Assembly line & Sub-Assembly Stock process optimizations at “WTE Präzisionstechnik GmbH”

Master Thesis for achieving the Academic Degree Master of Science in Production Engineering & Management

By Oliver Kirschey


Supervisor KTH: Mr. Jerzy Mikler

Supervisor MAPAL: Mr. Bernd Dürr

Company: MAPAL Dr. Kress KG
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73431 Aalen
Germany
"Lean is the art to achieve challenging goals with simple methods"

(Lean Institute)
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ABBREVIATIONS

BOM – Bill of Material

WIP – Work in Progress

PCD - Poly-Crystalline Diamond

PCBN – Polycrystalline Cubic Boron Nitride

SA – Sub-assembly

CNC- Computerized numerical control

WPC – Workpiece carrier

Pcs. – pieces

EDM – Electromagnetic discharge machine

TPT – Throughput time

MC – machine

FA – Full-Automated

MA – Manual

Acc. – according to
1 FOREWORD

The present thesis was developed as a project as a free employee of the company MAPAL Dr. Kress KG in Aalen during the period of January 2012 – May 2012.

The topic of this thesis is the “assembly line & sub-assembly stock optimization at WTE Precision Tools GmbH”, which is a part of the MAPAL Group. The shown trust and the granted help, which I got from my supervisor Mr. Bernd Dürr and all the employees of MAPAL and WTE I would like to thank a lot.

Furthermore I would like to thank my supervisor at KTH Mr. Jerzy Mikler for the provided helpful information, improvements and chats.

Furthermore I would like to thank my parents, who supported me during my whole studies and made this master degree possible. Thank you.

Finally I want to mention, that this thesis contains company internal processes and should be therefore handled carefully. All parts of the Appendix consist of company internal data and are not allowed to be published publically. Thank you for your understanding.

Oliver Kirschey

Aalen, Germany, 15.05.2012
2 ABSTRACT

2.1 GENERAL

Decreasing takt times and frequently changing customer demands and customized products are the challenges of modern companies. To achieve these targets topics like increasing flexibility, decreasing the lead time and decreasing the lot size are just some of the measures companies work on to meet the customer demand. To be able to realize these topics, it is compulsory to have lean and working manufacturing processes. But the value stream is not ending in the manufacturing area. In the last step before the delivery, all the manufactured and bought components have to be assembled together.

Due to the Toyota Production System and further methods, which came from Japan, the main focus of a lot of companies and research has been to make the production as lean as possible, generate a continuous flow of products and eliminate waste. Very often the optimizations, which were performed in the previous stages, caused a bottleneck transfer to the assembly department, which has not been focused on that much. But especially this sector is important to finally grant the demanded customer quality.

Due to this fact, this master thesis will mainly focus on finding an appropriate assembly system; analyze the value streams during assembling, eliminate waste and decouple the sub-assembly stock from the assembly line to have a clear separation between assembly and logistics. The main target is to generate a lean assembly line, which can feed the high product variability and increasing customer demands for the future. Therefore topics like One-Piece-Flow, Kanban, decreasing Work in Progress (WIP) and Chaku-Chaku lines are just starting points to generate a future oriented assembly system.
2.2 INITIAL SITUATION

After the global demand break down in 2009 the German economy could record a great economic growth in the year of 2010 and 2011. Also the exemplary company in the Aalen region, Germany, MAPAL Dr. Kress KG has recorded continuously growth after the crisis and therefore is expanding both in site-related and product spectrum width. To grant a continuous growth, MAPAL decided to integrate the company WTE Präzisionstechnik GmbH into the MAPAL Group in the year 2009.

Due to the good groups situation in 2011, not only an extension of the actual production factory with a new building in 2012 in Aalen has been approved but also a new factory hall for WTE Präzisionstechnik GmbH, to be able to feed the heavy expected increase of the customer demand in the next 2 years. In order to optimize the production flow at WTE, an overall value chain process analysis has been performed and divided into several subprojects to get a modern and lean production chain. One of these subprojects is the above mentioned master thesis.

The goal of this master thesis is to develop concepts for the assembly area to reach the goal of a productivity increase of around 50 % over the upcoming two years. Due to the movement of the assembly area to the new factory hall in autumn 2012, this thesis should be the fundament for a new and modern assembly area at WTE. Therefore, several assembly line types should be investigated (from manual assembly line over Chaku-Chaku line to full automation line) if they bring the desired results or if other assembly layouts like assembly islands or single assembly places bring better results. Furthermore a concept of a better integration and organization of the sub-assembly stock and various work-flow optimizations should be developed. The constraints for the optimizations are that the productivity increase of 50 % should be achieved with the same amount of employees. The results of this thesis will be the foundation for the following implementation.
Assembly line & Sub-Assembly Stock process optimizations at WTE Präzisionstechnik GmbH

3 THE COMPANIES

3.1 MAPAL DR. KRESS KG

"MAPAL is today the major specialist worldwide for individual machining solutions with the highest precision and cost-effectiveness. We concentrate on the complete bore machining and on demanding milling and turning operations using PCD and PCBN tools. In close co-operation with our customers, perfect results are produced from innovative first class technology, comprehensive services and unique application know-how. The basis for these results is our engineering knowledge, the high level of qualification of our employees and the leading manufacturing quality within the corporate group. Our commitment to our German sites is marked by our drive for consistent quality and perfection. In close proximity to the customer, our subsidiaries ensure with their high level of commitment that our products and our know-how are available on markets all over the world."

(Quote by Dr. Dieter Kress CEO of MAPAL Dr. Kress KG (http://www.mapal.com)

3.1.1 HISTORY OF MAPAL

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</tr>
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<td>60s</td>
<td>New building in Aalen</td>
</tr>
<tr>
<td>1969</td>
<td>Entrance of the founder's son Dr. Dieter Kress in the company MAPAL</td>
</tr>
<tr>
<td>70s</td>
<td>Changing the production program to cutting tool inserts for to precise drilling operations</td>
</tr>
<tr>
<td>1977</td>
<td>Founding of the first subsidiary MAPAL USA</td>
</tr>
<tr>
<td>80s</td>
<td>Extension of the product spectrum and entrance in the automotive industry</td>
</tr>
<tr>
<td>90s</td>
<td>Extension of the product spectrum in PCD-tools, feeder and ISO-tools, chucks and multi-cutting edged reamers; founding of 18 subsidiaries worldwide.</td>
</tr>
<tr>
<td>Since 2000</td>
<td>Further internationalization of the group, to generate cutting solutions for manufacturing problems in direct contact with the customer.</td>
</tr>
<tr>
<td>January 2008</td>
<td>Entrance of Dr. Jochen Kress in the executive board.</td>
</tr>
<tr>
<td>2009</td>
<td>Integration of WTE Präzisionswerkzeuge in the MAPAL Group</td>
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3.1.2 DATA AND FACTS

The MAPAL Group 2011

3,400 employees worldwide, thereof ca. 2,000 in Germany
Turnover 2010: 310 million Euros
Establishments with regional production, sales and service in 21 countries
Sales agencies in 25 countries
CEO: Dr. Dieter Kress (acting partner), Dr. Jochen Kress

3.1.3 LOCATIONS

Figure 1 Locations of the MAPAL group
3.2 WTE PRÄZISIONSTECHNIK GMBH

“WTE Präzisionstechnik GmbH is manufacturer of high accurate drill chucks in the field of tool clamping technology. More than 60 employees provide perfect design and manufacture, together with a comprehensive service to cover their precision tools. We have achieved market leader position in Europe with the precision drill chucks. The new products of shrink- and hydraulic clamping technology will strengthen the philosophy of high precision. WTE is working on new products to increase the product range in the high precision clamping tools. Know-How, innovation and a motivated staff are the basic for the success during the last years. The two general managers, Peter Tausend and Hans-Ulrich Voigtländer decided for a production location in Germany and will increase the production plant in the next years together with MAPAL Group.”

Quote by the company website WTE Präzisionstechnik GmbH (http://www.wte-tools.de)

3.2.1 HISTORY OF WTE

2000: Opening of new production plant
2000/2001: Start with the new standard drill chuck
2001: Merging of WTE-Spanntechnik & AWT Präzisionstechnik to WTE Präzisionstechnik GmbH; Start with the shrink program
2002/2003: Increase of the product range for the shrink and high precision drill chucks
2005: Start with the hydraulic chucks
2006: Increase of all product ranges
2007: Award of honor from the town Ehrenfriedersdorf for developing the region
2008: Building and opening of a temperature controlled grinding hall
2009: Partnership with the MAPAL-Group; Start with the new HPH clamping chuck
2011: Member of the “tool-traders-partner.com”
2012: Opening of the new factory hall

Website: (WTE Präzisionstechnik GmbH, 2012)
3.2.2 PRODUCTS

In the following I will give you a short overview of the product groups of WTE Präzisionstechnik GmbH. The product groups CNC-Universal-Drill chucks, hydraulic chucks and shrink chuck will be explained in more detailed to provide the reader the most important background information to the main turnover and fast moving products.

![Product groups of WTE Präzisionstechnik GmbH](image1)

**3.2.2.1 HYDRAULIC CHUCKS**

By means of an Allen-“T”-wrench a hydraulic tension unit (thrust bolt, pressure pin, seal) compresses hydraulic oil. The created pressure causes a symmetrical deformation of the extension sleeve and the tool shaft is clamped with a high accuracy of cyclic running.

1 Allen-“T”-wrench; 2 thrust bolt; 3 pressure pin; 4 seal; 5 hydraulic oil; 6 hydraulic sleeve (Product Catalog, 2012)

![Hydraulic Chuck Scheme](image2)
3.2.2.2 SHRINK FIT CHUCKS

Heating the clamping area of the shrink fit chuck causes an expansion of the clamping bore and the tool can easily be inserted. After the cooling a very firm joint arises.

(Product Catalog, 2012)

3.2.2.3 CNC-UNIVERSAL-DRILL CHUCKS “WTE PRÄZISION”

The CNC-Universal-Drill-Chuck “WTE Prädision” unifies mechanical functions as well as easy handling within outstanding progressive technology. Precision demanded by engineers, technology departments and industry are performed by an improved precision of cyclic running and substantially higher tension. Clamping security, independent of rotation direction, brief clamping and preparation periods, very short construction and high rpms are the most striking characteristics. Standard is set by precise manufacturing and the unique WTE design.

(Product Catalog, 2012)
4 THEORY OF ASSEMBLY PROCESS OPTIMIZATIONS

4.1 THE PROCESS STEP ASSEMBLING

If we ask people about the assembly process, you will mostly hear definitions like “putting together some parts” or “final step in a production factory”. In fact, assembling is much more than just putting together some parts. Having control over the assembly process means having control of the final quality. The assembly process involves building together all relevant parts, which were manufactured or bought, performing quality checks and prepare the products for the logistics department. There the amount of single components can vary between a few and several thousand parts in the complex machine building or automotive industry. To grant a continuous flow of components and products in such working environments, it is essential, to group components to sub-assemblies over several levels until the final assembly, which is primarily consisting of already assembled subassemblies, can be assembled.

To maintain quality over the whole process, an inline quality check of specific features is inevitable and a clear structure in the assembly area in the factory is fundamental. If and only if these points are fulfilled and the necessary workstation are clearly defined, structured and documented, the workflow is optimized, the work in progress is reduced to a minimum and the assembly system is flexible to product changes, the company managed to install an assembly system, which is prepared for the challenges of tomorrow.

In earlier times, the assembly process was a process step, which was performed nearly 100% manually. Nowadays also in the assembly section, the influence of automation and robot arms is increasing steadily. But this development doesn’t come along without problems. The human being is much more flexible concerning movements, gripping and last but not least adjusting to extraordinary situations. Therefore a lot of efforts have been performed like “Design for Assembly” to adjust the products to the restrictions of the robots. Nevertheless it is important to evaluate the economic grade of automation depended on the products specifications, the quantities, the product variants and the needed flexibility in the assembly system.

In this master thesis, the actual assembly process, which is mainly performed manually, will be analyzed and checked which level of automation, is reasonable and economically depending on the cycle times of each assembly station, the amount per order, the total quantity and the accessibility of the product, to implement.
To reach the best flow of the products in the assembly area it is essential depending on the products (size, weight, and quantity), the available space and personal. Therefore several assembly systems have been evaluated.

**Figure 6 Orientation Help for the Pre-Selection of the Assembly System (Source: Robert Bosch GmbH)**

(Peter Konold, 2009)
4.3 SELECTION OF THE ASSEMBLY LAYOUT

After choosing the equivalent assembly system, the assembly layout has to be defined. Therefore the following topics have to be considered:

4.3.1 TYPE OF WORK ORGANIZATION

In this category, the work content has to be analyzed. In the assembly section there are several possible ways of assembling the final product.

The first one is the complete assembling on one workstation. In this type, the employee has the full responsibility of the product he/she assembles. This type can be performed either in one big workstation with several independent employees or several parallel working workstations, where each workstation covers the whole work content.

The second type is the work-sharing assembly. In this type, the whole work content is divided into several smaller working steps which are normally placed in one line. Here each employee or automat does only perform one small part of the whole work content.

The third type is the group work assembly. In this type it is typical to have a planned rotating working allocation. This type of assembly requires the highest qualification level of the employee but also makes the assembly work more flexible and interesting. Typical work contents can be component preparation, changeover, maintenance etc.

(Peter Konold, 2009)
4.3.2 LINKING TO THE IN-PLANT MATERIAL FLOW

Another criterion for finding the relevant assembly layout is the in-plant logistic system and the way of implementation to the assembly area. Therefore two places have to be considered: the incoming material and the outgoing material. Respective the assembly layout it is important that both material supply stations are in the direct working area of the employee to save non-value-adding walking distances. Two ways of providing the material to the workplace are supermarkets or component wagons. For the outgoing material, the flow should be either considered on the same side the material flows into the workstation or on the opposite site.

Figure 7 Ingoing and Outgoing Material Flow square system (acc. (Peter Konold, 2009))

Figure 8 Ingoing and Outgoing Material Flow line system (acc. (Peter Konold, 2009))
4.3.3 FLOW PRINCIPLE

The Flow principle describes the way the material flows within the assembly area. There you have to differentiate between three different main types.

In the “Main Flow Principle” the material flows in one direction from one workstation to the next.

In the “Side Flow Principle” the work content is distributed to 2 or more parallel working workstations.

In the “Circular Principle” the work pieces and the employees are both moving from workstation to workstation (convenient for more places than employees)

Most commonly the applied flow principles are combinations of the above introduced basic principles. These systems are designed as combinations of automated stations and manual work stations. When designing the flow principle in the assembly line it is important to take into account, that manual and automated workstations should be decoupled.
### 4.3.4 TYPES OF ASSEMBLY LAYOUTS

When finishing all the pre-studies, the final step is to define the final assembly layout. Generally you have to differentiate between 4 different types. Each of these types also differentiates whether the workpiece transportation is performed manually or on a workpiece carrier system. The workpiece carrier (WPC) solution is normally in combination with roller belts or similar.

<table>
<thead>
<tr>
<th>Basic shape</th>
<th>Without WPC</th>
<th>With WPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Square</td>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td>2. U-Form</td>
<td><img src="image3" alt="Diagram" /></td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>3. Line</td>
<td><img src="image5" alt="Diagram" /></td>
<td><img src="image6" alt="Diagram" /></td>
</tr>
<tr>
<td>4. Special Forms</td>
<td><img src="image7" alt="Diagram" /></td>
<td><img src="image8" alt="Diagram" /></td>
</tr>
</tbody>
</table>

*Figure 12 Types of Assembly Layout (acc. (Peter Konold, 2009))*
5 SUB-ASSEMBLY STOCK ANALYSIS AT WTE

The sub-assembly stock is the upward step before the assembly area. In this stock all the components for all product variants are stored. Next to the components store the sub-assembly stock also contains the main bodies of all products. These main bodies come out of the manufacturing area go to an external hardening process and are then temporary stored here as well until a customer order is available.

The stock system at WTE itself worked quite well though the main topic in this part of the thesis was to optimize the integration in the whole manufacturing and assembly workflow. There several changes have been applied.

5.1 ACTUAL SUB-ASSEMBLY STOCK SITUATION

In the WTE stock management we have to differentiate between two types of products: The customer orders special customer made clamping solutions or standard stock products. Dependent on the availability of a customer order, the batch of main bodies are either going to stock (catalogue products) or are forwarded directly to the assembly area where the final product is assembled.

In case of all product categories, the employees in the assembly area are responsible for the assemble tasks but also for picking their components out of the sub-assembly stock. During the time of the picking, the worker is not available for any assembling task and the orders are waiting as WIP in front of the assembly workstation.

Sub-assemblies are at the moment assembled in big batches by trainees. This additional capacity cannot be resourced any more in the new factory hall and therefore a new work distribution concept had to be developed.
5.2 FUTURE STATE OF THE SUB-ASSEMBLY STOCK

In the new plant, the stock is clearly structured dependent on the quantity of components needed per year and the component category. Dependent on these two factors it is possible to arrange the huge shelf rows in a way, that the searching and walking time to pick the needed parts can be reduced to a minimum.

In the future, and dependent on the ongoing development of the sales, a purchase of a Megamat is considered as well to stock all the parts which are needed in a less regular time periods can be stored. The Megamat allows us to store the parts not only on the shop floor which blocks a lot of space but using the height of the factory hall as well.

In the future layout the work content of the assembly area and material logistics are clearly separated from each other. This material logistics part will contain tasks like preparing the sub-assemblies dependent on the customer order, managing the customer orders and providing the right customer order with the correct components to the relevant assembly workstation (taking into consideration the final delivery date and the changeover of the machines or fixtures). This job will later be performed by 1-2 fixed persons who are responsible for the logistics. Through this measure the workers on the assembly work stations will always know, which product they have to assembly next, have all relevant components for the customer order available.

As a result of the better integration and coordination of the sub-assembly stock with the assembly area, a quality increase (more focus on the main work), a better capacity planning and last but not least searching time and therefore unproductive time could be reduced.
6 ASSEMBLY SITUATION ANALYSIS AT WTE

6.1 METHODOLOGY OF THE SITUATION ANALYSIS AT WTE

The situation analysis is one of the most important steps in every optimization project. Depending on these data, future optimizations, economic and investment calculations can be performed and evaluated. Therefore a precise and complete analysis of the actual state has to be performed. Therefore several methods have been established in various optimization projects. In the following list you will find a short listing of present state analysis tools and methods which have been taken in this project.

<table>
<thead>
<tr>
<th>Method</th>
<th>Goal</th>
<th>Data type</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spaghetti – Diagram</td>
<td>Evaluate Value Stream and Layout Design</td>
<td>Time / Distance</td>
<td>General</td>
</tr>
<tr>
<td>Video - Analysis</td>
<td>Evaluate assemble process, times, non-value adding activities</td>
<td>Time / Process steps</td>
<td>General</td>
</tr>
<tr>
<td>Brainstorming</td>
<td>Evaluating improvements by the assemblers</td>
<td>Optimization basics</td>
<td>General</td>
</tr>
<tr>
<td>Product Analysis</td>
<td>Find common workstations/components for all product groups</td>
<td>BOM / assembly groups</td>
<td>Hydro/Precision/Shrink Chucks</td>
</tr>
<tr>
<td>Analysis of the sub-assembly stock structure</td>
<td>Optimizing the logistics between assembly area and sub-assembly stock</td>
<td>Time / BOM</td>
<td>Logistics</td>
</tr>
</tbody>
</table>
6.1.1 SPAGHETTI-DIAGRAM

To collect data about walking routes during the production of a product, the spaghetti diagram helps to figure out main walking distances. Therefore the different workstations are schematically displayed in a plant layout plant and the walking ways of the employees over a predefined time period are shown\(^1\). In this thesis this method was on the one hand used to evaluate the walking distances along the whole production value stream of the different product groups (from raw material to delivery) on the other hand to find workplace and workstation layout improvements within the assembling area.

6.1.2 VIDEO – ANALYSIS

Another tool for recording the present state in a company is with the help of a video analysis. This tool can be a highly effective way of evaluating handling and assembling steps and can help to get the relevant times needed for later improvement evaluations. Important in the video analysis is to get the permission of the companies head and only record the process steps. This permission is linked to the labor union in Germany which ensures, that employees are not recorded during their work to evaluate and record their working performance. Furthermore it is important to explain the function of this tool to the employees as well and just record the hands of the workers. If all these requirements are given, the video analysis can be used to figure out non-value adding working steps, walking distances, process times and workstation improvements. Furthermore it helps to review the relevant assembling steps over and over again to get familiar with every detail of the processes. For this thesis it was used for getting all the above mentioned data and helped a lot in reviewing the processes. Due to the fact that I was employed by MAPAL in Aalen to analysis the assembly area in one of their subsidiaries WTE Präzisionswerkzeuge, the thesis was managed from Aalen. During the thesis, several visits to WTE have been performed to analyze, manage and implement various measures. By using synergy effects between MAPAL Aalen and WTE in the assembly and manufacturing area, already proven methods could be partly transferred and modified to the WTE working environment.

\(^1\) (Blom Product Development Team, 2007, p.53)
6.1.3 BRAINSTORMING

Brainstorming is an ideal tool for collecting process and product knowledge of the employees. Meetings with the relevant employees have been performed to ask them, which improvements they would perform, if they could. Especially with the freedom of designing the working area completely new in the new built factory hall generated an atmosphere of bringing forward the employees improvements and experiences to help me designing the new working area.

6.1.4 PRODUCT ANALYSIS

The basic of all optimization in the assembly section is the analysis of the products to assemble. Therefore it is not only important to break down the final product to all its single components but also to analyze how these components are provided to the actual assembly section. In the this thesis, the product structure was first broken down via the SAP bill of material and later completed with the source information of each component (purchase part or self-manufactured).
6.2 PRODUCT GROUPS

The actual product spectrum of WTE Präzisionstechnik is build up on the three main volume product groups “Shrink Fit Chucks”, “Hydraulic Chucks” and “CNC-Universal-Drill Chucks (WTE Präzision)”. Furthermore the product spectrum contains HPH chucks, which are a subgroup of the hydraulic chucks, capable of resisting higher temperatures and oil pressures, the WTE NC-Drill-Chucks, which is the standard NC-Drill Chuck which are providing a concentricity of 0,05 mm instead of 0,03 mm and finally the Drill Heads, which can be exchanged at the CNC-Universal-Drills.

Due to that distribution, the main focus of this thesis will be on the assembling of these three product groups, synchronizing common workstations and optimize the logistics of the components supply.
6.3 PRODUCTION KEY FIGURES AND FORECASTS

With the entry in the wholesale distribution and the fusion with the MAPAL group, WTE has to increase its product output massively. In nearly all sectors, quantity increases of nearly 50% over the next two years are expected. Linked to this development, the productivity of both the manufacturing area and the assembly area has to be increased. In the middle of 2011 first improvements have been performed to adjust the manufacturing area to the new goals. This steady productivity increase is still in progress and will cause a bottleneck in the assembly area, if the improvements would not be transferred to this area as well. Therefore the goal of this thesis is in combination with the new factory hall, which will be finished in the end of July 2012, to design a complete new assembly area, which is capable of handling the productivity increases of the next two years.
6.4 PRODUCT COMPONENTS

6.4.1 HYDRAULIC CHUCKS

- **Hydraulic Chucks**
  - SK30
  - HSK 32
  - SK40
  - HSK40

- **Adaptor type**
  - SK50
  - HSK50
  - HSK63

- **Clamping diameter**
  - Ø6
  - Ø8
  - Ø10
  - Ø12
  - Ø14
  - Ø16
  - Ø18
  - Ø20
  - Ø25
  - Ø32
  - Ø40
  - Ø50
  - Ø63
  - Ø80

- **Final Assembly**
  - Sealing bolt
  - Steel ball
  - Air-vent screw
  - Cylinder bolt
  - Pressure screw

- **Main body**
  - Ø3 mm
  - Ø4 mm
  - Ø6 mm

- **Single Components**
  - Upper housing
  - Lower housing
  - bushing
  - Hub
  - Copper wire bonding

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Oliver Kirschey 860515-T656  
KTH & MAPAL Dr. Kress KG
6.4.2 SHRINK FIT CHUCKS
6.4.3  CNC-UNIVERSAL-DRILL CHUCKS

Main body

<table>
<thead>
<tr>
<th>Clamp diameter</th>
<th>Adaptor type</th>
<th>Chuck length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ø8</td>
<td>SK30</td>
<td>80 mm</td>
</tr>
<tr>
<td></td>
<td>HSK32</td>
<td>120 mm</td>
</tr>
<tr>
<td></td>
<td>HSK40</td>
<td>160 mm</td>
</tr>
</tbody>
</table>

Single components

- Spreader jaw
- Clamping claws
- Shell
- Pinion
- Pinion bolt
- Lid
- Thrust member
- Thrust washer
- Bevel gear
- Spindle Standard
- Spindle IK
- SA spindle
- SA thrust member
- BT30
- BT40
- BT50
- Ø8
- Ø13
- Ø16
- Ø50
- Ø63
- Ø110
- Ø160

CNC-Universal-Drill Chuck

Ø8
Ø13
Ø16
SK30
HSK32
SK40
HSK40
80 mm
120 mm
160 mm
6.5 ANALYSIS OF THE ASSEMBLY PROCESSES

6.5.1 SHRINK FIT CHUCKS

The shrink fit chucks are the main fast moving products of WTE. Due to its single component manufactured body, the assembly part is reduced to a minimum. The whole value stream starts in the manufacturing area, where the main body is produced. In an external process, the chucks are hardened and after an inbound control, the bodies are glass bead blasted to eliminate the oxide layer, induced by the hardening process. The next process step is a grinding action to grind the outer and inner diameter of the chuck to the final specifications. After a 10% sample inspection of each lot, an order neutral, unique ID is marked via laser into the main body. In a next process step, the assembly leader checks, if a customer order is available or not. In WTE we have two different types of production, produce to stock (mainly catalogue products) and produce to order (customer made products, mainly small design adjustments). Depending on this status, the main body is either put to the sub-assembly stock or the customer order specific specifications like, logo, customer ID are laser-marked into the main body and then given to the first assembly station. There the stop screw is manually inserted into the tool clamping hole and if necessary (only for internal cooling chucks) screws for locking the cooling channel are installed. Depending on the type of the shrink fit chuck (with internal cooling channels or not) the body goes to the electric discharge machining (EDM) workstation. After the EDM process the chucks are sent to a balancing process. This is performed at every shrink fit chuck, to grant the customer set balance quality. If the balance is approved, the product is oiled again to prevent oxidation, packed and sent to the customer.
Figure 15 Process Flow Chart of shrink fit chucks
6.5.2 HYDRAULIC CHUCKS

The hydraulic chucks are clamping the tools by establishing a specific clamping pressure in the clamping bush. Therefore a complex oil filling and adjusting process has to be performed during the assembling. In the beginning the main body and the bush are independent parts which are manufactured and then glass bead blasted. The bushes are manually prepared with three brazing rings and after a cleaning process of the main body with alcohol pressed into the fitting of the body with a lever press. This cleaning process is necessary to ensure a completely fat free surface during the brazing process. In the following external process step the part is vacuum hardened and at the same time, the bush is brazed to the main body due to the melting process of the brazing ring during hardening. After the part is back in the factory, a leaking test is performed, if the brazing process has sealed the bush-main body bond correctly. If the test is successful, the part is again glass bead blasted, to remove the oxidation layer, created by the hardening process. In the next process step the clean parts are sent to the honing area, where the hole for the oil pressure adjustment bolt and seal will be honed to the final specifications. The following step is the filling of the oil chamber, to grant the right clamping pressure without air bubbles. After filling the chuck with the right amount of oil, assembling the seals and screws to close the oil chamber and performing a clamping test with the maximum available pressure, the part goes to the grinding area, where it is manufactured to its final specifications. From the grinding area, the chuck goes to the assembly area, where the unique WTE ID is laser-marked onto the body. In a next process step, the assembly leader checks, if a customer order is available or not. Depending on this status, the main body is either put to the sub-assembly stock or the customer order specific specifications like, logo, customer ID are laser-marked into the main body. In the next assembly process the stop screw (for the tool-length adjustment) is manually inserted into the tool clamping hole and if the customer whishes a radial adjustment mechanism for adjusting the height of the stop screw is assembled. In a final step before the sending, a balancing process is performed at every hydraulic chuck, to grant the customer set balance quality. If the balance is given, the product is oiled again to prevent from oxidation, packed and send to the customer.
Figure 16 Process Flow Chart of hydraulic chucks
6.5.3 CNC-UNIVERSAL-DRILL CHUCKS “WTE PRÄZISION"

The CNC-Universal-Drill Chucks are granting highest concentricity with \(<0.03\) mm (when clamping with 8-15Nm depending on the diameter). To be able to keep this concentricity, a complex assembling and concentricity check process has to be performed. The optimization of these processes will be one of the main focuses of this thesis due to its enormous time saving potential.

Before the chucks can be assembled, the main assembly groups and components have to be provided from the sub-assembly and components stock. This allocation of the components and assembly groups is happening in big boxes order independently. Just the main components like the main body and the shell are taken out of the sub-assembly stock order specifically.

The first step in the assemble area is to lubricate the assembly group spindle to grant a fluent drive of the clamping gear. In a next step the assembly group thrust member is taken and assembled on the assembly group spindle. This is then turned to the right assemble position. After putting the assembly group on an assembly block, the spreader cone is placed over the spindle. In a next step, the clamping jaws, which are a mass purchase product, have to be deburred. This action is necessary because some surfaces on the clamping jaws are exactly grinded and still have a small burr, which could cause an imprecise slide of the jaws along the spreader cone when clamping the tool. After this process step the three clamping jaws are inserted in the slots of the spreader cone and the shell is put over the whole assemble group. Then the assemble pinion and pinion bolt are assembled into the product. These two parts will later be replaced by new unused components and are just acting as dummy components for adjusting the concentricity now. In a following concentricity measurement, the chuck is tested to grant a concentricity of 0.03 mm. This is being performed with 3 different sized gauge rods which grant a complete concentricity in three different positions of the spindle. This measurement is performed with two measurement clocks to prevent of having a run-out in the chuck. If the concentricity is not approved, the assembler decides which clamping jaw causes the problem (measuring needle reaches its maximum amplitude on the opposite side of the “bad” jaw), disassembles the whole chuck again, regrinds the relevant jaw, and assembles the chuck again. If this process was not successful, a complete change of the single components like spindle, jaws are considered and changed as long as the concentricity is granted. If the concentricity is approved, the product data and concentricity values are entered into an Access databank, the right labels set up into the label printer and the cus-
A customer specific label is printed. On the last work station, the assemble pinion and the pinion bolt are removed and replaced by the final components, which are then glued into the chuck. Depending on the customer wish, a final balancing action is performed. Most of these chucks are not balanced on the balancing machine any more. Before the chuck is delivered to the customer it is oiled to prevent from oxidation, hermetically sealed into foil and packed into a plastic bush.

![Assembly Components Universal-CNC-Drill Chuck](image)

**Figure 17 Assembly Components Universal-CNC-Drill Chuck (acc. (Product Catalog, 2012))**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Shell</td>
<td>11.</td>
</tr>
<tr>
<td>2.</td>
<td>Spreader cone</td>
<td>12.</td>
</tr>
<tr>
<td>3.</td>
<td>Clamping jaw</td>
<td>13.</td>
</tr>
<tr>
<td>4.</td>
<td>Spindle</td>
<td>14.</td>
</tr>
<tr>
<td>5.</td>
<td>Pinion</td>
<td>15.</td>
</tr>
<tr>
<td>6.</td>
<td>Bevel gear</td>
<td>16.</td>
</tr>
<tr>
<td>7.</td>
<td>Thrust member</td>
<td>17.</td>
</tr>
<tr>
<td>8.</td>
<td>Pinion bolt</td>
<td>18.</td>
</tr>
<tr>
<td>9.</td>
<td>Lid</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Thrust washer</td>
<td></td>
</tr>
</tbody>
</table>

This list shows all components which might apply to a product. Not all products contain all the components, especially these, which are necessary for internal cooling like the o-Rings.
Preparation of the Shell

Assembler takes main body out of the sub-assembly stock

Spreader cone with internal milled slot is prepared for assembling

If the drill chuck is with coolant supply, pre-assemble of the relevant seals

Assembling the thrust washer on the thrust member

Components and assembly groups are provided on a wagon

Assembly group spindle lubricated

Remove the relevant amount of material in the clamping jaws (experience)

Put the relevant clamping jaw into the grinding device

Decide which clamping jaws have to be reground by evaluating the metering needle amplitude

Check concentricity with accuracy of 0.05 mm with gauge rod 13 mm

Complete Dis-assembly

Concentricity of 0.03 mm is given?

Enter the product data + customer order in Access database

Set-up the right label type and printing of the label

Assemble final pinion

Glue the lid and the pinion bolt

Assemble customer specific o-ring

Balancing wished?

Oil the CNC-Universal-Drill Chuck

Hermetically seal the chuck into foil

Packaging into plastic bushes

Delivery

Laser-marking of the shell with the WTE ID, logo and adjustment ring

Spindle is turned into its assemble position

Assembly is put on an assembly block

Spreader cone is assembled on the spindle

Deburring of the clamping jaws

Insert the clamping jaws in the slots of the spreader cone

Put the shell over the spreader cone

Assemble pinion and pinion bolt are assembled

Screw the assembly group shell on the main body

Tighten the assembly group shell with the main body

Place the drill chuck into the concentricity measurement instrument

Check concentricity with accuracy of 0.03 mm with gauge rod 13 mm

Balancing wished?

Figure 18 Process Flow Chart CNC-Universal-Drill Chucks
Due to the rapid expansion of WTE Präzisionstechnik in the previous years, new machines have been bought and put into the factory just considering the factor of space left. This resulted in a quite chaotic way of the value stream with a lot of walking distances between each process step. With the building of the new factory hall, the complete layout planning of the old and the new factory will be redesigned based on the idea of an optimum value stream and minimized walking distances. The analysis of the actual situation resulted in the following average walking distances for the three main volume product groups per item:

- Shrink Fit Chucks: 192m / 156m --- 139s / 113s
- Hydraulic Chucks: 576m – 416 s
- CNC-Universal-Drill Chucks: 96m – 74s

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Station</th>
<th>Distance [m]</th>
<th>Time [s]</th>
<th>Nr.</th>
<th>Station</th>
<th>Distance [m]</th>
<th>Time [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Mainbody to Hardening</td>
<td>25</td>
<td>18</td>
<td>8-9</td>
<td>Laser-Marking Custom to EDM</td>
<td>18</td>
<td>13</td>
</tr>
<tr>
<td>2-3</td>
<td>Hardening to Blasting</td>
<td>20</td>
<td>15</td>
<td>9-10</td>
<td>EDM to Balancing</td>
<td>21</td>
<td>15</td>
</tr>
<tr>
<td>3-4</td>
<td>Blasting to Grinding</td>
<td>13</td>
<td>10</td>
<td>10-11</td>
<td>Balancing to Oiling Chuck</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>4-5</td>
<td>Grinding to Quality Control</td>
<td>58</td>
<td>42</td>
<td>11-12</td>
<td>Oiling Chuck to Foil Packing</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>5-6</td>
<td>Quality Control to Laser-Marking neutral</td>
<td>12</td>
<td>9</td>
<td>12-13</td>
<td>Foil Packing to Delivery</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>6-7</td>
<td>Laser-Marking neutral to Assembly Screws</td>
<td>3</td>
<td>2</td>
<td></td>
<td>Sum with coolingholes</td>
<td>192</td>
<td>139</td>
</tr>
<tr>
<td>7-8</td>
<td>Assembly Screws to Laser-Marking Customer</td>
<td>3</td>
<td>2</td>
<td></td>
<td>Sum without coolingholes</td>
<td>156</td>
<td>113</td>
</tr>
</tbody>
</table>

Table 1 Distances Shrink fit chucks
Assembly line & Sub-Assembly Stock process optimizations at WTE Präzisionstechnik GmbH

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Table 2 Distances Hydraulic Chuck

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Station</th>
<th>Distance [m]</th>
<th>Time [s]</th>
<th>Nr.</th>
<th>Station</th>
<th>Distance [m]</th>
<th>Time [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>Main body + bush to blasting</td>
<td>20</td>
<td>15</td>
<td>11-12</td>
<td>Honing to Oil Filling</td>
<td>85</td>
<td>61</td>
</tr>
<tr>
<td>2-3</td>
<td>Blasting to Washing</td>
<td>5</td>
<td>4</td>
<td>12-13</td>
<td>Oil Filling to Grinding</td>
<td>75</td>
<td>54</td>
</tr>
<tr>
<td>3-4</td>
<td>Washing to Copper Ring on bush</td>
<td>63</td>
<td>45</td>
<td>13-14</td>
<td>Grinding to Laser Marking</td>
<td>70</td>
<td>50</td>
</tr>
<tr>
<td>4-5</td>
<td>(CR on bush to Press small)</td>
<td>2</td>
<td>1</td>
<td>14-15</td>
<td>Laser Marking to Balancing</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5-6</td>
<td>CR on bush to Press big</td>
<td>10</td>
<td>8</td>
<td>15-16</td>
<td>Balancing to Oiling Chuck</td>
<td>15</td>
<td>11</td>
</tr>
<tr>
<td>6-7</td>
<td>Press big to Hardening</td>
<td>60</td>
<td>43</td>
<td>16-17</td>
<td>Oiling Chuck to Foil Packing</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>7-8</td>
<td>Hardening to Quality Control</td>
<td>55</td>
<td>40</td>
<td>17-18</td>
<td>Foil Packing to Delivery</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>8-9</td>
<td>Quality Control to leak test</td>
<td>20</td>
<td>15</td>
<td></td>
<td>Sum</td>
<td>576</td>
<td>416</td>
</tr>
<tr>
<td>9-10</td>
<td>Leak test to Blasting</td>
<td>68</td>
<td>49</td>
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</tr>
<tr>
<td>10-11</td>
<td>Blasting to Honing</td>
<td>20</td>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3 Distances CNC-Universal-Drill Chuck

The above mentioned values are evaluated out of the plant layout drawings which can be found in the Appendix. The times have been calculated with an average walking speed of 1.4 meter per second.
6.7 ACTUAL SITUATION OF THE ASSEMBLY AREA

The actual assembly area is split into several areas: The Universal CNC area, where 4 employees are responsible for assembling the Universal CNC Drill Chucks; the balancing and marking section where all products are laser-marked and if needed balanced; the repair area and the Hydro section.

In the Drill Chuck area, the major assembly layout is represented by single workstations which are all working independently from each other. The customer orders are printed and cumulated in an ideal changeover sequence (order horizon of 1 week are taken into consideration) and the main bodies are taken out of the stock on an order wagon. These order wagons are then placed in a free space in the assembly area. The problem in this work content preparation system is that due to the lack of space in the assembly area. The worker always has to search for the next order to assemble. This results in waste of time by searching, walking and taking out single components out of the stock. This wasted capacity could be used in a more efficient way to overcome the shortages in productivity.
In the balancing and marking section 2 employees are bound for balancing the chucks. This process is completely handled manually and with a lot of changeovers between the balancing machine and the drilling machine to remove the excess material. In the future this area will be structured in 2 cells, where several work contents can be performed simultaneously and will therefore result in a cycle time reduction of these processes.

The hydraulic chucks section is a good example of the fact that new developments have not been implemented considering the overall value stream of the product. As shown above, this product group contains the most non-value adding times (walking distances). With the fact that in the new production hall, a whole area will be assigned to the hydraulic chuck assembly process, a better workflow could be installed. More details to the new workflow you can find in Chapter 9.3.3.

The main target when designing the new assembly area in the new hall is first to set a preset area, where a logistic person can prepare all order wagons in a ordered way and therefore every section knows exactly where to find the next order wagon and when the final delivery date is. Secondly, with the implementation of a cell structure and half-automation, a better and faster work flow will be implemented. Third, several separate workstations now will be combined in one universal workstation (i.e. complete assembly of a CNC-Universal-Drill chuck on one workstation instead of two) to eliminate walking distances which are not necessary.
At the end of the actual situation analysis, several starting points for process optimizations have been found. These optimizations have been categorized into 2 categories: the optimizations which can be implemented immediately to improve the throughput time actively before the movement into the new factory hall to be able to handle the increasing need for capacity even before the movement. All the other improvements will be implemented with the complete concept for the new factory hall. All measures have been evaluated depending on their implementing or investment costs, savings and difficulty to implement. Out of these first estimations an implementation ranking has been worked out (total amount of improvement measures: 50). The top 10 measures which are expected to bring the best time savings in the places with the highest capacity need with the lowest costs and low implementation difficulty have been selected to be implemented first. In the following diagram you can see the Top 10 selection.

By implementing these measures the overall goal was to reduce the cycle times of the assembling process to be able to meet the increasing demand on products with improved capacity situations.

Next to this action plan, further detailed improvements respective workstation design and material flow are performed as well.
8 OPTIMIZATIONS OF CURRENT PROCESS FLOW

8.1 EDM – CHANGEOVER OPTIMIZATION

8.1.1 DESCRIPTION

The EDM is used at WTE Präzisionstechnik to erode deep coolant and hydraulic holes after the hardening process of hydraulic and shrink fit chucks. Due to the depth and the fact that the chucks are hardened already, drilling of the oil (hydraulic) and the cooling channels (shrink fit) is not possible any more. This results in relatively high cycle times for each hole and a lot of changeovers and readjustment of the machine equipment. To grant a good flow of the chucks to the downstream assembly area, especially reducing the high changeover times were an important point. Due to the fact, that the clamping devices are self-constructed with a lot of screwing operations several instant optimizations have been performed.

8.1.2 PROBLEM

To complete one cycle of eroding, the employee has to switch the position of the product twice by 180° (2 opposing holes with contrary eroding angles). After eroding these two holes, the employee has to perform a complete changeover and readjustment of the fixture, to erode the horizontal holes. The whole changeover procedure takes around 9 minutes per part including checking the angles of the eroded channels in the quality control. The problem of the actual solution is that the angle adjustment process is not fulfilling the angle accuracy, which is demanded in the design drawing. For example: The angle is preset a little bit bigger than demanded (reason: capability of fine adjustment). Then the demanded angle is set in an optical angle measurement device. This device is then positioned on the rotatable table. In the next step, the worker is adjusting the angle of the fixture with a hammer as long as the measurement device and the electrode of the machine are parallel. The problem of this parallelism is that it is completely based on the workers evaluation if the parallelism is reached or not (eye evaluation). By having such an uncertainty in the measurement it is compulsory to let the angle check in the quality department, after the first part is finished.
8.1.3 SOLUTION

The solution for this problem is a sine table. This sine table is traversable by 45° and can be set to the final angle by gauge blocks. To get the right angle a table is attached to the workstation where the exact setup of the gauge blocks for the demanded angle is defined. These sine tables will be installed twice to cover the eroding area for the horizontal and vertical holes.

On top of these sine tables is one rotatable dividing head and one 90° dividing head installed. On top of this comes the EROWA 0-point-clamping system.

This clamping system ensures, to perform the unproductive changeover times during the up-time of the machine. Therefore the only changeover operation is to exchange the completely prepared EROWA adapter. The clamping system works via compressed air which is pushing balls of the clamping ring into the slot of the adapter where the part is clamped onto. By releasing the air pressure, the balls go back to its original position and release the adapter for the changeover.

By having this solution, not only a highly precise angle setup can be granted but also a reduction of the machine down time due to changeover.
8.1.4 EVALUATION

With this solution, the uncertainty of the angle adjustment, the walking distance to the quality control and the checking can be eliminated. Furthermore a time reduction for the angle adjustment within the changeover process from 9 to 2 minutes could be achieved. Next to the time saving also the process stability could be increased and the probability of wasting one dummy product with wrong angles could be eliminated. By implementing the 0-point clamping system not only the repeatability is granted but also the possibility, that the whole changeover will be performed in the up time of the machine. The actual down time due to workpiece changing can be reduced to a minimum. The following savings for the changeover has been estimated:

Old Changeover Time:

<table>
<thead>
<tr>
<th>Process Time [min]</th>
<th>Savings Angle adjustment</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

By adding all the relevant factors (Angle adjustment, better changeover) total savings at the EDM workplace of 90 hours per year can be reached. That results in a payback period for the necessary investments of 4 years.

### Table 4 Savings Angle Adjustment

<table>
<thead>
<tr>
<th>Name</th>
<th>Hoursly Rate EDM 30,6 €/h</th>
<th>Process Step time [s]</th>
<th>Process Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle rough setup</td>
<td></td>
<td>35</td>
<td>Angle adjustment with sine table</td>
</tr>
<tr>
<td>Setup of the optical measurement device</td>
<td>15</td>
<td>Setup of sine table</td>
<td>40 s</td>
</tr>
<tr>
<td>Fixing the fixture and control</td>
<td>18</td>
<td>Amount of changeovers</td>
<td>2</td>
</tr>
<tr>
<td>Testing the holes via the electrodes</td>
<td>14</td>
<td>Sum</td>
<td>120 s</td>
</tr>
<tr>
<td>Walking distance to the quality check</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Angle Check</td>
<td></td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>Walking distance back to the EDM machine</td>
<td>30</td>
<td>Sin tables 2x</td>
<td>3.000 €</td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>274</td>
<td></td>
</tr>
<tr>
<td># Angle checkings + Setup</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td></td>
<td>548</td>
<td></td>
</tr>
<tr>
<td>Yearly quantity at EDM machine of shrink fits</td>
<td>1.112</td>
<td>Savings per year</td>
<td>10</td>
</tr>
<tr>
<td>Yearly quantity at EDM machine of hydro</td>
<td>642</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Checking of the Angle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDM Quantity 2011</td>
<td></td>
<td>1.754</td>
<td></td>
</tr>
<tr>
<td>Angle adjustment 2011 [s]</td>
<td></td>
<td>961.192</td>
<td></td>
</tr>
<tr>
<td>Angle adjustment 2011[€]</td>
<td></td>
<td>8.170</td>
<td></td>
</tr>
</tbody>
</table>

### Investment costs

- Erowa 0-point-clamping system 2x: 5.700 €
- Dividing Head Golmatic: 1.900 €
- Investment costs: 10.600 €

---

Oliver Kirschey 860515-T656

KTH & MAPAL Dr. Kress KG
8.2 CLAMPING JAWS TOLERANCES AND CONCENTRICITY OPTIMIZATION

8.2.1 DESCRIPTION
In the assembly section of the Universal-CNC Drill Head Chucks has been found the biggest time saving potential for immediately optimization. The problem of the concentricity measurement is that in the end a final concentricity of 0.030 mm has to be achieved. This can be quite a competitive task due to the fact that a lot of different parts with their tolerances are assembled together and therefore a lot of factors can influence the final result of the concentricity check.

8.2.2 PROBLEM
The problem was, that after the first assembly of the chuck, the concentricity is checked and just in some very seldom cases, the demanded concentricity can be approved. Until this time the whole assembly and concentricity check takes around 3 minutes which is the overall target time for this process. The employee now has the choice what counteraction should be performed to reach the demanded concentricity. He chooses out of the following measures:

- Change the position of the clamping jaws by one position to the spindle
- Regrinding the clamping jaws
- Exchange the clamping jaws
- Exchange the spindle
- Exchange the bevel gear

The first action which is being performed generally is to turn the clamping jaws. To do this the whole chuck has to be disassembled again, the jaws turned and then assembled and checked again. If the concentricity is still not granted, the other methods are tried. As soon as the concentricity is approved once with all three gauge rods, the part is sent to the final assembly and laser station and then sent to the customer. This whole procedure can last up to 20 minutes. During this time the labor capacity is completely bound to the “rework” procedure.
8.2.3 EXPERIMENT PROCEDURE

The first step of the experiment was to investigate all single components which are directly influencing the concentricity of the final product. The following specifications have been measured and compared with each other:

<table>
<thead>
<tr>
<th>Description</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Angle of the clamping jaws</td>
<td><img src="angle_clamping_jaws.png" alt="Picture" /></td>
</tr>
<tr>
<td>• Measurement of the sloping level to the long side of the clamping jaw</td>
<td><img src="sloping_level.png" alt="Picture" /></td>
</tr>
</tbody>
</table>

Table 5 Experiment Details Clamping Jaws

Furthermore the following components have been measured and compared with the technical specifications and tolerances as well:

<table>
<thead>
<tr>
<th>Description</th>
<th>Picture</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Depth of the spindle slots for the clamping jaws</td>
<td><img src="spindle_slots.png" alt="Picture" /></td>
</tr>
<tr>
<td>• Internal angle of the shell</td>
<td><img src="internal_angle.png" alt="Picture" /></td>
</tr>
<tr>
<td>• Comparison of the spreader cone and the guiding slot</td>
<td><img src="spreader_cone.png" alt="Picture" /></td>
</tr>
<tr>
<td>• Concentricity of the spindle – bevel gear system</td>
<td><img src="concentricity.png" alt="Picture" /></td>
</tr>
<tr>
<td>• Flatness of the thrust member system</td>
<td><img src="thrust_member.png" alt="Picture" /></td>
</tr>
</tbody>
</table>

Table 6 Experiment Details Spindle

After measuring all relevant dimensions and their tolerances a framework of data had been build up to test several assembly configurations.

In a first test run, components with perfect dimensions (in tolerance and close to the optimum value) have been assembled and measured with several configurations. Each experiment has been performed in a way, that only one variable has been changed from experiment to
Assembly line & Sub-Assembly Stock process optimizations at WTE Präzisionstechnik GmbH

experiment and all other factors were kept constant. In case the concentricity testing, the following testing steps have been performed:

1. Constant position clamping jaws and spindle -> changing position of the spreader cone (varying guiding slots)
2. Constant position spindle spreader cone -> changing position of the constant system to changing clamping jaw positions
3. Complete exchange of each clamping jaw with clamping jaws with exactly the same dimensions
4. Changing of the shell and therefore varying guiding angle
5. Changing of the whole spreader cone
6. Disassembling and assembling with exact the same configuration (test of repeatability)

The result of all the measurements was that the whole concentricity measurement how it is performed in the assembly line doesn’t grant any repeatability. As soon as the concentricity is reached once, the product is not disassembled anymore and sent to the customer. By testing the approved chuck again by disassembling and assemble it with exactly the same configuration it was figured out that just by doing this step the concentricity changed within 0.030 mm. By having such a big variance in the measuring process another starting point has been tried.

After receiving the relevant design drawings of all components (Universal-CNC-Drill Chucks) the tolerances and their influence on the concentricity have been checked. Due to the fact, that the spindle already had a play of 0.020 mm and this play had a direct impact on the overall concentricity, a new design solution for this part with two new guidance channels with less tolerance has been discussed with the design department.

This new solution will be evaluated in the next design update and tested, if the repeatability and therefore new huge time savings in the assembly section can be accomplished.
Due to the fact, that the realization of the optimization will cause some major changes in the design of the product, during the time of the master thesis, the final savings of the measure can just be theoretically evaluated.

The optimizations in this section are split into two optimization fields. The first is the procedure of the multiple disassembly action; the second one is related to a more efficient way of measuring the concentricity.

During the measurement, the employee tests the concentricity once, then unclamps the gauge rod, turns it by 180°, clamps it again and measures again. By testing the repeatability of this action, it had been found out, that the concentricity is not changing in a relevant way and the repeatability is given. By eliminating this extra step, the whole measurement process step could be reduced from 120 seconds to 60 seconds.

If the discussed design changes and the process optimizations during the measurement bring the expected result, WTE will save between 3-15 minutes per CNC-Universal-Drill Chucks. Considering the annual quantity and the hourly rate at WTE, the savings are expected to be as followed:

Savings clamping jaws optimization: 2.837 hours per year » 76,600€ per year

Savings concentricity measurement: 473 hours per year » 12,771€ per year

Overall savings: 3310 hours per year » 89,371€ per year
8.3 BALANCING OPTIMIZATION

8.3.1 DESCRIPTION

The balancing process step is one of the main process steps in the assembly area. Here all hydraulic, shrink fit and some of the Universal-CNC-Drill chucks find a common station to optimize the balance of the chuck to the demanded balancing quality. Balancing for chucks is important because an unbalanced chuck which is used with fast-rotating tools or tool systems generates a centrifugal force which causes a geometrical error during the machining process or can even damage the spindle of a machine tool. Therefore a well-balanced chuck, tool and spindle are essential to grant high precision machining (Wohlhaupter Service, 2012).

Due to the importance of this step and the relatively long cycle time of this process, a research about process improvements has been performed.

The balancing process itself is split into two parts. The balancing detection and evaluation of the chuck and the material removal process which is performed on a classical drilling machine tool. In a first step the chuck is clamped into the balancing machine and analyzed. After completion the chuck is turned by 180° and analyzed again to evaluate the position, where material has to be removed and how much to grant the pre-set balance quality. The location is shown with a laser directly on the chuck, so the employee has to mark this position, hand it over to the drilling machine and remove the displayed amount of material. After this, the chuck is re-clamped into the balancing machine and a second run is done to check the balancing quality.
8.3.2 THE BALANCING MACHINES

<table>
<thead>
<tr>
<th>Type</th>
<th>BMT 200</th>
<th>Haimer TD2009</th>
<th>Haimer TD2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallel operating possible</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>TPT single</td>
<td>297 sec</td>
<td>192 sec</td>
<td>72 sec</td>
</tr>
<tr>
<td>TPT parallel</td>
<td>168.5 sec</td>
<td>96 sec</td>
<td>72 sec</td>
</tr>
<tr>
<td>Investment costs</td>
<td>50.000€</td>
<td>76.000€</td>
<td>174.000€ / 138.000€</td>
</tr>
</tbody>
</table>

Table 7 Balancing Machines

In the times of the BMT 200 and the TD2009, the necessary changeover times from the balancing machine to the drilling machine, the drilling operation and the further measurement is included. By using the parallel operating mode, the cycle time can be reduced to half the time. This parallel operating mode is just possible for the BMT 200 and the Haimer TD2009 due to the uncoupling of the balancing and the drilling operation. Due to the fact that the drilling operation and the balancing operation in case of the TD2009 are very similar, the cycle time can be divided by 2. In case of the BMT 200 we have a 10 seconds longer balancing time. As a result of this the worker has to wait for 10 seconds for the balancing operation.

In case of the Haimer TD2010 another configuration has been taken into consideration when doing the investment planning, a full automated solution with a robot arm loading and unloading the machine. Further details to the investment calculation and to the chosen solution will be shown later.
8.3.3 SITUATION ANALYSIS PROBLEM DESCRIPTION

In case of the WTE GmbH, two different types of balancing machines are used: One older BMT 200 and one newer Haimer TD2009. The following three problems have been discovered and will be further investigated:

- Time difference of the balancing process between the BMT 200 and the Haimer TD2009.
- Parallel processing of balancing and drilling
- Stability problems with the drilling machines

In the following each problem will be described in more detail:

Time difference:

Between the older BMT 200 and the newer Haimer TD2009 lies a time difference in the first balancing operation of total 20 seconds and in the second balancing operation 15 seconds which results in an overall time difference of 35 seconds per balancing operation. By adding up all necessary cycle times of balancing, drilling and changeover, the total process time of the BMT 200 is 297 seconds (ca. 5 min) and for the Haimer TD2009 192 seconds (ca. 3 min) per part.

If this time difference is considered over the annual quantity of balanced parts a time loss of around 758 hours per year is the result. This results in potential savings of around 20.466 € / year (hourly rate: 27€/h). The hourly rate in MAPAL/WTE is defined for each workstation and consists of machine costs (fix and variable), indirect costs for lubrication or cooling and labor costs. The more complicated a workstation is (manually or automatic) and the more qualified the worker has to be to perform the job on this workstation, the higher the hourly rate will be.

Besides the consideration of investing in another Haimer TD2009 machine and selling the BMT 200, a third machine has been taken into consideration of a new investment instead of the BMT 200, the Haimer TD2010. This CNC-controlled balancing machine combines the balancing and the drilling process in one machine with the advantage, that no changeover, no re-drilling and higher balancing quality can be granted. In a time comparison, the whole process time could be reduced to around one minute per part depending on the amount of material, which has to be removed.
Parallel processing:

During the process recording the observation could be done, that on the older BMT 200 machine parallel processing has been performed by one worker, but not from the other one at the TD 2009. The parallel processing can be understood as balancing a chuck and at the same time performing the drilling operation of a second part. Overall this causes that in the cycle time of the 5 min respectively 3 min, 2 parts can be completely balanced.

Due to the enormous time loss, which occurs by a single product processing, the employees have to be sensitized for the impacts on the total lead time of the production and the money which can be saved.

Stability problem drilling machines:

When touching the surface of the chuck with the clamped drill, the gear box of the drilling machine is yielding around 0.5 mm before the drill finally enters the material. Due to this fact, the employee never goes to the analyzed depth of the balancing machine and prefers to do the balancing operation in several steps (balancing, drilling, balancing, and re-drilling). This loop can be performed up to 3 times until the demanded balancing quality is reached.

8.3.4 MACHINE EVALUATION

In the following I will shortly present the selected improvements and will explain the impacts on the overall throughput time.

Time difference:

To evaluate the single impact of each machine on the overall time, two parts are simultaneously produced in a single processing mode on each machine. By doing this with the actual equipment, the overall processing time has been shown as 8 minutes. By the above shown savings, investing in a second Haimer machine and therefore replacing the older BMT 200 machine was a necessary investment. In scenario 2, the BMT 200 has been replaced by the
Assembly line & Sub-Assembly Stock process optimizations at WTE Präzisionstechnik GmbH

TD2009, where the drilling operation is still performed manually. Nevertheless a time reduction from 8 to 6 min could be reached. Investing in the Haimer TD2010, the processing time could be lowered to 3.9 minutes.

8.3.5 INVESTMENT CALCULATION

As the fundament of the new investment, an investment calculation has been performed. For all investments which are done before October 2012, WTE gets subsidies from the state. This state aid has been granted for companies to help building up the economy in eastern Germany.

The investment calculation has been performed twice: once with the production figures of 2011 and once with the forecasted figures of 2012.

Base for the investment calculations are on the expected production quantity and the hourly rates of WTE. These hourly rates are considering of investment costs, exploitation costs and labor costs.

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings C / Time</td>
<td></td>
</tr>
<tr>
<td>TD2009 &amp; TD2009:</td>
<td>14.211 € / 526 h/y</td>
</tr>
<tr>
<td>TD2009 &amp; TD2010 FA:</td>
<td>25.926 € / 770 h/y</td>
</tr>
<tr>
<td>TD2009 &amp; TD2010 MA:</td>
<td>18.602 € / 770 h/y</td>
</tr>
<tr>
<td>Payback Time:</td>
<td></td>
</tr>
<tr>
<td>TD2009 &amp; TD2009:</td>
<td>5,35 years</td>
</tr>
<tr>
<td>TD2009 &amp; TD2010 FA:</td>
<td>6,71 years</td>
</tr>
<tr>
<td>TD2009 &amp; TD2010 MA:</td>
<td>7,42 years</td>
</tr>
<tr>
<td>Productivity per day:</td>
<td></td>
</tr>
<tr>
<td>TD2009 &amp; BMT 200:</td>
<td>364 parts per day</td>
</tr>
<tr>
<td>TD2009 &amp; TD2009:</td>
<td>560 parts per day</td>
</tr>
<tr>
<td>TD2009 &amp; TD2010 FA:</td>
<td>630 parts per day</td>
</tr>
<tr>
<td>TD2009 &amp; TD2010 MA:</td>
<td>630 parts per day</td>
</tr>
</tbody>
</table>

Table 8 Payback Calculation 2011 Balancing Solutions
Considering the future layout and the material flow within the assembly area, the scenario of having the TD2010MA (manual loading/unloading) has been examined again. By using this machine under the circumstances and the product distribution 90%-10% between TD2010 and TD2009, a payback time of this solution of 3.79 years could be achieved (more to that in Chapter 9.4.3.1).

**Parallel processing:**

By making all employees aware of the impact of single part processing, the parallel part processing could be implemented at all workstations. Considering the actual existing BMT 200 and the Haimer TD2009, time improvements of 2.5 respectively 1.5 minute could be implemented. This improvement will result in a total reduction of the throughput time.
Assembly line & Sub-Assembly Stock process optimizations at WTE Präzisionstechnik GmbH

Stability problem drills

The main reason, that the suggested amount of material which should be removed to balance the chuck has not been removed at once was the instable gear box of the drilling machines. After investing in new drilling machines and performing successful experiments about the balancing results when removing the suggested material at once, time improvements dependent on the BMT 200 or the Haimer TD2009 of 2 respectively 1 minute could be achieved.

This improvement will positively influence the throughput time and the quality of the products.

8.3.6 FINAL DECISION

By implementing the TD2010 into the new assembly layout and considering the expected demand increase for the next two years, the final decision was to implement the TD2010 as an automated solution with manual loading and unloading procedure. Though 90% of the whole product types are coupled with the adapter HSK63, HSK100, SK40, SK50 and will run in big batches on the TD2010 before putting the finished parts to stock, the changeovers on this machine can be kept to minimum and the long uptimes will help WTE to handle the heavy demand increase.

Savings overview of the 3 scenarios:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5.56</td>
<td>6.13</td>
<td>4.47</td>
</tr>
<tr>
<td>Payback Period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Savings per year [h]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>964</td>
<td>964</td>
<td>609</td>
</tr>
</tbody>
</table>

Table 10 Savings of new Balancing Solution
9 FUTURE STATE ASSEMBLY SCENARIO

To reach an optimal flow and be prepared for the higher productivity rate from the main body manufacturing, a future assembly area concept and layout has been developed. In this concept not only workstation optimizations, assembly assistant devices and waste elimination has been performed, but also major investments in new machines, which will help to grant a productivity output increase and increase the quality.

9.1 CALCULATION OF THE FUTURE TAKT TIME

The takt time is the rate the customer is buying the product. To be able to meet that demand, it is necessary to design the assembly area in a way that variations in demand, time for equipment failure or stock outs can be absorbed.

As a base, the following production forecasts have been taken to calculate the takt time, which has to be maintained in order to fulfill the customer demand.

Due to the fact that 92% of the total production is covered by the three main product groups, the takt times (TT) of them are separately calculated:

9.1.1 TAKT TIME CALCULATION

480 min – 45 min break = 435*250 = 108.750 s/year

TT Shrink Fit Chucks: 1.8 min/pcs

TT Hydraulic Chucks: 5 min/pcs

TT CNC-Universal-Drill Chucks: 7.7 min/pcs

(A more detailed calculation of the takt times you can find in the Appendix)

Due to the fact, that these takt times are dependent on forecasted amounts, which the system has to be capable to handle the layout will be designed in a way that the takt times are around 25% more and in case the forecasted amount will appear, the capacities are easily expandable.
9.2 LEVEL OF AUTOMATION

The level of automation is an important decision to make before the assembly line can be designed. As can be seen in the following graphic it is important to evaluate the product spectrum on factors like “how easy are the assembly steps to automate” or “how much automation is still economical”. This is very much dependent on the output per year, the takt time, amount of variants and the type of assembly processes. Especially when it comes to automatic loading and transfer systems, high investment costs for robots, programming and automated transfer lines are inevitable.

<table>
<thead>
<tr>
<th>Level</th>
<th>Load machine</th>
<th>Operating the machine</th>
<th>Unload machine</th>
<th>Product transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Automatic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Automatic</td>
<td>Automatic</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
</tr>
</tbody>
</table>

*Figure 24 Level of Automation (acc. (IPA, 2012))*

Due to the fact that the production in WTE Präzisionstechnik is not based on highly standardized short takt time products with a low amount of variants; the result of the level of automation which is reasonable is an automated operating system of the machine & unloading of the machine (Level3) or manual unloading (Level 2). This decision is fundamental for the later cell layout and workstation planning.

In a final evaluation it has been figured out, that the most reasonable way to design the new assembly hall is Level 2. Two cells have been implemented which are working in a Chaku-Chaku principle and therefore consist of an automatically operating machine (the balancing machine).

Next to the two cells, the other assembly areas are considered as manual workstations.
9.3 FUTURE LAYOUT PLANNING AND MATERIAL FLOW

9.3.1 COMPLETE NEW ASSEMBLY LAYOUT

The new assembly layout is separated into 5 different areas:

- The CNC-Universal-Drill Chuck Final Assembly

Figure 25 New Assembly Layout
In the following section of this thesis first the new overall material flow through the whole assembly area will be described for the three main product groups and then each workstation will be described closer. For the whole layout, the three main product groups have been investigated on an optimum flow through the factory and similar or same process steps have been cumulated to reduce the walking distances.

9.3.2 NEW MATERIALFLOW FOR SHRINK-FIT CHUCKS

In the first step the shrink-fits come out of the external hardening process and are delivered to the factory in two to three boxes per day. From there the products are forwarded to the glass bead blasting where the oxidation layer, which occurred during the tempering and transport from the hardening company to WTE, can be cleaned. The next step is in the grinding area, where the shrink-fit chuck is grinded to its final specifications. From the grinding area the lot is separated dependent on their adapter type. There it is further processed before the products are put into the stock (A detailed explanation of the cell processing and design will follow in the next chapter). As soon as a customer order arrives, the logistic per-
son takes the demanded lot out of the stock and sends it to the new laser marking machine with the rotation axis. There the final customer specifications are marked, oiled and then sent to the shipping department where the products are packed and shipped.

9.3.3 NEW MATERIALFLOW FOR HYDRAULIC CHUCKS

In the hydraulic chuck sector, two parts are arriving separately out of the manufacturing department: the main body and the bush. The first step in the new hall is the glass bead blasting process which is just performed on the bush. In the following workstation the main body and the bush are combined and sent back to the hardening. There the parts are not just hardened but simultaneously the brazing rings which fuse the bush and the main body is brazed as well. This causes a closed bond between bush and main body. After the hydraulic chuck is sent back to WTE, a leaking test is performed if the bond between bush and main body has been sealed correctly. If the products are approved, a final glass bead blasting process follows before the lot is sent to the hydraulic cell (further description in the next chapter). The semi-finished product is then sent to the grinding area where the final hydraulic pressure settings are set up and ground to the final specifications. The rest of the process follows the flow of the shrink fit through the balancing-marking cells, the stock and the customer specific laser marking before the products are sent to the customer.
9.3.4 NEW MATERIALFLOW OF THE UNIVERSAL-CNC-DRILL CHUCKS

The Universal-CNC-Drill Chuck is the product group with the most components and manual assembly steps. After the manufacturing, the main body is hardened external and comes to the sand blasting into the new factory hall. From there it is forwarded to the grinding area, where the final specifications of the main body are grinded. After a quality check, the main body will be laser marked on the manual laser marking machine. There the production number is laser marked and exits the cell to be forwarded to the stock. As soon as the customer order is available, the logistics person is responsible to pick all the relevant components out of the stock and forward it to the assembly workplaces. After the product is assembled and the concentricity approved, the lot is sent to the new laser marking machine, where the customer specific IDs are marked on the chuck. After that step the chuck is oiled and sent to the shipping department.
9.3.5 IMPROVED WALKING DISTANCES

- Shrink Fit Chucks: 167m → 92.5m / 131m → 72 -> 119s → 66s / 93s → 51s
- Hydraulic Chucks: 576m -> 123m --- 416 s -> 87s
- CNC-Universal-Drill Chucks: 79m = 58m --- 56,45s = 41,5s

Due to the new layout and the optimized workflow, overall improvements in this sector of 44h per year could be reached (average lot size 50).

9.4 WORKSTATIONS IN DETAIL

9.4.1 HYDRAULIC CHUCK CELL 1

The hydraulic chuck cell combines three work processes in one cell. In the old layout these processes were standing far away from each. This resulted in a lot of walking distances between the processes. Furthermore an additional quality check has been introduced to increase the quality and eliminate problems which occurred due to not perfectly honed holes. The whole cell is handled by one to two employees. Due to the fact that the worker has to wash his hands after the honing process a one-piece-flow system is not applicable. Therefore the material flow is handled in small batches with low WIP between the workstations. The hydraulic chuck’s hole for the seal entry is super-finished with the honing operation. Due to the fact that the employee doesn’t see, if the quality is all the same along the honed surface, an endoscope inspection has been introduced into the process flow. After the quality of the honed hole is approved, the parts are going to the oil filling station. In this station, the hydraulic chuck gets its oil filling which provides the chuck later on with the clamping pres-
sure necessary to clamp the tool in the chuck. This work station has been one part of the optimizations. To help the worker with assembling the parts to the chuck, the following helping devices have been designed.

9.4.1.1 HYDRAULIC CHUCK ASSEMBLY WORKSTATION

To get an overview of the assembly process of this station a short introduction in the assembly process will be given.

In a first step, the oil which will grant the hydraulic clamping functionality is pushed with high pressure into the chuck. As soon as the chuck is completely filled and it is granted that no air is remained in the oil chamber, a seal and a pin is inserted into the pressure hole. To remove the last piece of air out of the oil chamber an additional ventilation hole has been drilled. This whole is now closed with a steel ball and the vent screw. In a final step the pressure screw is entered into the pressure hole.

The operation of the seal and the pin entering was performed with a self-designed helping device. The functionality of this device was already good but with a lot of screwing operations which took quite long. Furthermore the pin and seal insertion have been separate work processes. By designing a new helping device where both components can be inserted simultaneously, the worker saves a lot of time. Furthermore the insertion of the 2 and 3 mm diame-
Assembly line & Sub-Assembly Stock process optimizations at WTE Präzisionstechnik GmbH

 (...) steel balls via a magnetic Allen key caused some problems in the picking and inserting operation. Overall, by introducing these 2 new helping devices, the assembly time could be reduced by 30 seconds per hydraulic chuck.

In the following I will shortly present the new helping devices:

9.4.1.2 ASSEMBLY HELPING FIXTURES

1. **Device for assembling the pin and the seal**

   The video analysis of this process showed, that the assembling of the seal and the pin were time consuming and hard to handle, due to the oily working environment and the gloves the employee wears. To combine the assembly steps “Inserting the seal” and “Inserting the pin”, an alternative device has been designed, which can not only assemble both components at the same time, but also saves a lot of time by not screwing the device into the product but using the thread as a guidance and press the components into its final position. In a first step the seal is put into the bottom of the device. Then the pin is inserted from the side, the bush inserted into the relevant thread of the hydraulic chuck and then pressed into its final position.

   In first tests of this device, it was figured out, that the idea is working quite well, but some optimizations considering the depth of the seal insertion have to be performed. This optimization was not considered in this thesis any more but will been realized until the movement into the new factory hall.
Figure 32 Pin and Seal assembly device drawing
2. **Device for assembling the steel balls**

Another time consuming step was to place the steel balls with a diameter of 2 and 3mm into the right hole. To ease that process a kind of steel ball pistol has been designed where a batch of steel balls are fed into the magazine (50pcs.) and with each press of the pin, one steel ball is released. Due to the fact that the guidance pipe in the end is made transparent, an additional control feature is implemented to be sure, the ball is inserted correctly.

![Figure 33 Steel ball assembly device (Source: By Bernd Dürr)](image)

### 9.4.1.3 EVALUATION OF THE TWO ASSEMBLY DEVICES

<table>
<thead>
<tr>
<th>Fixture</th>
<th>Description</th>
<th>Time Before</th>
<th>Time After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seal &amp; Pin Stamp</td>
<td>Inserting 2 components in 1 step</td>
<td>34 sec / part</td>
<td>14 sec / part</td>
</tr>
<tr>
<td>Steel ball pistol</td>
<td>Inserting the steel ball</td>
<td>10 sec / part</td>
<td>1.5 sec / part</td>
</tr>
</tbody>
</table>

Total savings with the hydraulic chucks production quantity of 2011 and a machine hour rate of 27€/h: 124 hours/year = **3,348 €/year**
9.4.1.4 MANUFACTURING COSTS SEAL & PIN STAMP

Turning: 120 minutes

Roundgrinding + Drilling 3H7: 45 min

Milling: 60 min

Hourly rate for machine: 65€/h

Manufacturing Costs: 243,75€

9.4.1.5 MANUFACTURING COSTS STEEL BALL PISTOL

Milling: 4h

Handwork: 1h

Turning: 0,5h

Hourly rate for machine: 65€/h

Manufacturing Costs: 357,5€

9.4.1.6 PAYBACK TIME

601,25€ / 3.348€/year = 0,18 years.
9.4.2 WORKSTATION LEAKING TEST & BUSH PRESSING

The leaking test work station is necessary to test if the coppering correctly brazed the main body and the bush. This can be tested by a simple leak test which is comparable to testing a bicycle wheel for holes. All holes are sealed with screws and in the vent hole of the hydraulic chuck an air pressure system is screwed in. By putting liquid soap on the top of the chuck and observing if air blisters are showing up, it can be tested if the parts are brazed correctly or if little holes in the bond occurred. Bad parts are rejected immediately.

9.4.2.1 LAYOUT OF THE WORKSTATION

This work station had been another source for several improvements and will be the first workstation, which will be realized actively as a showcase workstation. As a base, the actual
workbenches will be taken and an ITEM profile will be build up. This profile ensures a stable structure of the whole workplace and grants to couple a lot of assembly workplace equipment to it.

In the following you can see one of these assembly workstations.

![Figure 36 Modern Assembly Workstations](image)

This workstation has been optimized to ergonomic factors, quick changeovers and easy handling. Therefore two helping devices have been designed:

1. **Implemented adapter holder for the workplace**
   Due to the fact that no torque is occurring during the leakage test, the chucks can be placed in a circular hole in the workplace which ensures a stable position.

![Figure 37 Table Tool Holder ProE](image)
2. **Quick coupling adapters with STÄUBLI pressure connectors**

The actual changeover for changing the pressure tube for the leak test took a lot of time because it was built together out of three elements which were linked by a quick coupling element. During the assembly process of the tube to the chuck, the whole tube element was already coupled and it was unhandy to screw in the whole device. Therefore the system of the STÄUBLI pressure connectors have been adopted to the leak testing scenario at WTE and customized. The result was just one element which can be freely screwed into the vent hole of the chuck and via one STÄUBLI pressure connector directly connected to a spiral tube with the air pressure supply:

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Before" /></td>
<td><img src="image2.png" alt="After" /></td>
</tr>
</tbody>
</table>

Table 11 Process Improvements Workstation Leak Test

9.4.2.2 **EVALUATION OF THE OPTIMIZATION ON THE LEAK TEST WORKSTATION**

Quick coupling: old with changeover: 24 sec; new 6s; savings: 18s

Workplace design savings: ca. 15 sec

Component supply: 12 sec, new: 2 sec, savings 10 sec

Total savings workstation leakage testing: 1:45 – 1:02 -> **43 sec / pcs**

Total savings per year: 188h = 5.076€
9.4.3 BALANCING-MARKING CELLS

For the balancing-marking cells, one employee has been assigned to each cell who is working in the flow of the material. As the form, the U-form is the most reasonable form due to the following advantages:

- Flexible in the production rate
- High volume flexibility by going in circles
- Small batches or One-piece flow from one workstation to another, small/no buffer
- No even time balancing of the workstations to each other (takting) necessary
- Short distances from workplace to workplace
- Short reaction times when errors in the machines or the process flow occurs
- Good overview of inbound and outbound products

As it can be seen in the Pareto above the product spectrum has been split into two categories: the fast products and the special products. This split has not been performed dependent on the product itself, though all product categories have to be processed in a similar way in the balancing-marking cells, but dependent on the tool holder type. By separating the types into these categories it can be granted, that on the automatic-cell similar products will run all the time. Therefore a minimum amount of changeovers with low changeover times can be granted. All other products will be handled in the manual-cell which makes it necessary to perform changeovers on the machines more often. When designing this cell it is important to
place all necessary equipment for the changeover as close as possible to the workstation to keep the changeover times as low as possible.

In the overall analysis over the product groups, the process steps: laser marking, assembling the stopscrew/setup screw, balancing and oiling have been found as common production processes. To handle all these process steps in the most time efficient way, for the automatic-cell a Chaku-Chaku line with One-Piece Flow has been implemented. The manual cell has to perform two different tasks. First it handles the tool holder types, the automatic one is not supposed to handle (around 10% of the whole product spectrum) to perform all processes except the customer specific laser marking. Secondly it will handle the whole product spectrum for the customer specific laser-marking, as soon as the customer order is available.

Therefore the products have been categorized into the specific tool holding fixture types. By aggregating the types of SK40, SK50, HSK63 and BT40 and lead those in the fast moving products cell (FMPC), 88% of the whole product throughput of the year 2011 can be covered in this cell.

9.4.3.1 AUTOMATIC BALANCING-MARKING CELL

This cell is capable of putting through a product within a cycle time of around 1.2 minutes. The key of this cell is the fully automated process of balancing with the Haimer TD2010. In former times, the employee had to perform the balancing measurement on the balancing machine and then manually drill out the given amount of material out of the fixture, to grant a good balanced tool. The Haimer TD2010 eliminates the need of the employee within the balancing process by having an integrated CNC-Drill. Therefore the part is measured, drilled and remeasured in one clamping action. With this advantage, the former 3.2 minutes balancing time per part could be reduced to 1.2 minutes. As the longest process in the cell, this machine is giving the cycle time of the whole cell. By having this machine building up a Chaku-
Chaku line is possible. During the up-time of the balancing machine which takes 1,2 minutes, the worker can oil the finished balanced part and prepare it for stocking (15s) perform the laser process (15 sec). This process is considered as marking the production ID only. From there the part is forwarded to the stop- and setup screw workplace. Here the mentioned parts are assembled (35s) and forwarded to the Haimer TD2010. There the worker unloads the finished part and loads it with the finished assembled part.

By using the cell in such a way, the above mentioned investment calculation for the Haimer TD2010 has to be updated. The reason for that lies in the savings you get by performing the tasks of oiling, laser marking and assembly in the up time of the balancing machine. Due to that constellation the overall savings in this cell is 800 hours per year. Due to that, the above mentioned payoff calculation is updated from a payoff period of 6,13 to 3,79 years. A detailed calculation you can find in the appendix.

To exploit the full potential of this cell and grant short changeover times, the software setup process for the machines can be easily automated as well. By preparing a barcode with the needed product specifications in the work preparation department and print this barcode on the order papers, it is possible by installing a barcode scanner in front of the cell to read all information needed at once and synchronize them immediately with the product programs, saved in the laser marking machine and the Haimer TD2010. With this system, the employee doesn’t have to search for any program in the machine data base anymore and the chance of a wrong data selection is eliminated.
9.4.3.2 MANUAL BALANCING-MARKING CELL

The last 10% of the product spectrum is fed in the manual balancing-marking cell. In comparison to the automatic balancing-marking cell, the main target here is not to aggregate lots to reduce the amount of setups but having small batches and guide them through the cell. As a result of this, this cell has more changeovers. Therefore it is important to keep the single changeover times as low as possible. This can be reached by optimizing the walking distances and the workstation layouts, to minimize the waste of non-value adding time during the changeover process.

The new investment in this cell is the Teschauer Laser Marking machine. This machine will be busy by two different work tasks. On the one hand, it will handle the last 10% of chuck holder types, which are not running on the automated cell to mark the production ID, on the other hand it will perform the customer specific marking details like logo, article number etc. This second marking process will be realized by implementing an automatic rotatable axis for the complete process. This will eliminate several clamping and unclamping actions during the laser marking process and ensure a complete laser marking in one step. Dependent on the complexity of the laser marking, the process takes in average 1.5 minutes.

The rest of the cell works similar than the automated cell. The material transport will not be realized in a one-piece flow but in small batches. Though the main capacity will be bound on the laser marking machine, the planned employee number will be 1,5 workers. The half employee will work as a jumper and helps out in workstations, where additional capacity is needed.
The CNC-Universal drill chucks are the most complex assembly tasks with the most components and sub-assemblies. These workstations contain the highest savings potential. As already described in chapter 8.2 the overall throughput time is varying between 5 minutes in the best case to 10 minutes in the worst case. By already eliminating the non-value adding step of turning the test pin during the concentricity measurement at least 1 minute per part could be saved.

The actual workstation is split into two sections which are located in an L-shape. This L-shape work place is designed as a sitting work station and allows performing the assembly as well as the measuring procedure without non-value adding walking times. The workstations itself are fed by the logistic person with the necessary components. Therefore the assembly employee is just responsible for his assembly work station and actions like finding the next order to assemble or take new components out of the stock are outsourced out of the responsibility area of the assembler.

Besides the optimization experiments of the clamping jaws, several workstation optimizations have been performed (5-S, Poka-Yoke, etc.).
### 9.4.4.1 ASSEMBLY SEQUENCE

In the old assembly sequence some non-value adding activities like deburring the clamping jaws have been found.

One example was the final assembly workstation. In this workstation the concentricity approved work pieces were stocked and as soon as an employee had time, final assembly steps have been applied. These steps were replacing the pinion by a new one and glue in the fixing cap. In the new layout this step has been completely integrated in the assembly workstations. As soon as the product leaves the assembly place, the product is ready for the final laser-marking process and shipping to the customer.

Through the deburring process at the workspace, grinding particles can still remain at the workplace and the clamping jaws itself. This can influences the quality of the concentricity measurements. By rearranging the workspace and relocating the deburring to the sub-assembly preparation area out of the assembly area, not only a time improvement from former 2,1 min TPT to 1,2 min TPT could be reached but also a measurement error due to grinding particles can be eliminated.

**Actual Sequence:**

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Station 2</th>
<th>Station 3</th>
<th>Station 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>12s</td>
<td>TPT</td>
<td>63s</td>
<td>TPT</td>
</tr>
<tr>
<td>Lubricate the spindle</td>
<td>6s</td>
<td>Attach the thrust member AG to spindle</td>
<td>4s</td>
</tr>
<tr>
<td>Turning the spindle to the right assembly orientation</td>
<td>6s</td>
<td>Position the AG on an assembly block</td>
<td>2s</td>
</tr>
<tr>
<td>Taking the spreader cone</td>
<td>10s</td>
<td>Disassembly fixing cap</td>
<td>3s</td>
</tr>
<tr>
<td>bear the spreader cone on the spindle</td>
<td>2s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deburring the clamping jaws</td>
<td>16s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insert the clamping jaws</td>
<td>6s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bear the shell on the spreader cone</td>
<td>6s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arrangement of the holes to each other</td>
<td>2s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
New Sequence:

<table>
<thead>
<tr>
<th>Station 1</th>
<th>Station 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>72s</td>
<td>90s</td>
</tr>
<tr>
<td>Position main body as base on assembly block</td>
<td>Concentricity testing</td>
</tr>
<tr>
<td>Add thrust member on the assembly block</td>
<td></td>
</tr>
<tr>
<td>Lubricate spindle and turn to right position</td>
<td></td>
</tr>
<tr>
<td>Add spreader cone</td>
<td></td>
</tr>
<tr>
<td>Insert clamping jaws</td>
<td></td>
</tr>
<tr>
<td>Put AG on the mainbody</td>
<td></td>
</tr>
<tr>
<td>Bear shell</td>
<td></td>
</tr>
<tr>
<td>Turn the shell to max.</td>
<td></td>
</tr>
<tr>
<td>Fix the shell with fix Nm</td>
<td></td>
</tr>
<tr>
<td>Assemble assembly pinion and pinion bolt</td>
<td></td>
</tr>
</tbody>
</table>

Furthermore, the deburring process has been eliminated out of the assembly process and allocated to an external brushing process.
9.4.5 WORKSTATION SUB-ASSEMBLY PREPARATION

This workstation is the key workstation for the whole order and material management. In this area the logistic person is doing the following operations:

- Prepare the customer orders to feed the assembly lines in an optimal sequence
- Sub-Assembly Stock Management
- Sub-Assembly preparation (for the Universal-CNC-Drill Chucks)
- Feeding the assembly line with the necessary components and sub-assemblies
- Transfer of the products from cell to cell

To help the employee with the process of assembling the subassemblies, improvements by the employee have been evaluated and a helping fixture for an internal o-ring assembly has been designed.

9.4.5.1 O-RING ASSEMBLY DEVICE

Due to the fact that the assembly process for the internal o-rings where a quite sophisticated job, the above shown device has been designed. The handling should be as followed: The worker inserts the o-ring around the u-shaped area. Though the diameter of the ring has temporarily to be reduced to pass the inner diameter of the spindle and reach the channel.
where the ring finds its final position and can expand to its original diameter, a pin is inserted into the whole device which forms the ring from its o-shape to a u-shape and therefore reduces its diameter. This whole structure is inserted into the spindle. In a following step, the pin is taken out again which should cause a relaxing of the ring to its original diameter.

After manufacturing this device it was figured out, that the o-ring is not behaving in the expected way and is still formed in the u-shape.

By reengineering the whole process, another solution for the problem has been found. After inserting the o-ring into the spindle, another plastic seal is pushed into the hole of the spindle. In the new solution this seal is taken as a carrier for the o-ring to be inserted. So the nut, which is turned into the spindle will be included into the plastic seal, the diameter of the o-ring will be reduced and as an assembly group inserted into the spindle. This solution does not only save assembly time but also time in the manufacturing area (turning the channel in the plastic part is faster than in the spindle.

9.4.6 SAVINGS OVERVIEW NEW WORKPLACE LAYOUT AND WORKPLACE HELPING FIXTURES

Due to combining workstations like the final assembly workstation with the normal assembly workstations, the improvements in the concentricity measurement (turning the gauge rod), outsourcing the deburring process out of the assembly area and finally solving the problem of the clamping jaws (not yet finished), a potential annual time saving of 3606 hours per year can be reached. Nevertheless, even without the big point with the clamping jaws, the optimizations in this workplace area reached 769 hours per year.
10 OPTIMIZATIONS FOR THE FUTURE PROCESS FLOW

10.1 LASER-MARKING OPTIMIZATION

10.1.1 DESCRIPTION

Considering the newly introduced cell layout for laser marking, balancing and assembling of the stop screw and the setup screw, it was necessary to buy a new laser machine. With this each cell is equipped with one laser marker with different tasks. The new laser marker will be equipped with a rotary axis to be able to laser mark the whole customer specific ID in one setup around the chuck collar.

10.1.2 FUTURE LASER MARKING STRUCTURE

In the future, the cells are located as the upstream step of the sub-assembly stock. The shrink fit and the hydraulic chucks are generally laser marked once before they go into the stock. This ID is the production ID of the manufacturing area. This ID is marked on the actual manual laser machine for the main adapter (HSK63, HSK100, SK40, SK50) (90%) and the rest is distributed to the new machine (10%).

As soon as the customer order is available, the logistics employee takes out the relevant chucks out of the stock and brings it to the automated Laser machine (with round table) to mark all products with the customer specific data (logo, article no., balancing quality etc.).

10.2 OPTIMIZATION OF THE ID AND LABEL MAKING SYSTEM

10.2.1 DESCRIPTION

Though the SAP System has been implemented in WTE in January 2011 and they used several other systems for the whole company processes before, the labeling system was still based on the pre-SAP System. Each customer order which was generated in the SAP system now was again entered into an Access databank. This access data bank was the base for all labeling actions and secondarily was used as a databank for retracing the customer order, if a customer complaint occurs to see who and in which batch the defect product was assembled.
In the following you see a short overview what has been entered for each product in a customer order:

![Access - SAP Comparison](image)

As can be seen in the table above, since the introduction of the SAP system, all data which are entered into the access databank is generated in SAP automatically when releasing the production order (assembly order).

### 10.2.2 NEW LABELING SYSTEM

In the following I will shortly show how each product group has been labeled and how it will be done in the future:

**CNC-Universal-Drill Chucks:**
Shrink-fit chucks

<table>
<thead>
<tr>
<th>Actual</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logo</td>
<td>Logo</td>
</tr>
<tr>
<td>PO: 1992001-001</td>
<td>PA: 1992001-001</td>
</tr>
<tr>
<td>Artno.: 15.306.40.16.Z</td>
<td>AO: 1992002-001</td>
</tr>
<tr>
<td>Sno.: S12345</td>
<td>Artno.: 15.306.40.16.Z</td>
</tr>
<tr>
<td>Balancing quality</td>
<td>Balancing quality</td>
</tr>
</tbody>
</table>

Hydraulic chucks

<table>
<thead>
<tr>
<th>Actual</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logo</td>
<td>Logo</td>
</tr>
<tr>
<td>PO: 1992001-001</td>
<td>PA: 1992001-001</td>
</tr>
<tr>
<td>Arrow</td>
<td>AO: 1992002-001</td>
</tr>
<tr>
<td>Sno.: H12345</td>
<td>Arrow</td>
</tr>
<tr>
<td>(Balancing Quality)</td>
<td>(Balancing Quality)</td>
</tr>
</tbody>
</table>

The serial number in the actual situation was a sequential number, which was generated by the laser marking machine. This number should grant an explicit ID for the assembly, like the production order number in the manufacturing area, to be able to trace back, to which customer and when the relevant product was leaving the company.

By eliminating this number and replacing it by the assembly number of the SAP System which still grants the full access to the customer dataset, the Access databank and the therefore coupled data input process by an assembly employee could be eliminated.

10.2.3 Creating labels for sending the articles

By eliminating the access databank, the possibility to manually print the labels for sending the products has been eliminated as well. Instead of that, the label making system has been completely implemented in SAP. By releasing the assembly order, the production documents are printed and on a separated label printer, the labels are printed automatically with the preset printing setup.
10.2.4 FINAL EVALUATION AND SAVINGS

By eliminating the access databank and implementing the whole functionality of printing the labels via SAP, a lot of bound capacity of the employee in the assembly area could be freed. Furthermore unnecessary work like entering customer order data and database inconsistency could be eliminated. SAP is now used as base for the whole documentation and order processing part.

<table>
<thead>
<tr>
<th>Table 14 Savings Elimination Access Databank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly Rate:</td>
</tr>
<tr>
<td>Entering Product Data into Accessdatabank [min]</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Product Data Entry 2012</td>
</tr>
<tr>
<td>Savings Optimization [h/year]</td>
</tr>
<tr>
<td>Savings Optimization [€/year]</td>
</tr>
</tbody>
</table>

10.3 PROVIDING OF COMPONENTS AND MATERIAL HANDLING

10.3.1 ACTUAL STATE

As already described in the actual state the material supply to the workstations is performed by the assembly worker. Therefore valuable worker capacity is bound for component picking actions.

The material handling today is performed on material wagons. In the universal-CNC-Drill chuck section, one of these wagons is located in the assembly area to supply the assembly stations with the necessary spindles, thrust member assemblies and spreader cones.

If the containers are empty or if another component is needed which is not available on the wagon, the employee goes to the stock and takes out the components he needs.

Additionally, these wagons are used as central medium for the assembly order supply. The problem with this system is that the needed main bodies are taken out of the stock by one person out of the assembly area who also prints out the customer order documents. In a following step he combines the orders which have the same adapter type to save unnecessary changeovers on the machines and clamping devices on the workstations. On one of these wagons can store up to 10 different orders, where the employee has to evaluate which order is the next to assemble (delivery date). As an additional challenge up to 8 wagons are distributed over the whole assembly area. By having such a situation, the worker is not only
looking for the next order on the wagon itself but also on several wagons. This situation is no longer acceptable in the new hall.

10.3.2 FUTURE STATE

In the future the whole order and component handling task is managed by 1-2 employees who are just responsible for the assembly logistics. In the field of responsibility of these employees are falling tasks like: order preparation (printing production papers & labels and sorting them in the right sequence), sub-assembly preparation (building together the thrust member subassembly and spindle subassembly), stock keeping (refill the bulk material containers on the workstations) and managing the orders in SAP when the assembly is finished.

By this measure the workers on the assembly workstations can stay on their places and don’t have to waste their capacity in finding the right order or preparing the components.

The only product group, where an order specific component picking is useful is in the Universal-CNC-Drill Chuck area. Here the components are split into two groups: the order specific components which change with every variant of the product like the spindle or the thrust member assembly and the bulk material. The bulk material on the workstations will be managed in a KANBAN system, that the logistic person gets a signal from the work station as soon as the employee has taken the backup container. The first container will then be refilled by the logistic person out of the stock.

The customer order component supply will be handled by flexible order wagons, where each customer order has its fixed position with the relevant customer specific assemblies and components directly assigned to the customer order. The wagon will look similar like the one on the right side. The first level will be for the main bodies. These are sorted via a plastic hole perforation plate. Before the picking, the employee is changing these plates dependent on the order lot size. Each section is clearly separated from each other that no mixing of the main bodies is possible. On the second level the employee puts all bigger components like spreader cone and the shell. All other components (small parts) will be hanged in small containers on the left and right side of the wagon. These containers can be taken and placed at the right position at the workstation immediately.
In all the other material groups the parts to assemble are directly located at the workstation via small picking containers or in nearby shelves.
### Table 15 Overall Evaluation

#### Final Evaluation of the Savings and Potentials

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking Distances along the value stream</td>
<td>72,4</td>
<td>28,6</td>
<td>44</td>
<td>realized</td>
<td>av. Lot size 50</td>
</tr>
<tr>
<td>Savings Drilling process (balancing) -&gt; new drilling machine</td>
<td>327,2</td>
<td>218,1</td>
<td>111</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings Parallel Balancing</td>
<td>163,8</td>
<td>81,8</td>
<td>82</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings implementation automated cell</td>
<td>1,921.5</td>
<td>1,121.5</td>
<td>800</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings Hydro Helping Devices + Workplace layout optimization</td>
<td>192,1</td>
<td>67,7</td>
<td>124</td>
<td>realized/opt.</td>
<td></td>
</tr>
<tr>
<td>Savings EDM machine angle adjustment</td>
<td>27,0</td>
<td>60</td>
<td>21</td>
<td>realized</td>
<td>av. Lot size 10</td>
</tr>
<tr>
<td>Savings EDM Changeover Time</td>
<td>9,0</td>
<td>8</td>
<td>8</td>
<td>realized</td>
<td>av. Lot size 10</td>
</tr>
<tr>
<td>Savings due to Zero-Clamping System</td>
<td>60,0</td>
<td>7,5</td>
<td>58</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings leak test workstation</td>
<td>449,6</td>
<td>261,9</td>
<td>188</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings by Balancing optimization (replacing BMT200 with TD2010)</td>
<td>2,453.9</td>
<td>1,177.9</td>
<td>1276</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings by Eliminating Acces Databank</td>
<td>975,1</td>
<td>0</td>
<td>975</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings in the concentricity measurement</td>
<td>945,6</td>
<td>472,8</td>
<td>473</td>
<td>opt.</td>
<td>with av. 2 meas.</td>
</tr>
<tr>
<td>Savings by clamping jaws optimization</td>
<td>3,546.0</td>
<td>879,2</td>
<td>2,837</td>
<td>not yet realized</td>
<td></td>
</tr>
<tr>
<td>Savings Universal-CNC Drill Chucks workstation optimizations</td>
<td>512,2</td>
<td>275,8</td>
<td>236</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Savings O-Ring Assembly device/design optimization</td>
<td>12,0</td>
<td>4,0</td>
<td>8</td>
<td>opt.</td>
<td></td>
</tr>
<tr>
<td>Savings Deburring Clamping jaws with brush</td>
<td>86,7</td>
<td>27,1</td>
<td>60</td>
<td>not yet realized</td>
<td></td>
</tr>
<tr>
<td>Savings Teschauer Laser with rotation axis customer spec. Laser</td>
<td>1,713.1</td>
<td>1,555,4</td>
<td>158</td>
<td>realized</td>
<td></td>
</tr>
<tr>
<td>Saving Helping Device for Cutting the brazing rings</td>
<td>392,9</td>
<td>327,4</td>
<td>65</td>
<td>opt.</td>
<td></td>
</tr>
<tr>
<td>Further Small Savings</td>
<td>50,0</td>
<td>0</td>
<td>50</td>
<td>opt.</td>
<td></td>
</tr>
<tr>
<td><strong>Overall Possible Savings</strong></td>
<td></td>
<td></td>
<td><strong>7,474</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Already realized Savings (without red)</strong></td>
<td></td>
<td></td>
<td><strong>4,578</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Capacity of [employees]</th>
<th>Additional Capacity [Employees through measures]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base of the optimizations</td>
<td>10 realized 2.6 total 4.3</td>
</tr>
<tr>
<td>More capacity for further productivity</td>
<td>realized 12.6 total 14.3</td>
</tr>
<tr>
<td><strong>Overall productivity increase</strong></td>
<td>realized 26% total 43%</td>
</tr>
</tbody>
</table>

**ECONOMIC EVALUATION OF THE SCENARIO**
Hereby I confirm, that the present master thesis

“Assembly line & sub-assembly stock process optimizations at WTE Präzisionstechnik”,

has been independently and without illegal alien help been written by me. All sources of theoretical knowledge and tips by my supervisor have been openly displayed.

All information, which have been transferred directly or indirectly (thoughts) have been marked as such and can be seen in the literature summary as well.

I ensure that I haven’t given out this thesis to any inspection process already.

Aalen, 15th May 2012

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Oliver Kirschey
With finishing this thesis, the first step to implement a new and modern assembly area has been accomplished. The presented concept is now the base for the final movement to the new factory building in August/September. During the time from June/July, the workstations will be modeled out in further detail and first investments and orders will be done to grant a fast and well organized movement. Furthermore a detailed timetable for the movement has to be worked out to adjust all movement steps to each other that as less down times as possible occur in the factory.

All these steps will be further implemented and fine adjusted by me until the final movement is complete.
14 LITERATURE


*Product Catalog.* (2012). Ehrenfriedersdorf, Germany: WTE.


