Can Kilicbay

Taking a step forward: Operator Oriented Solutions for the Future of the Assembly Industry

Uppsala University
Department of Informatics & Media

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Abstract

This study targets assembly industry, which deals with varying businesses that require any product assembly. It reflects on the challenges of the current production lines at assembly industry regarding the trends of both the consumer and the industrial developments on technology investigated which aspects can be improved or re-designed under the given delimitations. Moreover further consideration is done on human operators' role in the assembly line and their future role in correlation with their current challenges and expectations. Results and further analysis are done from the drift of the R&D on future assembly environment by considering interconnected software-hardware-human sides of the interaction, the change in the balance of products and also to point out new areas of research to Marketing and R&D Departments.

To my dearest family
for supporting countless times and
to my grandfathers, timeless innovators

1. Introduction

1.1. Aim of the thesis

This thesis is written as a part of an on-going project at Atlas Copco Tools and Assembly Systems under the Research and Development Department. The company is a world-leading developer and manufacturer of pneumatic and electric tools and assembly systems, which achieves precise joint fastenings and error-proof production methods for automotive, aerospace and general industries. Under the R&D department ergonomics, interaction, hardware and software topics are being investigated for product development and knowledge building.

This study reflects on the challenges of the current production lines at assembly industry, challenges on human aspect, moreover regarding to the trends of the both consumer and industrial developments on technology, it is being investigated which aspects can be improved or re-designed under the given delimitations. The recommendations are to help to drift of the R&D on future assembly environment by considering interconnected software-hardware-human sides of the interaction and also to point out new areas of research to Marketing and R&D Departments.

Varying in size, product range and culture, visits had been done in two different countries to six customer plants. Along with the visits, seven blue collar and five white-collar customers as well as Atlas Copco salesman had been interviewed on site. To catch up to current trends in technology in consumer and industrial market, three conferences had been visited. As confidentiality reasons the identities of the companies and people will be withheld.

1.2. Why Correct Fastening of Joints is Important

The usage of threaded joints is result of searching simpler products, a result of seeking disassembly / reassembly freedom and a result of to finding allowance at flexibility and availability at the production. [Bloch, 1997]

The consequences of a misfastened safety-critical joint can be fatal. The safety critical joints that are being used at such as safety belts, pedals, steering wheels, wheels have to be done accurately and traceability of such joints is crucial as follow up.

The reason of such failures can be caused by fatigue, vibration, fracture under static load and joint leakage. [Toor, 1995] The failure can be avoided by calculation of correct fastening strategy with correct equipments as well as traceability of results and avoidance of any human error at production. Thus the assurance of correct fastening is very important for both manufacturers and customers.

1.3. Atlas Copco Tools & Assembly Systems

Atlas Copco is an industrial group with world leading positions in power tools and assembly systems, construction and mining equipment, compressors, expanders and air treatment systems. The company was founded in 1873, is based in Stockholm, Sweden with a global reach spanning more than 170 countries to provide solutions for sustainable productivity. In 2011, the company had 37 500 employees and revenues of €9B. [Atlas Copco, 2012]

Atlas Copco Tools & Assembly Systems consists of two departments, Motor Vehicle Industry and General Industry, both being listed under Industrial Technique business area. Products ranges from power tools to assembly systems, quality assurance products and services through a global network to customers in the automotive and aerospace industries, in vehicle service, industrial manufacturing and maintenance. Principal product development and manufacturing units are located in Sweden, France, Japan and Germany. [Atlas Copco, 2012]

1.4. Quality Integrated Fastening Strategy

The ongoing customer trends create a basis for Quality Integrated Fastening Strategy. Increased quality; error proofing and the trend towards zero-fault assembly are strong goals in production. Maximum Flexibility; more and more different products are built on the same line, this results in increased complexity of assembly operation and need of better operator support. Also assembly lines need to be rebalanced more frequently in order to adapt to the final customer demand. Reduced Costs; at the same time reducing production costs is the key to remaining competitive.

To meet these customer trends, also to avoid costly reworking, raise productivity and to ensure quality on production line, Atlas Copco has expanded its portfolio to build a complete Error Proofing Station solution. Fastening Tools and controllers create the core business. Currently, the tools are being integrated more and more with new station hardware and software and propose Complete Station Solutions instead. [Atlas Copco QIF, 2012]

1.5. Delimitations

The inflicting issue for conceptual projects like this is that in assembly industries, the customers tend to be in a product-oriented approach. This attitude obstructs trials. The driven customers, in most of the successful cases, lean on embracing the trials with the demo setup, as it is a new product. However for the developer companies such as Atlas Copco, this creates complications such as the customer will be expecting support from then. However the local salesman and product specialists are not trained for such conceptual projects along with demos' support and the development team is expected to have on-site support where their assignment is to test and reflect on the results instead of product support. These dynamics reflected on this project as most of the clients wanted to keep the demo even though it had no initial purpose to be a product.

Another inflicting issue was the scope of the interviews and observations were carried out in Europe and in motor vehicle industry. During the interviews a lot of information had been gathered from salesman and marketing on other markets and in other geographies. However hands-on trials and observations are missing from different other geographies where work culture differs from Europe that can provide many more aspects to this topic. [Hopkins, 2009]

2. Background

2. 1. Human Operators and Environment

Elements that are consisting are production line differ from the application’s scope, which makes the modern production line very flexible. To understand clearly the dynamics and the process of the assembly, team players of this event should be well explained.

2. 1. 1. Strategy

Atlas Copco drives a core strategy to solve process quality at the assembly line, not just reducing production costs but also increase productivity. If the automotive industry is taken into the consideration there are three bolt classes accordingly. These will be safety-critical, function-critical and customer-critical joints. German VDI Standard that applies for the automotive industry has a similar categorisation also.

These categorises are very helpful at process quality as their tightening results are documented and traced to understand fault patterns and reduce further errors before they arrive to the end-user.

To assure error-proof production, Atlas Copco has derived a five tightening process control steps. The decision is customers’ to stay on which step as accordingly to their needs and strategy.

First of the steps that is supplied is to assure a correct tightening torque. This is the most basic step at assurance. The tool is preset with a torque value. In this step, products, joints and operators are not observed for assurance.

Second step is the assurances of all screws are tightened. This step is to avoid if any joints has been missed by the operator or done a faulty tightening in a batch or tries to re-tighten an already tightened joint.

Third step is to assure that the joint is correct, meaning that neither the process nor the performance has any faults but the actual joint itself can cause of an incorrect tightening. These errors is being handled by tightening monitoring during the tightening such as observing the achieved torque level, required angle value and such.

Forth step is to assure critical joints has been tightened properly. These joints carry high level security of the product which would directly the end-user. To avoid any future errors that can come from these joints, extra precautions are taken on this step. More advanced tools with an advanced tightening control system are used.

Finally and the highest step of assurance is to guarantee zero fault fastening. Achieving previous steps does not guarantee zero fault fastening without taking the fifth step. This step requires the highest complexity, which involves factory network integration, product information retrieval and automatic parameter adjustments of the tools accordingly.

To sum up all these steps, accordingly to clients' needs, products that are being produced, different levels of error proofing is served by Atlas Copco. After all these steps, documentation of tightening are collected in a database for monitoring, trend analysis and for more purposes which can be used by the client. This supplies traceability of each tightening that can ease recall process or discovery of errors.

2. 1. 2. Products

The Products that is built with tightening tools varies from business to business. These products require different levels of error-proofing as explained in *Strategy* chapter. To go through, tools are being used at power generator assembly, automotive assembly, aircraft assembly, beverage container industry, quality assurance and so forth. As each customer comes with different needs, different products and setups are proposed to them.,

2. 1. 3. Human-Machine Interaction

Accordingly to Johannsen *"Human-Machine interaction can be described as the communication and the interaction between human users and a machine, a dynamic technical system, via a human-machine interface"* [Johannsen, G. Human-Machine Interaction, 2007] Even though the domain tends to be more complex in practice.

In industrial applications, a visual feedback supplies component-oriented information, moreover additional views enhances functional knowledge. In this frame auditory support which supplies warnings, alerts, situational information is becoming more applied in Human-Machine Interfaces. Also Knowledge-Based systems are used more often to improve the functionalities and usability. [Johannsen, G. Human-Machine Interaction, 2007]

3. Research Questions

The study aims to question five topics that investigate the current status of the assembly line and the operators' interaction with it. The questions aim to attract attention to current developments at the technology and to the potential that can recover existing problems at the production line's interaction design and functionality issues at error proofing.

3. 1. What can be operator oriented solutions for the future of assembly?

Investigation of the subjects which are looking at the human aspects of assembly industry's current situation, limitation of current systems in favour of human centric approach and referral of literature in the industry that had been done.

3. 2. How do operators experience current tools?

Inquiries are done during the study questions how does the operators challenge the assembly equipment, tools and accessories. The feedback from the assembly industry focuses on how is the routine in assembly line, questioning of error proofing and the human factor at error-proofing.

3. 3. How is the usability of information displays at the assembly line?

Inquiries are done for the usability of information displays at the assembly line, which are the problems that operators face during these events. Investigation of design issues also included that they face during their routines.

3. 4. What is the performance feedback in assembly industry?

Study of any feedback related issues at the production line, such as supported by the display systems, the tools haptic feedback or visual feedback. Is there any work related culture that interferes with feedback or with any additional feedback systems that had been developed in-house, are some examples of the question.

3. 5. What are the possibilities for improvement by using upcoming technologies?

The initial investigation of the technologies in the scope referring to the background studies, their technical aspects, pros and cons for the assembly industry. However the studies weren’t focused in product development but more on knowledge building.

4. Method

4. 1. Research Approach

The overall research problem and the question is regarded as it has not being clearly defined. During this study it has been tried to capture the nature of the environment, to find the relevant data collection method and research design to investigate the topic. As also this study is being held in defined geographic regions and given limitations, it has been tried to gather preliminary information to generate relevant hypothesis for the research instead of making definitive statements. Thus *Explorative Study* fitted much well to the scope. [Stebbins R.A., 2001]

4. 2. Choice of methods

The interviews had been held at the factories where the environment was dynamic and challenging. These are not suitable for holding up production and question the process. Instead this environment provides most irregular and unexpected observations. Furthermore a stranger to the environment and to the process comes with a different perspective while observing. Also these environments are well supported with computer systems by individuals or teams. Due to these reasons, following a survey with a fixed set of questions would not be suitable for the study. On the other hand, contextual interviews are more suitable for these purposes.

4. 3. Contextual Inquiry

Contextual inquiries are designed to support the existing systems, extend their functionalities and ameliorate the work process of individuals, groups, teams or businesses through computer systems. [Schuler, 1993] The target systems of contextual inquiries consist of hardware, software, services and support.

This particular inquiry method has derived from a Scandinavian union oriented partnership in 70’s that aimed to empower workers and their skills by using new technologies to enhance them. However the workers in the factories were forced to use computer systems by the management team, so that their production could become more productive. However the users tend to have little experience with the computer systems thus this resulted as workers disbanding the systems. The researchers and designers got together to redesign the systems so that would ease the use of such state-of-art systems by workers with no prior knowledge with such systems. Even though the aim was user-oriented, the feedback process and revision of the technologies for optimisation had a missing link. Thus the researcher and designer alliance got together to involve users in the redesign process. This involved the workers direct feedback at the redesign process. Results are ended as a range of techniques such as Participatory Design. [Spinuzzi, 2002]

However Participatory Design aims to achieve industrial democracy such as direct involvement of workers in the design process during the production. Except in Scandinavian production, other competitor markets such as Asia and United States who are weak on labour unions prefers functionality more rather than democracy. [Bjerknes, 1987] This led to other sub-design methods that are focused to be less direct interaction with the workers for other markets but still they asked for being functional oriented. [Spinuzzi, 2002] For such cases the Contextual Inquiry, proposed by Karen Holtzblatt in 1993 had merged. The main goals by Karen Holtzblatt were listed such as; [Schuler, 1993]

- Identification of a process for designing systems that support users who engage in similar work in different business contexts and cultures.
- Identification of gathering information from users in the time available.
- Identification of means of gaining appropriate and helpful information about users' work.

The objectives are aimed to observe the work culture to find out organisational differences, difficulties, spell out both individual and team work's role at the production from the member's vision, and let them articulate the system's status and the flow of the interaction between the users and the difficulties that they face during their work.

4. 4. Informants and Workplaces

This inquiry is being used for the concept called Moving Target Rule which is the formation of socio-technical workplace, tends to change constantly with mental constraints result as adaption in cognitive work even though the domain constraints remain the same. [Dekker, 2003]

In different challenging industries such as automotive industries, the profound change is essential to the production line as new models are released and some are discontinued. The change affects the sub-suppliers such as Tier1 and Tier2 as they are very attached to the products from customers. This dynamism creates an inevitable Moving Target Rule.

As the confidentiality rule applies to the customers and employees of these customers that had inquiry, respecting the issues only numbers will be delivered in this study but no personal information, name, gender, age will be supplied. During the inquires two different countries has been visited along with five different companies which consist of three major automotive companies, one Tier 1 and one Tier 2 who also supplied to automotive industry with six customer plants in total. At their premises, there were five white-collar inquiries and fifteen blue-collar inquiries. From blue collar interviews there were seven out of fifteen were working as a team in different applications. The applications were consisted of assembly of highly important, called safety critical joints that require absolute error-proofness. In two factories, there were new products released thus the production was on change. Thus the workers were in a state of learning and teaching to the fellow colleagues. Also in one production line there were few products that were discontinued and so their production lines were shut down. As it can be seen from the environment, the Moving Target Rule was valid for each visited customer.

4. 5. Procedure

To decide on the visits, first of all the clients are being selected since their industries, applications and the products they use tend to vary accordingly the studies aim. The importance is the customers' spectrum of different scales as parameters in the inquiry. The identification of customers followed by contacting required contact people at the customer site. In automotive and assembly industry the contacts are mostly done through salesmen who have the right knowledge on interest groups at the customer site. In some other cases, contact people are found through related projects, consortiums, and research papers.

Thereafter the establishment of the visit day with customer, the visit is planned with an agenda such as what would be discussed and presented to the customer. Required invitations are sent to the interested people at the customer also via contact person at the customer premise.

During the visit, procedures that are performed can be grouped under three stages; orientation, interview and wrap-up. [Schuler, 1993] At the contextual inquiry visits, orientation begins with a meeting with the white collars. There would be initial presentation of the project and its aim. Then there would be a question session with the white collars. This step would continue with a feedback session on related experience that they had meanwhile. Then the next step will be to move on to the production line. There would be different teams of blue collar who would be working as a team or individually depending on the application. During each station the white collar would present what the application is and the aim and the problems that they have during the production. In most of the cases the blue collars contribute to the problems that they face at the application. Afterwards the interview part of the inquiry begins as the observation process where the blue collars are observed on their application for at least an hour. However the time limit can vary according to the factory's size, the number of applications that will be observed and the time limit.

Throughout the observation process the operators explains how they do the process, how they handle the tools, how they interact with the products. In a way it becomes as a master-apprentice relationship. During this period notes are taken and if recordings are being done, permissions are acquired. After the observations, the final part; the wrap-up comes in and the brief explanation of the application is done to the blue collar, questions are asked if there are any unclear ones. [Coble, 1995]

5. Results

After all the observations done at the factories, various answers had been received from assembly workers during and after the assembly process. Moreover as a part of the contextual inquiry methodology, observations have been done at the assembly facilities. These results can be categorised under five chapters;

- Usability and Accessibility
- Feedback
- Error-proofness
- Work Culture
- Sustainability

The reason of this categorisation can be explained with the usage of the tools, relation between the assembly equipment and the operators, evaluation of assembly process by assembly workers, mistakes has been observed, missing issues expressed by assembly workers, social relation between assembly workers and the reflection to their environment and finally use of resources efficiently and in a manner of possibilities of replenishment such resources.

5. 1. Usability

An example of usability application can be more illustrative such as at automotive industry, at the final assembly where the dressing of product is being done as on top of pure chassis, such as body, cable dressings, doors, interior other part of the assembly line as pre-assembly, engine dressing are done at other stations. These assemblies often require guidance instructions such as the model’s final state pictures, component part listings and sometimes each steps instruction. Guidance is either on paper or physical units displayed as show case. Interactive, one-to-one matching instructions are often missing in guidance. Also in some areas such as custom model painting, cable dressing, state check of critical parts are required to check manually, meaning that they miss an overlapping guidance system, challenging the final product quality.

It was observed that the guidelines are provided by a paper which is stationed on the body of the product and is produced from a database system that creates accordingly to the products details. The information that is supplied to the assembly workers are such as which components to be used at the assembly, what are the details about the product, identification number and additional details about the product. Such guidance system required operator to read the paper and go through the list one by one. In case he missed a product he had to find out the big product catalogue to figure out. This was an unusual case but as the production lines are flexible, newer products are always greeted to the assembly line; the chance always exists for operator to perform such task. Another issue is, there are more than one operator who works on products such as at final assembly and in these cases the guidance/detail list is placed on top of the product and each operator has to visit to check the list, in case the operator forgets a point, he has to visit the list one more time, besides creating more cognitive stress.

It was important to trace of the products along the results. In case of a problem the product should be able to be traced from stocks and have service or re-assemble work on it. In this case rework required a lot of operator guidance as each problem had a different level of performance required. Both operators and production engineers that is more simple, easy to setup operator guidance for such cases is very crucial as rework is a very challenging and critical part of the assembly expressed it. Required work involves layer of disassembly, finding and setting up correct values of torque and angle, finding the problem, fixing the problem and after all assemble again.

5. 2. Feedback and Accessibility

The operators' daily job routine is very attached to the assembly tools, the systems that they are communicating with and also with the guidelines they should follow. These systems are formed from quite complicated units such as an assembly tool communicating with the controller unit which also communicates with the database to submit the fastening results and also to fetch the correct settings for the current assembly job. The controllers are quite important units in this sense as being a gateway between the tools and the databases while supplying visual feedback to the operator of the each assembly with OK/NOK status, torque and Newton meter values. However in most of the factories the controllers have been placed out of sight, close to the ceiling or on a moving rail, making their accessibility visually impossible.

The result of each assembly is shown not only on the controller's screen but also on the LEDs of the tool. The LEDs supply the results however operators tend to hold the tools in many different angles during the assembly of different components and in some cases operators disregard LEDs as they can be out of sight.

Each factory is formed of many different assembly stations where the assembly challenges vary. Moreover in some stations the orders of the products that are being assembled are random which supplies the flexibility of the productivity to the companies. This flexibility creates new challenges at the assembly line to manage different assembly instructions for different products in a dynamic order. Besides there can be various brands of assembly products at the assembly line. Depending to the brand, the model of tool and controller, the results are shown to the operator as designed by the each company's mean of standards. In this heterogeneous feedback environment operators tend to create a cognitive mindset to work such conditions such as creating behavioural strategies to cope with different errors that they get from different brand of tools.

Observations showed that in most cases operators check OK / NOK results of the assembly from the tools haptic feedback which is a distinctive feedback source. However as it is told by the operators that newer technology equipped tools, such as battery tools, supply less haptic feedback for operators. The battery tool count of each factory varies as the business approach of each company decides how to focus to their production line but it is evident that battery tools become more and more a mean of standard at the assembly industry in everyday.

Often it is observed that a feedback report system was missing such as it required operator to mention the problem that had been faced to the production engineer where this required dependence to the operator to remind himself until he sees next time the production engineer. Besides production engineer is to solve such problems but this matter covers multiple production lines, which requires investigation and reporting constantly which makes the task to become redundant.

5. 3. Error-proofness

The aim of error-proofness is one of the biggest both in the business aim and the production aim. This provides far better quality products, less chance of rework, less chance of recall of products; more secure products that create eventually better brand promise and brand value.

So far observed biggest request is traceability of joints from the fastening station to the end product. This helps to understand major problems, deviations and trends about production, security and achieving more error-proof production. Therefore locating joint location is the bottleneck of this problem as no current tool location system can promise high accuracy. Even though the batch of joint fastening results can be saved, disguising joint in the batch is impossible. So far production engineers can assume the operators will follow estimated joint fastening order and can sort out numbers but no production engineer dares to estimates their results with such vague estimation. Although some fastenings requires an order strategy as product is required to be build in such way but there is no error-proof system that can correct, warn and report such situation.

Joint level traceability is not only required at the assembly line but also at the rework stations it is required to understand and evaluate joint’s specific value to disassemble. Each rework is a costly and long process thus minimising such errors and performing efficiently is a common request.

With joint level tracking, it is common to see each joint requires a specific value about fastening. The demands are due to automatism of such value based systems. So far it is achieved by socket selectors, where operator has to change tip of the tool which forces to change the fastening values, however socket selector has error-proof issues itself, as operators can borrow the tips from other stations, replace them with metal objects, which means trick the system, destroying error-proof production methods.

Another need of joint traceability is to detect if every joint is done correctly. Besides tools and controllers in some factories a manual check is being performed by assuring each joint is done and marked by pen, forces operators to check every step they have performed, count and mark. This work is very crucial as a mistake can have serious consequences with laws, business agreements and extra rework need.

Not only joints require traceability but also tools do require traceability. Such new generation tools as battery tools can be transported to any unit at the factory, assuring the location and activity of each tool at correct station is an important error-proof need, so far tool location systems such as carbon arms or new generation wireless tool location systems (TLS) promises this but accuracy, flexibility, agility and ease of modification are always problems at the production line.

5. 4. Work Culture

After all the visits to customer plants, many differences between at work environment had been observed. Even though the standardisation exists in these environments, many crucial differences exist. These significant differences that affect the work environment can be categorised as;

- Factory layout
- Assembly line setup
- Daily routine of an operator
- Assigned tasks density
- Tools supplied per operator
- Operators' peer interaction
- Company culture

In assembly industry, tools and products are essentially attached to the human factor as the end user performs and delivers the products by using the tools in specified environment.

Factory layout is laid out accordingly to the industry standards, laws, company standards and internal customisation. The complexity of factories is correlated with products that they produce. Some factories built multiple product assembly and some does product parts' assembly.

Besides being clean, secure and open-space driven structures, factories are very complex automation locations. Product assembly should flow line to line and the design of layout is strictly attached to ease of the flow. When a product is introduced to range, at the factory a lot of work is performed at line for integration, operator trainings, trial tests and finding the right time slot to perform these instances.

Essential company differences are seen the most at Tier 1 part supplier plants. Tier 1 suppliers are assigned as to be a manufacturer to the vehicle assemblers who are responsible for delivery of the finished assembly, product development and continued technology renewal. Visited Tier 1 part suppliers were responsible of making delivery to final assembly line; the product range was not very large. Thus the count assembly lines were less.

The line setup is focused on products that are produced. Some lines were fully automated with fewer operators involved and some were formed as only operators with stationary units where operators performs fastening with stationary tools. Such stations are observed at as mentioned Tier 1 suppliers. In comparison to final assembly, the line allows operators to walk-in and perform fastening in a dynamic moving line environment with long cable tools or battery tools with multiple operators involved working on the same product in the same time. The fastenings are performed in many angles with having the property of a long line.

The heterogeneous environment of plants supplies different possibilities to have much different type of tools. Battery tools are observed more and more on final assembly line to allow operator to be freer to move with the tool while stationary assembly units required armed tools to ease torque reaction and detect tool position. Cables are an issue at each station as the setup of each company has different policy to handle cables at stations. In general cables run on top of the assembly line but battery tools require no cables.

Cognitive and physical stress during the day at 8 hour shifts and operating differs much from operator to operator. Daily routine of operators required using low torque and/or high torque tools, lifting and holding up heavy objects. As observed working with higher torque tools without a proper ergonomic practice, the tool handling, performed practice duration and rest time cause ergonomic issues to operators and manufacturers have to allocate these highly skilled operators to low physically-stressed stations. Cognitive stress is related to the tools and process where the operator has to perform a complex task, follow an assembly order, ensure that the task was correct, and watch for the feedback such issues.

As mentioned some stations required multiple operators to perform a task. Such stations required a good communication between operators; not only they perform a task together but also assure that the task is performed correctly. Some conflicts do occur if there is no good communication between operators. There is not a system that can help operators to help to perform their tasks together or ease the process, guide.

Company culture is very important in the sense if creating efficient relation in the factory between stations and operators. The daily flow of human of the industry and some companies the quality of this relation more than others.

5. 5. Sustainability

It would be wise to say any industry would aim to have a sustainable approach to their business plans. In this sense there are some cases that had been observed that become a big challenge for assembly industry.

The lack of the feedback reporting system missing was a problematic issue where the engineer should make sure these issues do not happen again in the future. A possibility to see each fastening's results and details about the process however report system was missing which is very crucial to understand similar problems. Another problem that was faced to trace each joint at the batch and to understand which joint had a specific problem to sum the data for the each joint which would prevent future problems.

In the matter of environmental concern, there are much consumption of paper which is supporting the guidelines to the operators on each product where they can read the properties of the product, which components are required for the product and the following tasks is to be performed. Both from blue and white collared workers complained about this consumption and proposed new ways to perform this task instead of paper administration. Besides this guideline system does not provide enough guidance as it is just written down as text.

An issue that require more investigation came from the logistics department that they wanted to look into how to understand the shortage of stocks at each station. This also required a better communication with operators and their task that they perform on each product.

An important finding was to figure out ergonomic issues with work environment, health of operators and the spent time at each station they work. It was common that all of the companies that had been visited were strongly looking into how to have a better ergonomic work environment for operators, the damage of the assembly work to operators and the recover and reassignment of operators to less physical-work required stations. Some companies were trying to record the time of the each operator that has been spent during each job and relate the physical load to operator and then cycle the operator to a less physical loaded station where he can rest. However there was a lack of tracking of each operator and the work he performed real-time. The work could be estimated by pre-calculations but also this required a far more complex planning.

6. Discussion

Observations, interviews, reference papers, experience at the industry have supplied valuable information and consequently generated ideas to discuss. Strongest question that came out is how crucial these issues that are observed for industry and why? In production, operators form the backbone of the assembly industry. Any problem that is reflected to them has both short and long term consequences. Thus to offer more structural or technological solutions, it is essential that operators themselves should be understood with limitations and differences.

As in industry, production and market leans more and more to the Asia and both economical and cultural differences emerge in comparison to Europe. The production methods, aims, workload of operators and tasks are distinguishably differs. *[Policy Priorities for International Trade and Jobs, 2012]* Accordingly to the interviews that had been done with marketing department and project managers who work with Asian market, workload, competence and production methods are very competitive and require agile methods compared to European production where methods are standardised and labour rights are highly protected with union rules. However trade openings in Asia and the labour condition revisions consistently added values to operators in Asian market and these advancements being kept revised continuously. *[Policy Priorities for International Trade and Jobs, 2012]* In the light of such socio-economic differences designing the assembly line for operators would require a different methodology than Participatory Design. The benefits and limitations are noted in methodology section, such as a close relation between blue and white-colour, less hieratic structure, power and the will to drive from both R&D and production line to enforce the design process. Also the market that will use the product shouldn't be forgotten. As in case of Asia is the focus market the terms would require investigation of profile of operators, skill sets, tasks, workload. Moreover the customer side is very important to understand as what they require from the products.

Such as an example that can fit both the market needs and operator needs can be fulfilled with, is a training unit that maintains the knowledge management from operator to operator. The training unit will not just train the operators for the new products to boost their learning curve and have a faster speed of adaptation the production line but also increase the overall productivity. Human factors should be considered when a next generation operator guidance system or a training unit is planned, the core functionality should focus on faulty tool handling, stress or also management of operator cycling at stations. *[Johansson, L. Working conditions for older assembly workers] [Reiners, Stricker, Klinker and Müller, 1998]*

New technologies on tools such as shift from cable to battery tools bring increase in the mobility of the tools however it affects a significant change in the tool's reaction force. Tools prior than battery tools supplied different reaction forces which was a distinctive tactile feedback for operators. [Lindqvist, B., Ahlberg, E., and Skogsberg, L., 1993] The most natural feedback element, the first feedback that supplies direct information for operator as being decreased due to a technological advancement, quantitive results will be obvious the need of new feedback units. [Lindqvist, B., 1986] [Petzold, Zäh, Faerber, Deml, Egermeier, Schilp, Clarke, 2004]

Constant requests and interviews indicate that achieving error-proof production is the ultimate business aim. One of the bottleneck issues for the error-proof production is the tool location system. There are few available systems in the market that achieves the location data however the current issue is none of these systems can support a global precise data. As explained in the results section, systems are static or not precise enough.

Issues that have been explained from the shift of the industry to differences and change in operator profiles, advancements in equipment and changes due to and aim in achieving production goals, requires a new overlook to the assembly industry. Looking over the limitations and possibilities at the assembly line few techniques can be integrated. [Fasth and Stahre, 2008]

Techniques to help operators to achieve additional feedback, operator guidance and to approach closer to the error-proof production, Augmented Reality can be a definitive help.[Hou and Wang, 2010] Such technical benefits from a vision unit, a processing unit and a display unit as explained in the background. These components collect the visual information from the environment and analyse it to find the target objects and then overlay the visual information that is required to be put on the current image. This creates an information layer on top of the reality. Instead of altering the reality, operator can see the status of the process that he is doing or the status of the objects that he is observing, [Logan, Taylor and Etherton, 1996] allowing him to match information and achieving his goals faster.

As observed that physical feedback units may sometimes become problematic. Operators tend to not check the placed display systems in some environments, as they are placed ergonomically inaccessible. The operators had rejected boldly other means of feedback that is experimented such as auditory feedback, even in damaging and disabling the equipment anonymously. Such means of feedback, that is implemented to boost the efficiency by the factory engineers or company standards, creates a disturbance in social relations between operators as their performance and reputation are directly related. Instead of intrusive methods more personalised and unobtrusive ways should be adapted such as; Portable mini displays that operators can interact with to not just to check feedback but also guidance or/and preferably tactile feedback systems that tools are lacking more and more that can be integrated to mini display units. [MyCar EU Consortium Project, 2011]

7. Conclusion

Referring to the results, need of consideration and revision of current assembly lines' status is evident. The subjects that should be revised vary from hardware related topics to human-system interaction and environmental topics. Of course these issues can be handled individually and independently however an approach for such complex structural change should be considered from the roots and primitively.

As the end user and focus group of assembly industry, operators are far most important group when a revision is considered. It could be easily thought that more automated human-less system are to be focused and a mean of automation, in many areas at assembly there are needs of humans. The needs are as a reason of technical limitations, challenges and intactness at assembly line. Nonetheless, technical limitations surely will be overcome and more automated systems will be having their places in the factories however there will be always in need of operators at assembly, logistic, quality check, optimisation and most importantly at problem solving subjects as no such automation system can achieve such complexity in combination at a foreseen time-rage. [Copeland and Sylvan, 1999]

However the present situation of the operators requires some interaction with software furthermore the industry is shifting towards empowering software more and driving it as a core tool such as hardware used to be, meaning that software products are being seen more often. This will require a better look at Human-Computer Interaction to overlook the operators' interaction with tools, system and product. Moreover it would be wise to think over in the future on the tool portfolio, system capabilities, and experienced issues and to investigate if there is a need to come up with a unified and simplified interaction model on operators' side. [Tang, Owen, Biocca and Mou, 2003] On side, it shouldn't be forgotten that the considerations must be towards a sustainable system that would aim to support oncoming products, re-usage of existing products and creating less carbon footprint.

The possibilities that Augmented Reality (AR) can supply can be a tool of vision, visualisation and interaction. Such system requires a setup dependant highly to vision systems but the flexibility that can be integrated to cut down on the dependency could supply less on-spot guidance but feedback could still be achieved. [Thomas, Lee, Zhou, Menassa, Farrant and Sansome, 2011] As technological complex systems are required to be setup on a highly static way, they have been always a concern for industry to get it as a standard. However the complexities are investigated by the leader technology providers on lessen static setup requirement, complexities and adaptation of the technology. [Pentenrieder and Meier, 2006]

As an application in an unobtrusive way, AR may support 'on the spot' guidance such as how to assemble, more info on the product and the components, task information and status. [Radkowski and Stritzke, 2012] It is important that the design must consider to not being on the way of the operator, discrete and natural. Such systems may also support intuitive feedback to operator from his tasks performed in real-time and more information on demand such as if an error occurs, providing efficient and non-negative way as further considerations should be performed looking over the system and operators interaction, avoiding any negative impacts on operators social status as mentioned earlier. [Hou and Wang, 2010]

To be concerned, ergonomically decreasing vibration can be a significant achievement as that would effect operators' physical tensions and injuries, it would be wise to consider when developing future products, and haptic feedback is a reliable source of feedback for operators. [Petzold, Zäh, Faerber, Deml, Egermeier, Schilp, Clarke, 2004] Nonetheless the user profile in the factories should be well considered and the haptic perception with theirs' age. [Fritzche, 2010] [Johansson, 2011]

In addition to operator approach, investigation of such systems will go hand in hand with error-proof goal of production. Tool location precision require a further investigation and design of a more universal solution instead of a localised version, meaning that covering the whole factory instead of a small assembly station. Thus tools' location in the factory, on the production line, on the station would be known. The investigation of more precise and global tool location system solution may also provide data for creation of concept of Auto ID for Joints such as *JointID*. This may create new opportunities at the production line to connect software and hardware together as traceability of the assembly will be more unified along with identification of each joint and tracking of each assembly. Moreover avoiding wrong fastening orders, guiding the operator for correct order, providing feedback for correct fastening information for correct joint may be the other benefits of this concept.

Creating such systems may be seen as state-of-art setups formed from components not commonly available commercially, [Shedroff and Noessel, 2012] more as science fiction thus it is important to question regarding these limitations, studying user's interaction with the system, looking into use cases and start from the bar set by real world applications.

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