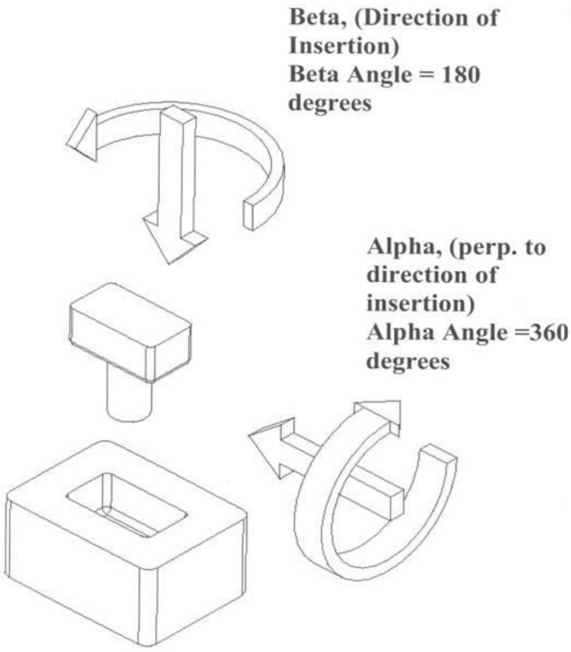
http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

Assembly Time

- Time to handle a part:
  - Pick a part, orient & get ready to insert it
  - 1.13 ~10 seconds depending on:
    - »Symmetry; Primary(α-) & secondary(β-)
    - »Size: Thickness, dimension, weight, …
    - »Handling ease: Tool, flexible, tangling, ...

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

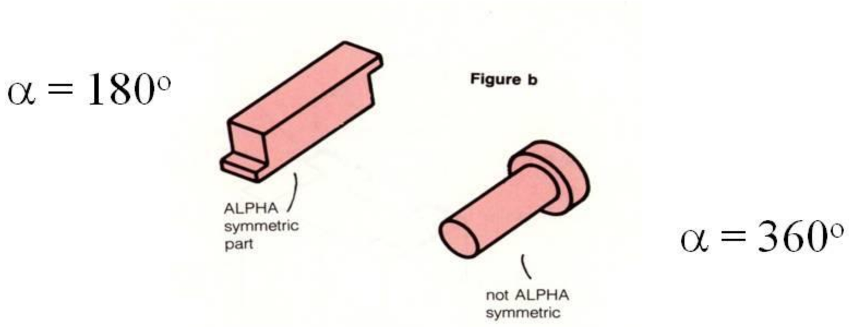
Design for Assembly
Alpha Beta Assembly Angles



http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

Part Symmetry

- Primary (a-) symmetry: Rotational symmetry perpendicular to the axis of insertion



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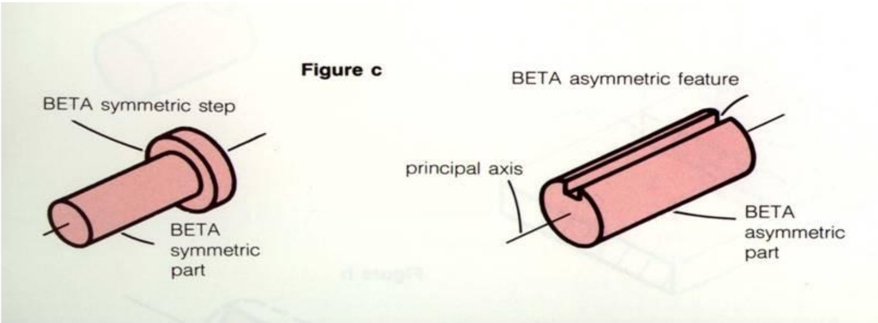
Part Symmetry

- Secondary (b-) symmetry: Rotational symmetry about the axis of insertion



$\beta = 0^{o}$ $\beta = 360^{o}$

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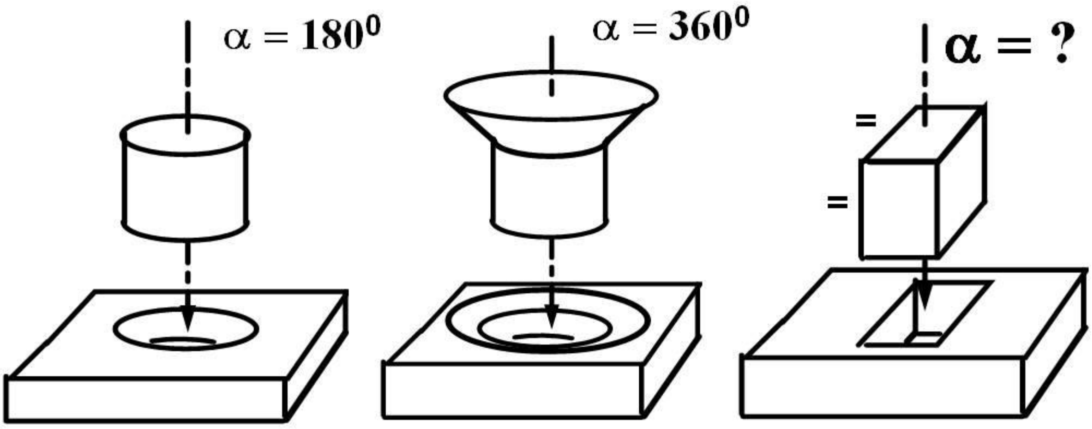
Part Orientation

- α *asymmetry:* rotational symmetry
- about an axis perpendicular to the
- axis of insertion



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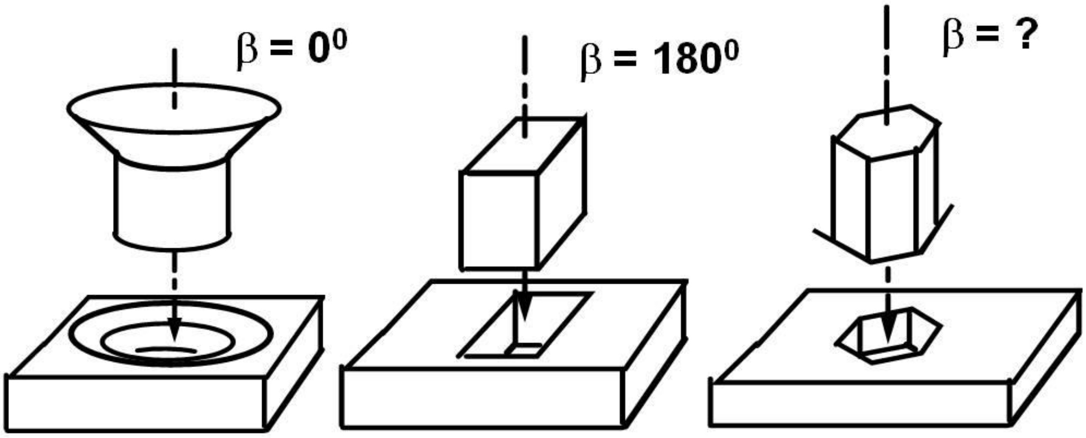
Part Orientation

β symmetry: rotational symmetry about its axis of insertion



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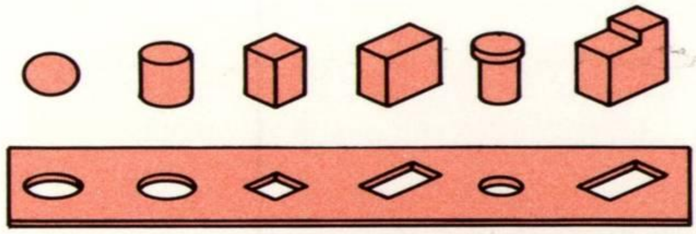
Part Symmetry



α	0	180	180	90	360	360
β	0	0	90	180	0	360

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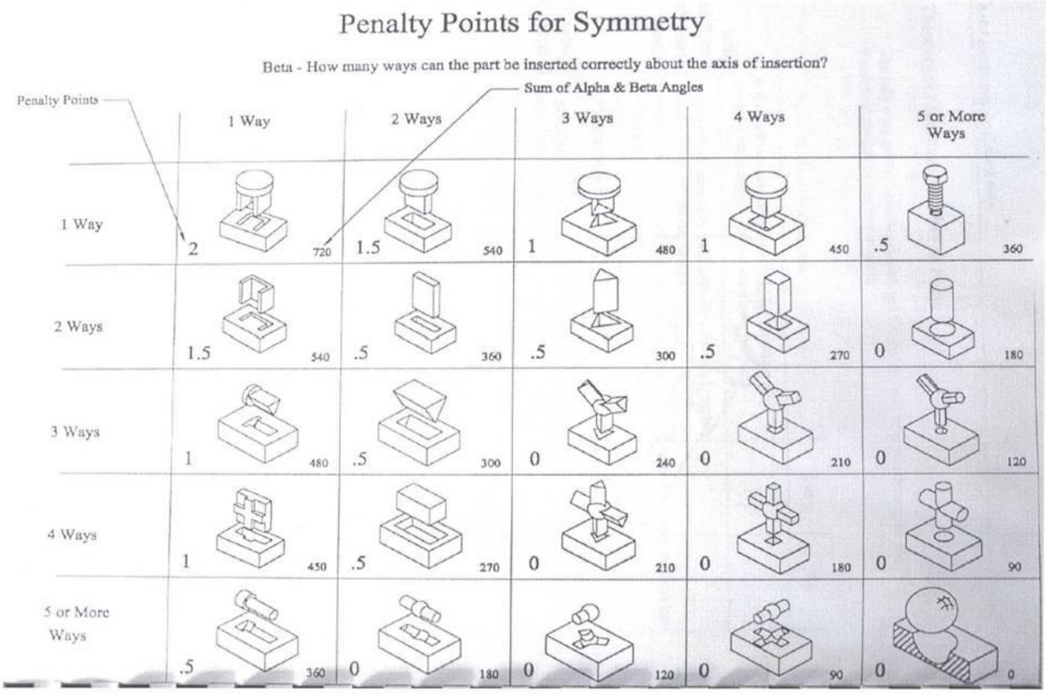

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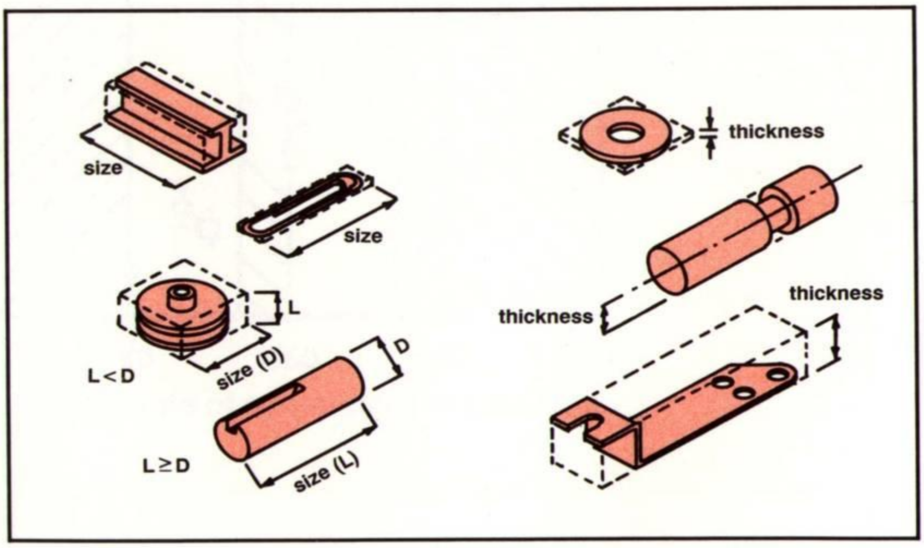
Part Size



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Assembly Time

- Time to insert a part:
  - Time to insert and secure a part
  - 1.5 ~ 12 seconds depending on:
    - »Ease of access: Visual & hand access
    - »Ease of positioning: Hold-down, alignment, insertion force, ..
    - »Securing requirement: Screw, snap, bending, soldering, ….
- Time to assemble all parts, one at a time

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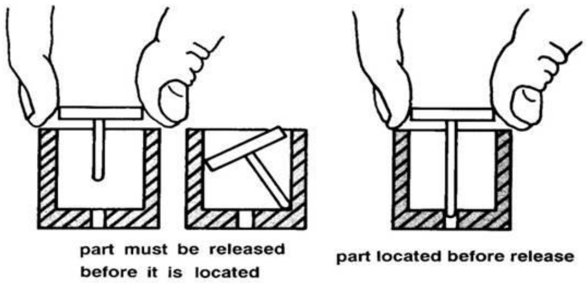
Assembly Time

- Time to insert a part



- Two-digit insertion codes for piston:

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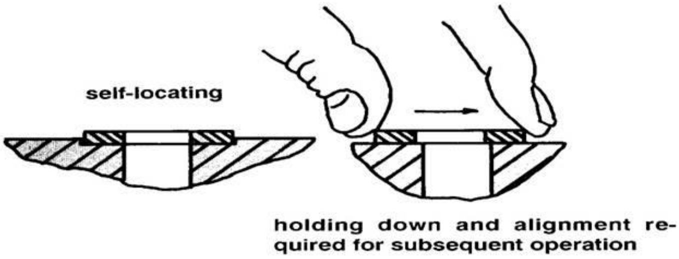
Assembly Time

• Time to insert a part



• Two-digit insertion codes for washer:

_ _ _ _

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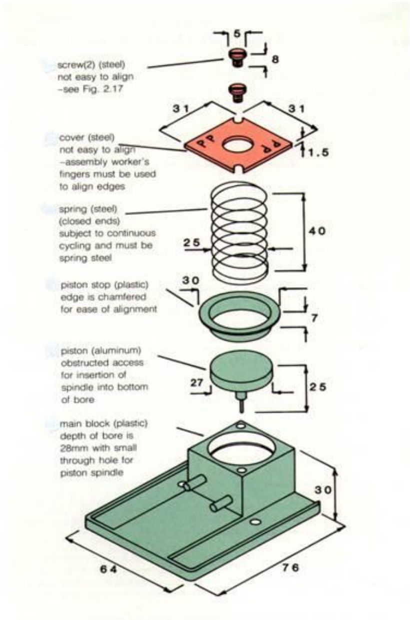
Pneumatic Pump Exercise with Boothroyd/Dewhurst DFMA

BDI DFMA: Pneumatic Pump

- Assembly Sequence:

  6. Two screws
  5. One cover
  4. One spring
  3. One piston stop
  2. One piston
  1. One main body

- Tool:
  – A screw driver



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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1					
2	Piston	1					
3	Piston Stop	1					
4	Spring	1					
5	Cover	1					
6	Screws	2					

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1					
3	Piston Stop	1					
4	Spring	1					
5	Cover	1					
6	Screws	2					
					Total Assembly Time		

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	10	4.00	5.50
3	Piston Stop	1					
4	Spring	1					
5	Cover	1					
6	Screws	2					
					Total Assembly Time		

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	10	4.00	5.50
3	Piston Stop	1	10	1.50	00	1.50	3.00
4	Spring	1					
5	Cover	1					
6	Screws	2					
					Total Assembly Time		

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	10	4.00	5.50
3	Piston Stop	1	10	1.50	00	1.50	3.00
4	Spring	1	05	1.84	00	1.50	3.34
5	Cover	1					
6	Screws	2					
					Total Assembly Time		

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	10	4.00	5.50
3	Piston Stop	1	10	1.50	00	1.50	3.00
4	Spring	1	05	1.84	00	1.50	3.34
5	Cover	1	12	2.36	08	6.50	8.86
6	Screws	2					
					Total Assembly Time		

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	10	4.00	5.50
3	Piston Stop	1	10	1.50	00	1.50	3.00
4	Spring	1	05	1.84	00	1.50	3.34
5	Cover	1	12	2.36	08	6.50	8.86
6	Screws	2	11	1.80	39	8.00	16.60
					Total Assembly Time		40.75 Seconds

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Part Reduction Method by Boothroyd/Dewhurst DFMA

BDI DFMA: Part Reduction

- Estimate assembly time:
- Identify critical parts & candidates for elimination/combination. Let's assume a product consists of a number of parts:
  - Are they all critical part?
  - What if a part is missing or broken?
  - What if two parts are replaced by a larger or different part
- Determine design efficiency

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BDI DFMA: Part Reduction

When ready to assemble a part, should this part:

- Move relative to all already assembled parts?
- Be made of different material from all already assembled parts?
- Be a separate part from all already assembled parts for assembly and disassembly?

If any answer is a "yes", this part is a critical part and may not be eliminated or combined!

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BDI DFMA: Why Reduce Parts?

A non-existing part never:

- Causes a quality problem
- Adds the cost
- Creates an inventory problem
- Requires design changes
- Creates a shortage problem
- Has a lead time

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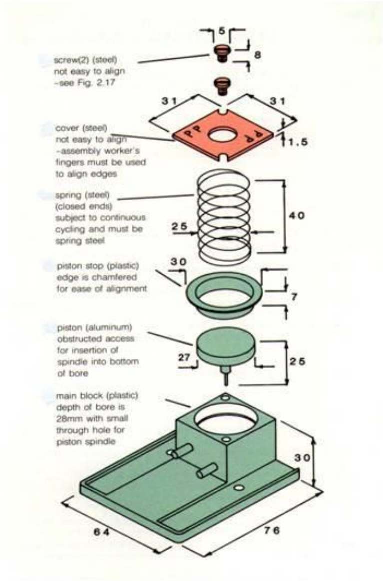
BDI DFMA: Pneumatic Pump

- Assembly Sequence:

  6. Two screws
  5. One cover
  4. One spring
  3. One piston stop
  2. One piston
  1. One main body



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BDI DFMA: Pneumatic Pump

- Part Reduction:

Part #	Part Name	Qty	With Respect to	Relative Motion	Different Material	Service & Assembly	Critical Part
1	Main Block	1					
2	Piston	1	Main Block				
3	Piston Stop	1	Main Block				
			Piston				
4	Spring	1	Main Block				
			Piston				
			Piston Stop				
5	Cover	1	Main Block				
			Piston				
			Piston Stop				
			Spring				
6	Screws	2	Main Block				
			Piston				
			Piston Stop				
			Spring				

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BDI DFMA: Pneumatic Pump

- Part Reduction:

Part #	Part Name	Qty	With Respect to	Relative Motion	Different Material	Service & Assembly	Critical Part
1	Main Block	1	--				Yes
2	Piston	1	Main Block				
3	Piston Stop	1	Main Block				
			Piston				
4	Spring	1	Main Block				
			Piston				
			Piston Stop				
5	Cover	1	Main Block				
			Piston				
			Piston Stop				
			Spring				
6	Screws	2	--				No

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BDI DFMA: Pneumatic Pump

- Part Reduction:

Part #	Part Name	Qty	With Respect to	Relative Motion	Different Material	Service & Assembly	Critical Part
1	Main Block	1					Yes
2	Piston	1	Main Block	Yes			Yes
3	Piston Stop	1	Main Block				
			Piston				
4	Spring	1	Main Block				
			Piston				
			Piston Stop				
5	Cover	1	Main Block				
			Piston				
			Piston Stop				
			Spring				
6	Screws	2	--				No

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

BDI DFMA: Pneumatic Pump

- Part Reduction:

Part #	Part Name	Qty	With Respect to	Relative Motion	Different Material	Service & Assembly	Critical Part
1	Main Block	1					Yes
2	Piston	1	Main Block	Yes			Yes
3	Piston Stop	1	Main Block	No	No	Yes	Yes
			Piston	Yes			Yes
4	Spring	1	Main Block				
			Piston				
			Piston Stop				
5	Cover	1	Main Block				
			Piston				
			Piston Stop				
			Spring				
6	Screws	2	--				No

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

BDI DFMA: Pneumatic Pump

- Part Reduction:

Part #	Part Name	Qty	With Respect to	Relative Motion	Different Material	Service & Assembly	Candidate for Eliminatio n
1	Main Block	1					Yes
2	Piston	1	Main Block	Yes			Yes
3	Piston Stop	1	Main Block	No	No	Yes	Yes
			Piston	Yes			Yes
4	Spring	1	Main Block	Yes			Yes
			Piston	Yes			Yes
			Piston Stop	Yes			Yes
5	Cover	1	Main Block				
			Piston				
			Piston Stop				
			Spring				
6	Screws	2	--				•Yes

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BDI DFMA: Pneumatic Pump

- Part Reduction:

Part #	Part Name	Qty	With Respect to	Relative Motion	Different Material	Service & Assembly	Candidate for Eliminatio n
1	Main Block	1					Yes
2	Piston	1	Main Block	Yes			Yes
3	Piston Stop	1	Main Block	No	No	Yes	Yes
			Piston	Yes			Yes
4	Spring	1	Main Block	Yes			Yes
			Piston	Yes			Yes
			Piston Stop	Yes			Yes
5	Cover	1	Main Block	No	No	Yes	Yes
			Piston	Yes			Yes
			Piston Stop	N o	No	No	No
			Spring	Yes			Yes
6	Screws	2	--				•Yes

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DFA of Pneumatic Pump

- According to the piston stop, the cover is a candidate for elimination or combination:
  - –Can the cover be eliminated?
  - –Can the cover be combined? If so with what?
- Fasteners are automatic candidates of elimination:
  - –How can the fasteners be eliminated?

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Part Reduction Is the Key for Design Improvement

- Eliminating one part reduces at least 3 seconds.
- In addition a non-existing part is the best since it never:
  - Requires purchasing and warehouse
  - Needs inspection
  - Causes a quality problem
  - Needs design changes and drawing
  - Be in shortage

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DFA of Pneumatic Pump

- According to the piston stop, the cover is a candidate for elimination or combination:
  - Can the cover be eliminated? No!
  - Can the cover be combined? Yes! Combine with piston!
- Fasteners are automatic candidates of elimination:
  - How can the fasteners be eliminated? Yes! Press-fit the cover!

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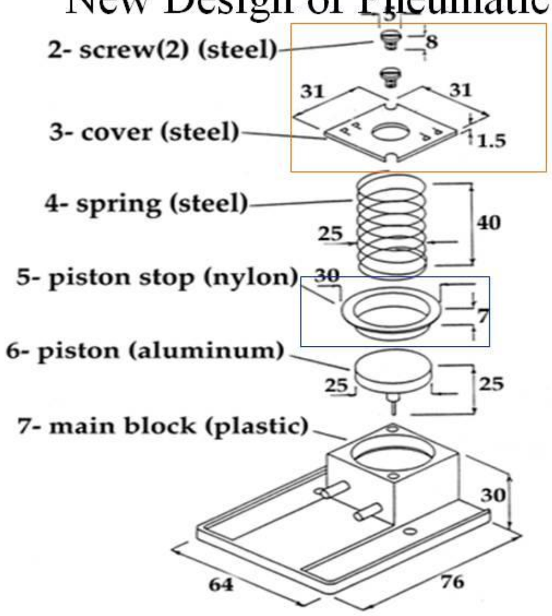
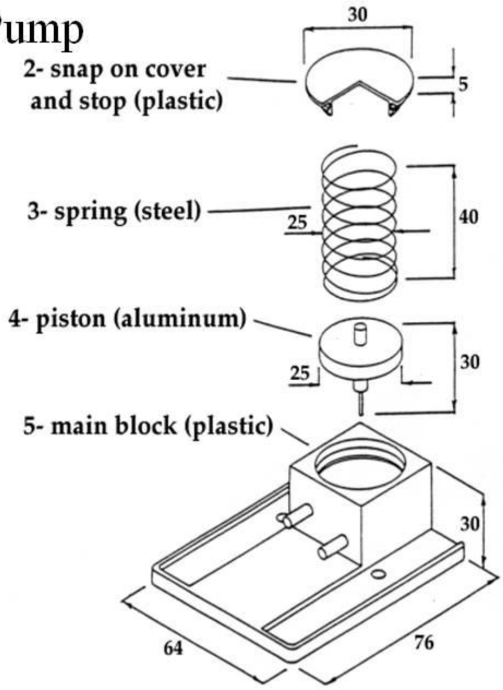
New Design of Pneumatic Pump



Pneumatic Piston Sub-Assembly
(dimensions in mm)



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BDI DFMA: Design Efficiency

- The pneumatic pump:
  - –Has 7 parts & needs 40.75 seconds to assemble
  - –Has 4 critical parts & 3 non-critical parts
- If the product is designed perfectly:
  - –Pump would consists of only four parts
  - –Each part would take 3 seconds to assemble
  - –Total assembly time would be 12 seconds
- Design efficiency from assembly view points is:
  - –*Design Efficiency = 12/40.75 = 29%*

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BDI DFMA: Pneumatic Pump

- Assembly Time:

Part #	Part Name	Qty (n)	Handling Code	Handling Time	Insertion Code	Insertion Time	Assembly Time (n Parts)
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	10	4.00	5.50
3	Piston Stop	1	10	1.50	00	1.50	3.00
4	Spring	1	05	1.84	00	1.50	3.34
5	Cover	1	12	2.36	08	6.50	8.86
6	Screws	2	11	1.80	39	8.00	16.60
					Total Assembly Time		40.75 Seconds

– What should we do to reduce handling time of the cover and insertion times of the cover and screws?

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BDI DFMA Assembly Time

- 1.13 ~10 seconds to handle a part depending on:
  - Symmetry; Primary(α-) & secondary(β-)
  - Size: Thickness, dimension, weight, …
  - Handling ease: Tool, flexible, tangling, …
- To reduce part handling time:
  - More part symmetry: α- & β-symmetry
  - Right part size : Thickness, dimension, …
  - No flexible, tangling parts

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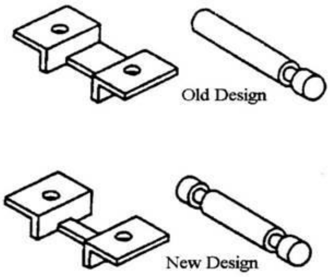
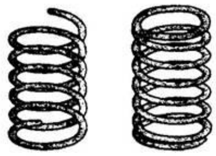
To Reduce Handling Time





Open springs will tangle

Closed springs tangle only under pressure

- Increase symmetry by introducing redundancy: α – symmetry from 360° to 180°
- Closed-end springs do not tangle

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BDI DFMA Assembly Time

- 1.5 ~ 12 seconds to insert a part depending on:
  - –Visual & hand access
  - –Hold-down, alignment, insertion force,
  - –Securing: Screw, snap, bending, soldering, ..
- To reduce part insertion time:
  - –Easy visual & hand access
  - –No hold-down, easy alignment, low/no insertion force, ..
  - –Easy/No securing requirement: Snaps instead of screw, bending, soldering, ….

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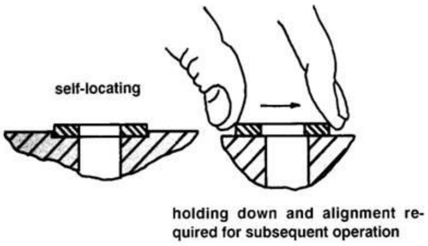
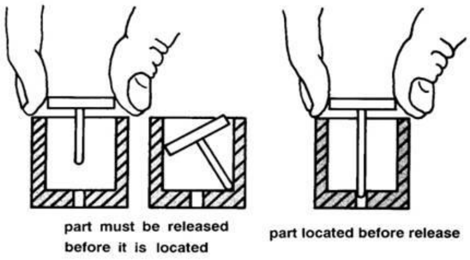
To Reduce Insertion Time



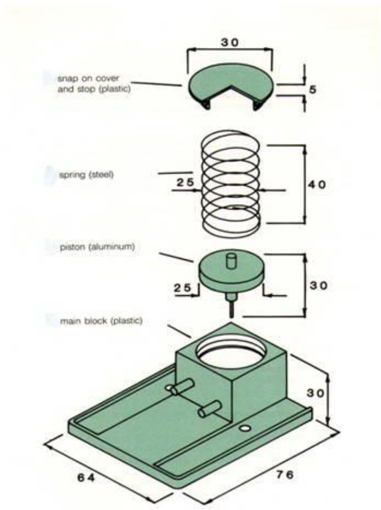


- The washer seat eliminates needs of holding
- The long shaft makes piston alignment easy

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

New Design of Pneumatic Pump

- Piston & piston stop are combined
- Cover is press-fitted



http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

New Design of Pneumatic Pump

- BDI DFMA Assembly Time Analysis:

Part #	Part Name	Qty	Handling Code	Handling Time	Insertion Code	Insertion Time	Total Assy Time
1	Main Block	1					
2	Piston	1					
3	Spring	1					
4	Cover	1					

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

New Design of Pneumatic Pump

- BDI DFMA Assembly Time Analysis:

Part #	Part Name	Qty	Handling Code	Handling Time	Insertion Code	Insertion Time	Total Assy Time
1	Main Block	1	30	1.95	00	1.50	3.45
2	Piston	1	10	1.50	00	1.50	3.00
3	Spring	1	05	1.84	00	1.50	3.34
4	Cover	1	10	1.50	30	2.00	3.50
					Total Assembly Time		13.29 Seconds

- Design comparison:

	Old Design	New Design	% Change
Number of Parts	7 Parts	4 Parts	43% Reduction
Assembly Time	40.75 Seconds	13.29 Seconds	67% Reduction

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Design Guidelines for Assembly

How to design a product for ease of assembly?

- Reduce the number of part
- Design each part for ease of handling
- Design each part for ease of insertion
- Examine trade-offs, other cost and other X's

Design Guidelines for Assembly

- Reduce the number of part:
  - Eliminate unnecessary parts
  - Combine parts
  - Reduce the different kinds of parts
  - Reduce/eliminate fasteners

Design Guidelines for Assembly

- Design each part for ease of handling:
  - –Increase part symmetry but avoid near symmetric parts
  - –Avoid tangling, nesting and sticky parts
  - –Reduce/eliminate fasteners
  - –Avoid custom-designed parts & use standard parts
  - –Reduce part variability. If not possible, make difference pronounced

http://www.scribd.com/doc/4355719/Lecture-5-DFA-Boothro

Design Guidelines for Assembly

- Design each part for ease of insertion:
  - –Design for top-down layered assembly
  - –Enhance self-locating & alignment capability
  - –Provide in-process verification process
  - –Design the base part for transportation & orientation & the last part to lock the assembly
  - –Avoid turnover & processing during assembly
  - –Design for one-hand assembly
  - –Design fixtures together with products

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Design Guidelines for Assembly

- Examine trade-offs, other cost and other X's:
- To hold a wash or provide a washer seat?
- Several standard parts or a single custom part?
- Different material?
- Different joining method?
- What about:
  - Service & repair
  - Packing and shipping
  - Recycle ...

Assembly is only one of many cost factors!

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