Waste Elimination in Setup Operations

Pavla Paseková

Bakalářská práce
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Univerzita Tomáše Bati ve Zlíně
Fakulta managementu a ekonomiky

Univerzita Tomáše Bati ve Zlíně
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Ústav průmyslového inženýrství a informačních systémů
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Zásady pro vypracování:

Úvod

I. Teoretická část

- **Zpracujte literární rešerši vztahující se k problematice optimalizace pracoviště.**

II. Praktická část

- **Proveďte analýzu současného stavu pracoviště využitím metody SMED.**
- **Zhodnoťte výsledky analýzy a formulujte možnosti pro zvýšení celkové efektivity pracoviště.**
- **Proveďte ekonomické zhodnocení možností.**

Závěr

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ABSTRAKT

Tato bakalářská práce se zabývá problematikou eliminace časových ztrát (plýtvání) během přípravných operací – výměna zápustek mezi jednotlivými zakázkami. Práce je rozdělena na dvě části: teoretickou a analytickou. Teoretická část obsahuje literární rešerši zaměřenou na vývoj výrobních systémů přes řemeslnou a hromadnou výrobu až po štíhlou výrobu a její implemetnaci. Dále je zde zmíněn Toyota Production System a základní charakteristika průmyslového inženýrství. Poté už následuje podrobný popis metody SMED, její vývoj a fáze její implemetnace. Analytická část v úvodu obsahuje stručné infromace o společnosti Kovárna VIVA a.s., její historii a výrobní program. Poté se zaměřuje na popis vybraného výrobního procesu – kování, jeho specifika, popis jednotlivých činností a následnou analýzu pomocí SMED a její vyhodnocení. V doporučeních jsou pak popsány návrhy na zlepšení na základě zjištěných infromací a jejich ekonomický přínos.

Klíčová slova: štíhlá výroba, Toyota Production System, průmyslové inženýrství, plýtvání, SMED.

ABSTRACT

The Bachelor’s thesis deals with the elimination of time loss (waste) within the preparatory operations - exchange of dies between production orders. The work is divided into two parts: theory and analysis. The theoretical part includes literature search focused on the development of production systems through craft and mass production to lean production and its implementation. There is also mention of the Toyota Production System and the basic characteristics of industrial engineering followed by detailed description of the SMED method, its development and implementation stages. The analytical contains brief characteristic about Kovárna VIVA a.s., its history and production program. Then it focuses on the description of selected production process – forging followed by description of workflow within the setup operations analyzed with the SMED method including the evaluation. The recommendations for improvement are then discussed in proposals including the economic benefits.

Keywords: Lean Production, Toyota Production System, Industrial Engineering, waste, SMED.

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"Improvement usually means doing something that we have never done before."

Shigeo Shingo

OBSAH

INTRODUCTION

Contemporary market development trend is to customize products meeting customer's requirements. This tendency forces manufacturing companies implement and further develop the Lean production principles. This process takes in the advantage of revolutionary approaches especially in Czech industry weakened by decades of communistic style of management and control.

This passed period has huge impact on industrial production which despite all efforts still cannot reach the world standard of productivity.

The analysis is realized in Kovárna VIVA a.s. This forging shop is dynamically developing company with the aim of increasing productivity of processes by lean production implementation. In general, the level at which the lean is adopted is high, but still there are processes difficult to optimize. The character of the production is really challenging for lean methodology. The setup operation analyzed in this thesis is realized on the forging unit of 2500 tons screw press; this unit was chosen by the management because it produces the most profitable products therefore it is desirable to increase its productivity. The setup operation represents the die exchange on the forging press.

The purpose of the Bachelor's thesis is to identify and eliminate waste which occurs within the operational processes. Even those processes are not productive and add no value, their lasting should be as short as possible in name of Overall Equipment Effectiveness (OEE). If the setup operations are conducted in short time, the variability of the production process is increasing and this leads to more flexible production. This is the goal for many manufacturers – to be flexible; the flexibility of production is essential competitive advantage, nowadays.

I. THEORY

1 LEAN PRODUCTION

1.1 The Birth of Lean

1.1.1 Craft Production

Craft production was the very first organized type of manufacturing. The impulse for manufacturer was driven specially by the customer's demand. Craft production still remains nowadays, especially for special and luxury products (e.g. Orange County Choppers and its custom made bikes).

Figure 1 – Custom made product (Orange County Choppers, ©2014)

By Dennis (2007, p. 1) the Craft production has following characteristics:

- Workforce is the independent tradesmen skilled in design and manufacturing.
- Decentralized organization – the craftsman coordinates the process in direct contact with customers.
- Use of general-purpose machines for cutting, drilling and grinding.
- Low production volumes and high prices.
- Only rich people can afford the product.
- Quality is unpredictable – each product is original.
- No share of improvement activities.

Obviously, this manufacturing has many disadvantages, which Henry Ford and Fred Taylor had overcome by introducing mass production.

1.1.2 Mass Production

No doubt, the greatest worth on foundation of mass production has Frederick Winslow Taylor. He was the first who converted scientific principles into manufacturing, trying to find the best way how to run production based on scientific principles – with this intension he invented Industrial Engineering. (Dennis, 2007, p. 2)

According to Dennis (2007, p. 2), the main principle of Taylor's system was to separate planning from production. Essential characteristics are following:

- Standardized work
- Reducing cycle time
- Time & Motion study

By measurement and analysis within the production process he also formulated the basics of PDCA cycle (Plan-Do-Check-Ask).

Meanwhile, Henry Ford was about to start his life-work: Model-T, a car easy to manufacture and cheap to buy.

Figure 2 – Assembly line in Ford's plant (Ford Motor Company, ©2014)

The production of Tin Lizzy (slang name for Model-T) was based on principles of mass production, which Jirásek (1998, p. 15) describes as follows:

- Uniform product
- Labor division (each worker performs set of operations, which are easy to learn)
- Forced-moving production (driven by conveyor belts)
- Central work management

Ford's factory in Detroit was the place where Eiji Toyoda got his idea of Lean production.

1.1.3 Lean Production

The historical moment for Lean production was in 1949 – a collapse in sales (caused by the ended production of military trucks). This year should be written in "dark history" for Toyota Motor Company, if Eiji Toyoda in 1950 does not visit Ford's plant in Detroit. After his study in the plant (then the largest and the most efficient company in the world), he and Taichi Ohno concluded that the mass production as Ford run in U.S. could never be implemented in Japan. This idea enforced them to create their own production system – the Toyota Production System and so the Lean production. (Womack, Jones and Roos, 2007, p. 47-48) Ohno claims (2013, p. 1) the Toyota Production System is "to produce what you need, only as much as you need, when you need."

Figure 3 – Taiichi Ohno and Eiji Toyoda in Toyota plant in Nagoya (Toyota Motor Corporation, ©1995-2014)

The facts preventing implementation of mass production in Japan was sum up by Womack, Jones and Roos (2007, p. 48-49) as follows:

- Even the Japanese market is small the demand requires a wide range of vehicles.

- Japanese workforce do not will to be treated as a variable cost, moreover after the American occupation, new labor laws strengthened the workers position in companies.
- In Japan, there were no temporary immigrants willing to work in challenging conditions in return for high salary – the philosophy of Japanese is to work for one employer for life.

1.2 Lean Production Implementation

1.2.1 Lean Management

As Tuček (2006, p. 225) states, Lean Management is orientated especially on customer's satisfaction – this is the essential premise of success. Lean Management stands on 4 principles whose adoption will ensure the achievement of the goal.

- Pull Model of Inventory Control
- Avoiding Waste
- Essential Activities
- Principle of Continuous Improvement

Pull Model of Inventory Control

This pull system of production planning helps to eliminate waste generated by traditional push production – a material is pushed forward to following operations while it is available. In pull system, the availability of material is what gives signal for start of manufacturing and material purchase is based on demand forecast of customers. (*Systém tahu ve výrobním prostředí*, 2008, p. 4)

Avoiding Waste

Approach of elimination all non-value adding activities is essential in increasing efficiency and productivity of manufacturing.

Essential Activities

This principle is related to the previous one – Waste Elimination. For effective use of resources, is desirable to focus on those activities which a company can do at its best (within the value-adding processes) and to outsource the activities which are not essential for the production. (Tuček, 2006, p. 225)

Principle of Continuous Improvement - Kaizen

The word Kaizen comes from Japanese and it literally means "change for the best". Kaizen refers to philosophy or practices focusing on continuous improvement of processes. The founder of Kaizen, Masaaki Imai, defines it as continuous improvement of personal, family, social and working life. Kaizen includes everyone into improvement process. The prerequisite to successful kaizen implementation is a standard, because as Taichi Ohno said, where is no standard, there can be no Kaizen.

1.2.2 Lean Company

Lean Company is not a set of methods and approaches helping to eliminate waste. The company is formed by people, by their work attitudes, knowledge and motivation. Main force ensuring competitiveness and long-term survival on market is, apart from efficient processing of material and information, the Knowledge Management. (Košturiak, 2006, p. 20)

1.2.3 Lean Layout

The elements of Lean Layout are 5S, ergonomics and linear value stream (pull system). In practice, the definition of lean layout is 5S actually. (Via chapter 2.3.1.)

Figure 4 – Lean Layout (Assembly Magazine, ©2014)

According to Košturiak (2006, p. 65) Lean Layout is formed by elements coming from six fields:

Table 1 – Lean Layout Characteristics (Košturiak, 2006, p. 65)

<table>
<tr><td rowspan="2">Ergonomics</td><td>Appropriate Conditions - physiological and social needs</td></tr>
<tr><td>Health Protection - to prevent injuries and work diseases</td></tr>
<tr><td>Work Analysis & Measurement</td><td rowspan="2">Optimal work organization, dislocation, time consumption and standardization</td></tr>
<tr><td>5S</td></tr>
<tr><td>Visualization</td><td>Visualization of Workflow</td></tr>
<tr><td>Jidoka</td><td>Workplace Autonomy - Halting and signalization when abnormality occurs</td></tr>
<tr><td>Poka-Yoke</td><td>Human Failures & Mistake Prevention</td></tr>
</table>

1.3 The Toyota Production System

The simplest definition of the Toyota Production System (TPS) can be sum up like “the system for the absolute waste elimination.” In fact, the TPS is 80 percent waste elimination, 15 percent production system and 5 percent Kanban. As Taichi Ohno (2013) states, the Kanban simply means achieving Just-In-Time (JIT). There is a misunderstanding between TPS and Kanban meanings (e.g. one of the Kanban rules requires not to pass defective products along to succeeding process – this is not a function of Kanban actually, it is one of the basic principles of the TPS. (Shingo, 1989, p. 67)

1.3.1 Basic Principles of the TPS

To avoid the misunderstandings among the terms related to the topic, in this chapter, the basic principles of the TPS are described.

Overproduction Waste

Shingo (1989, p, 69) defines two types of overproduction:

- Quantitative – to produce more product than is needed
- Early – to produce product before it is needed

According to Chromjaková (2011, p. 47), overproduction is not just a higher production beyond the customer's requirements, it is also overproduction of information and material. Based on this context, following examples of overproduction sources can be defined:

- More information than process requires
- Making unnecessary standards
- Unused worker's capacity
- Overproduction of paperwork
- Badly defined requirement (leads to new process)

Just-In-Time

The TPS is stockless, meaning that each process must be supplied with the required material in the required quantity and at the required time. (Shingo, 1989, p. 69)

Toyota's just-in-time system had evolved into an exceptional source of competitive advantage based on achieving required quality and productivity and on lowering cost. (Salvendy, 2001, p. 544)

Worker & Machine Separation

Workers and machines have to be separated in case to raise production efficiency and to support effective use of human resources. Shingo (1989, p. 70) divides the process of automation into several stages:

Handwork – workers manufacture a product without any machine help.

Manual feeding with automated machining – worker feeds and removes products out of the machine, he also performs the tool feeding, the machining itself is automatic.

Automated feeding and machining – worker feeds and removes products out of the machine, the machining and tool feeding is automatic.

Semi-automation – worker detects and corrects an abnormal conditions, other work is carried out by machine.

Pre-automation – worker corrects the defects only, other functions are performed by the machine.

Automation – fully automatic processing, defects detection and correction.

Low Rate of Utilization

In fact, Toyota has more equipment than most companies and this makes Toyota so strong in production efficiency. (Shingo, 1989, p. 72)

Andon

When the production process works on principle of keeping inventories at minimal level, the need of JIT comes up. And when the company works on JIT principles, there has to be insurance in case a problem in production process occurs. That is why the TPS included Andon into its basic principles.

The machines are equipped with the detection of production problems and shut down when some problem occurs. This signalization also indicates the type of problem and its placement. Workers are also allowed to stop the production line when they have feeling a problem can occur. (Shingo, 1989, p. 74)

2 INDUSTRIAL ENGINEERING

Industrial Engineering (IE) deals with choices. When other disciplines of production management emphasis on using skills in very specialized field, IE allows to work in a variety of businesses – IE provides flexibility. It does not matter in which business or Production Company IE is applied because all share the common goal to save money and to increase efficiency.

The need from Industrial Engineers had grown, when companies adopt philosophy of continuous improvement and quality management to survive in highly competitive market. Industrial Engineer is the only engineering professional who was educated and trained to be specialist in implementing the lean philosophy in companies. (Industrial Engineering, ©2006)

2.1 Definition

Industrial Engineering is discipline which puts into context knowledge of Mathematical Statistics and technical fields as well as Psychology and Sociology, trying to find optimal way how to secure the production of goods and services of high quality, yet with minimal costs, by optimum utilization of all factors entering the production process. The purpose is to design, to organize and to control the cooperation of production systems, people, material, energies and information in order to maximize the productivity. (Tuček, 2006, p. 106)

2.2 Waste – MUDA

Muda is Japanese word for waste. Womack (2003, p. 15) specifies it as any human activity absorbing resources with no value addition, such as mistakes requiring rectification, production of unneeded stuff (so the inventories and remaindered goods pile up), unneeded processing and workers movement, goods transportation from place to place with no purpose etc.

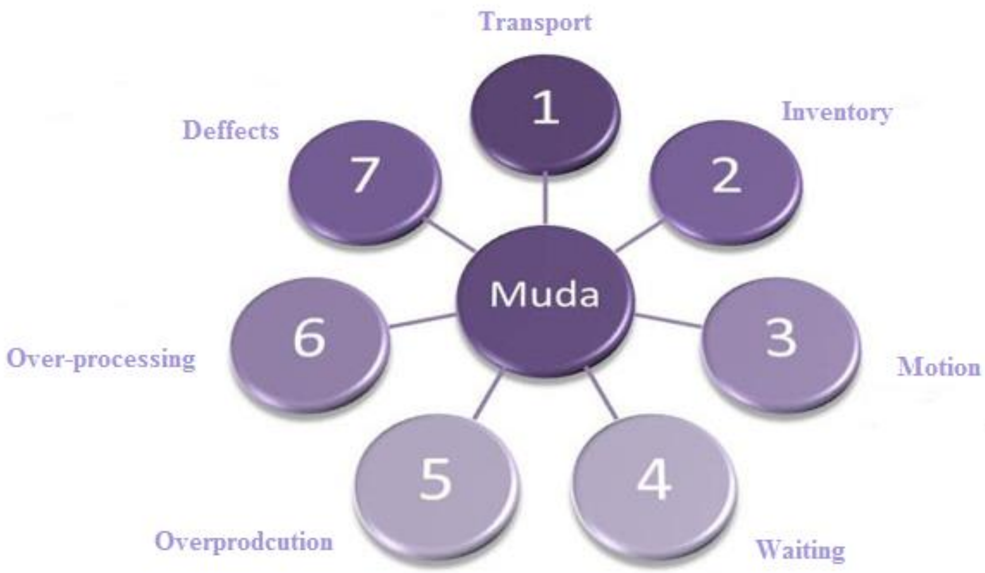


Figure 5 – Muda (Beyond Lean, ©2014)

Taichi Ohno sorted out muda into seven types of waste:

Transport – meaningless relocation of goods, material etc.

Inventory – presence of various inventories among the production process with misconception of future need of these things.

Motion – unnecessary movements of a worker or machine adding no value into the process.

Waiting – waiting times for machines, for products, for people, etc.

Overproduction – production beyond customer's demand.

Over-processing - conducting operations beyond customer's requirements.

Defects - faulty products and rework.

2.3 Tools for Waste Identification and Elimination

Once the waste is identified, the following set of "lean" tools is applied to eliminate this waste. (Mind Tools Ltd, ©1996-2014) It is not necessary to use all of these tools, but in name of efficiency, the best choice would be to use them all.

Just in Time – this tool is based on the "pull" system. JIT helps to minimize inventories and resources to ensure the purchase of material, production and distribution of products only when required. The optimal option is to combine JIT with Kanban. (Tuček, 2006, p. 2005)

Kanban – is the key tool how to involve workers in the "lean" process. The principle is to signal when there is a need to replace order or locate something. The aim of Kanban is to reduce overproduction and inventories. (Tuček, 2006, p. 74)

Zero Defects – this system focuses on producing right product at required quality first time, to save time and money spent on corrections. (Dennis, 2007, p. 96)

SMED (Single Minute Exchange of Dies) – via chapter 4.

5S – via chapter 2.3.1.

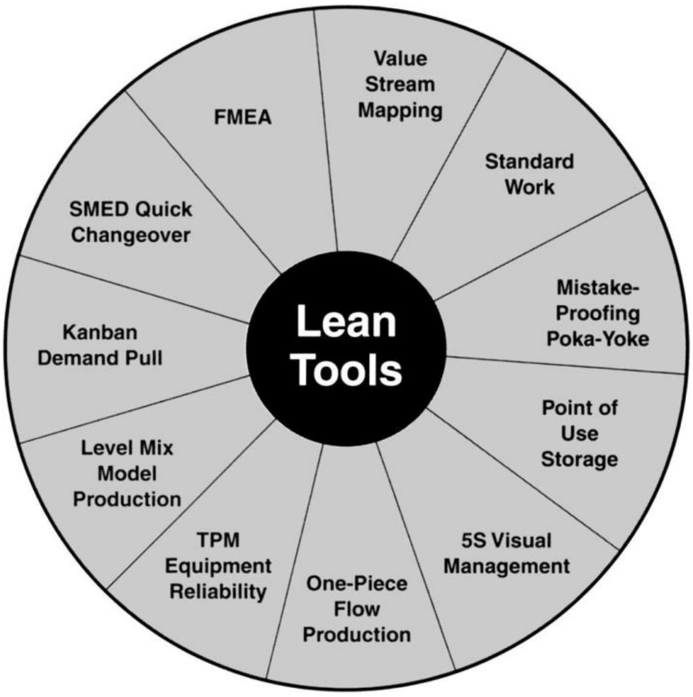


Figure 6 – Lean Tools (Business Excellence, ©2009)

In the analysis, only SMED and 5S are used, so these tools are described in detail in following chapters.

2.3.1 5S

5S is methodology of standardization and visualization. The name comes from Japanese words: Seiri, Seiton, Seiso, Seiketsu, and Shitsuke.

- 整理 Seiri - Sort
- 整頓 Seiton - Straighten

- 清掃 Seiso - Shine
- 清潔 Seiketsu - Standardize
- 躾 Shitsuke – Sustain

According to *5S pro operátory* (2009, p. 12) these five stages are the basis for improvement actions. Indeed, the sorting and the setting of order are the basis for defect reduction, cost reduction, safety improvement and injuries prevention. When the standards of 5S are implemented, the production process achieves these advantages:

- Higher productivity
- Elimination of defects
- Meeting deadlines
- Safe working environment

3 SETUP OPERATIONS

3.1 Explanation of Terms

3.1.1 Processes versus Operations

Shingo (1985, p. 7) claims that the manufacturing process is divided into phases; generally there are four of them: work, inspection, storage and transportation. Each of these phases has its own operation; accordingly there are operations of work, inspection operations, storage operations and transportation operations. More in-depth, every operation has sub-categories: setup operation, essential operation, auxiliary operation and margin allowance operation.

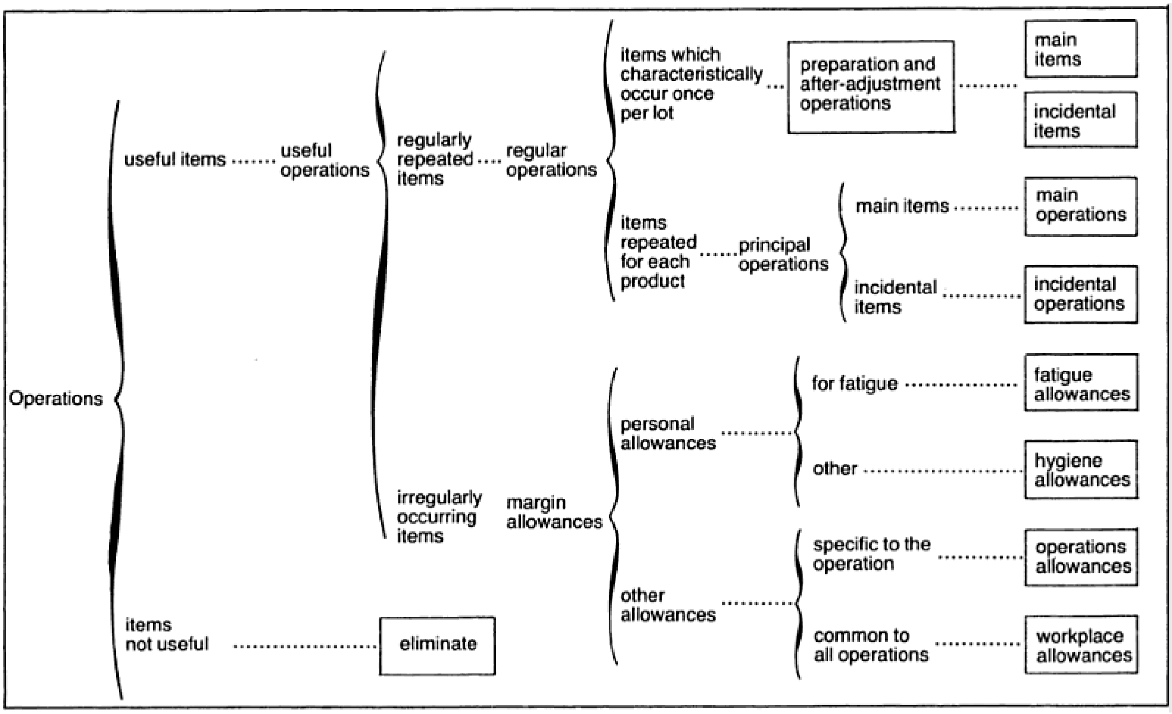


Figure 7 – The Structure of Operations (Shingo, 1985, p. 8)

3.1.2 Lots

In manufacturing three main lot sizes are distinguished: small, medium and large. It is up to the company how these sizes will be defined. It is obvious that plant which produces 10 units of goods has no reason to plan the production in specific lots. Generally, the lot sizes can be defined as follows:

- **Small lot:** 1 – 500 units
- **Medium lot:** 500 – 1000 units

- **Large lot:** 1000 units and more

3.1.3 Surpluses

In general, two types of surpluses exist in manufacturing. It is excess inventory and excess anticipated production.

Excess Inventory – it is a stock of goods, which were produced extra, with the intention it could cover shortage in case of scraps.

Excess Anticipated Production – it is a kind of production strategy, when intermediate or finished goods are produced in advance, meaning before when they are actually needed to be produced. (Shingo, 1985, p. 11)

3.2 Improving Setup Operations in Traditional Ways

Shingo (1985, p. 12) states that the need of setup operation comes from the fact that the demand pushes companies into variable production; to diversify products, e.g. in automobile industry it means to develop a full line of cars offered. It is generally considered that customers require many kinds of products in low quantity. This is the challenge that every company faces. There are several strategies to solve the problem:

- Strategies of Skill
- Strategies of Large Lots
- Strategies of Economic-Lot

3.2.1 Strategies of Skill

From the perspective of traditional manufacturing operation is assumed that efficient setup change requires knowledge and skill of operators.

- **Knowledge** – awareness of the structure and function of the workplace followed by familiarity with the equipment (tools, mountings and clamps, dies etc.).
- **Skill** – ability of operator to mount and remove dies in short time with zero fails.

3.2.2 Strategies of Large Lots

The time during which the setup operation is realized is not negligible. E.g. if production of a part lasts 1 hour and setup exchange takes 30 minutes, it is 50 % of wasteful time of non-value adding activity. Then it is obvious that most of the companies tend to reduce these setup times to minimum. Increasing the lot size might be the solution. In case customer places a request for diversified, low-volume orders the lot size increases when these low-volume orders are combined and enter the production together. The advantage of this is that the producer can anticipate the demand leading to better production planning.

3.2.3 Strategies of Economic-Lot

According to large lot strategies, the Economic-lot concept is based on balance between lot sizes and costs. In general, large-lot production results in lowering costs connected with setup operations duration but it also raises costs because of enlarging inventories. The economic-lot strategy looks for the optimum lot size (Figure 8) when the costs are acceptable.

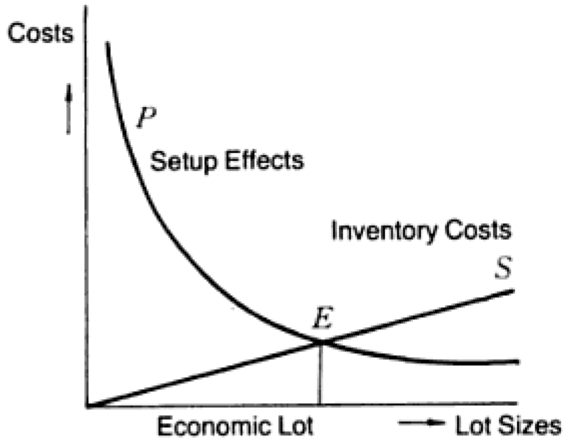


Figure 8 – Economic Lot Size (Shingo, 1985, p. 18)

3.2.4 Blind Spot in the Economic-Lot Strategy

The biggest issue in the concept of economic-lot is the impossibility of perceptible setup time reduces. Producing in large lots leads to mitigation of the effect of short setup time. The bigger the lot is the more imperceptible is the effect. Luckily, with development of SMED system, all of these strategies had lost their entire reason.

4 SMED

SMED, as known as Single-Minute Exchange of Dies is very efficient tool of industrial engineering for significant reducing setup times ideally to less than 10 minutes. Each step of changeover in order to reduce wasteful activities to minimum by organization, simplification and rationalization of workflow and the equipment needed to realize the changeover. The principle of the SMED system is to convert as many changeover steps as possible to “external setups” (performed while the machine is running already), and to reduce the “internal” ones to minimum. Meeting these conditions gives the reduction of changeover time to the single digits (“Single-Minute” means less than 10 minutes). (Lean Production, ©2010-2013)

A successful SMED application gives the following benefits:

- Lowering of manufacturing costs (the shorter the changeover is the more is the machine productive)
- Small lot production (faster changeovers enable more frequent product changes)
- Flexible production (smaller lot sizes enable more flexible production planning)
- Lowering inventories (according to small lot production, the inventories become lower)
- Smooth workflow (further more the result of successful application of SMED is standardization of the workflow) (Lean Production, ©2010-2013)

The SMED system was developed by Shigeo Shingo, a Japanese industrial engineer who had helped many companies with reducing their changeover times. His multi-year research led to actual reductions in changeover times reaching 94 %. (e.g. from 90 minutes to less than 5 minutes).

The most significant example of SMED in daily life is replacing a tire on a car:

- For many people, changing a single tire can easily take 15 minutes.
- For Ferrari’s F1 pit crew, changing four tires takes less than 10 seconds. (Lean Production, ©2010-2013)

Figure 9 – Practical use of SMED (Operational Excellence Consulting LLC, ©2014)

4.1 History

The very first Shingo's intension to start working on SMED was in 1950, when he was asked to analyze options of increasing efficiency in Mazda plant which had been part of Toyo Kogyo in Hiroshima. Mazda had been focusing on manufacturing three-wheeled vehicles and Toyo intended to reduce bottlenecks caused by body-molding presses which were not working up to capacity.

Shingo (1985, p. 21) decided to conduct a survey of the workplace instead of buying new presses at the first place. Based on this analysis he draws conclusions. Within adjustment of the press he discovered the issue why the exchange lasted so long. The operators had zero organization concerning the tool needed for exchange on the press. They had been looking for the mounting bolts for hours or they had taken them from the other workplaces (where the bolts will miss in future). And so Shingo realized that all the operations were of two different types:

- **Internal setups (IED)** – internal are those operations which have to be performed on stopped machine (e.g. dies removing and mounting)
- **External setups (OED)** – the operations which can be conducted while the machine is running already (e.g. transportation of dies needed for oncoming exchange, tools preparation etc.)

Preparing the bolts needed in advance will shorten the setup time by one hour actually. Shige had recommended sorting out the needed tools into boxes – one box for one type of setup. Thanks to this proposal the productivity raised by 50 % and the bottleneck was removed. This was the first “kick” for SMED. 16 years later, Shingo had visited the Toyota Motor Company’s main plant, where he had succeed in shortening setup time (1000tons press) from 4 hours to only 90 minutes (by using IED and OED only). After some time, the management of Toyota decided that the exchange has to be performed in 3 minutes only. That was impossible for Shingo at the first moment, but then he realized he can achieve this by transforming IED to OED. In belief, the exchange can be realized in less than 10 minutes, he named this method SMED – “Single Minute Exchange of Dies” (die exchange within single minute). Later, this method was included in process engineering in every Toyota plant and it laid the foundation for TPS – the Toyota Production System. And so was the 19-year development of the system, which is basic skill of every industrial engineer nowadays, and which is applied whenever there is a need for increasing efficiency of process. (Shingo, 1985, p. 22-26)

4.2 Techniques for Applying SMED

For successful use of SMED, 4 stages have to be followed. Shingo (1985, p. 33-52) divided these stages as follows: Stage 1 of separating internal and external setup, Stage 2 of converting internal setups to external and Stage 3 of streamlining all aspects of the setup operation. He also included the Preliminary stage which describes situation where internal and external setups are not distinguished.

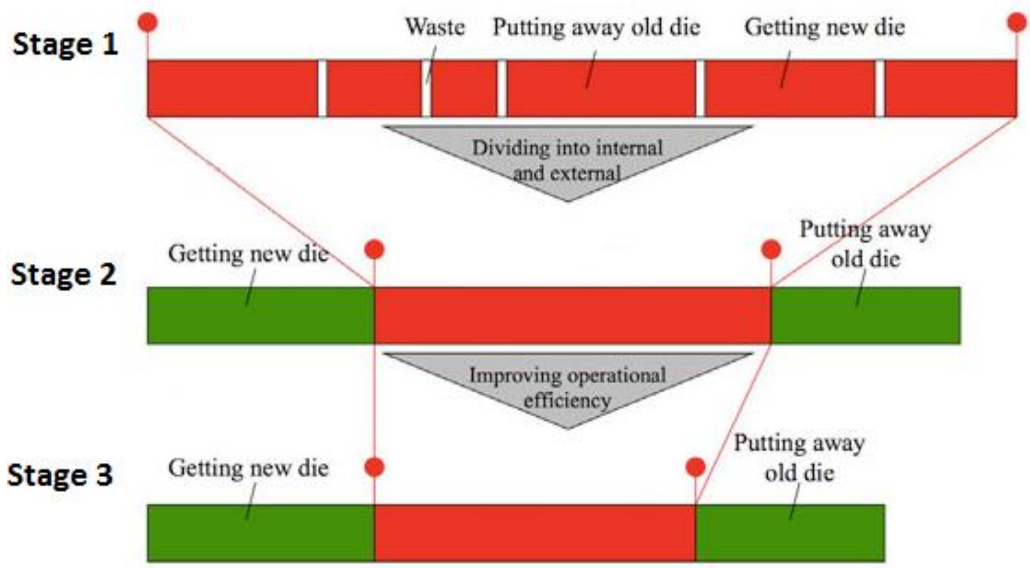


Figure 10 – SMED diagram (Manager Services, ©2009)

4.2.1 Stage 1

In this stage are selected such operations that can be performed while the machine is still running. It requires transportation improvement (preparation of dies, tools, etc.) as well as assigning responsibilities on operators to ensure smooth and continuous work flow.

4.2.2 Stage 2

The very first step is to prepare operating conditions in advance (e.g. Dies preheating – the dies can undergo the procedure of preheating before they are mounted into the press already by using external preheating machine).

4.2.3 Stage 3

After accomplishment of stage 1 and stage 2, the process can proceed to stage of improving every elemental operation to achieve time reductions of internal and external setups. External operations can be improved in storage and transportation. The internal ones can be performed as parallel operations that involve more than one operator. Next option is to use quick clamping tools, pneumatic hand-operated tools, etc. The improvements depend on disposition and character of the production.

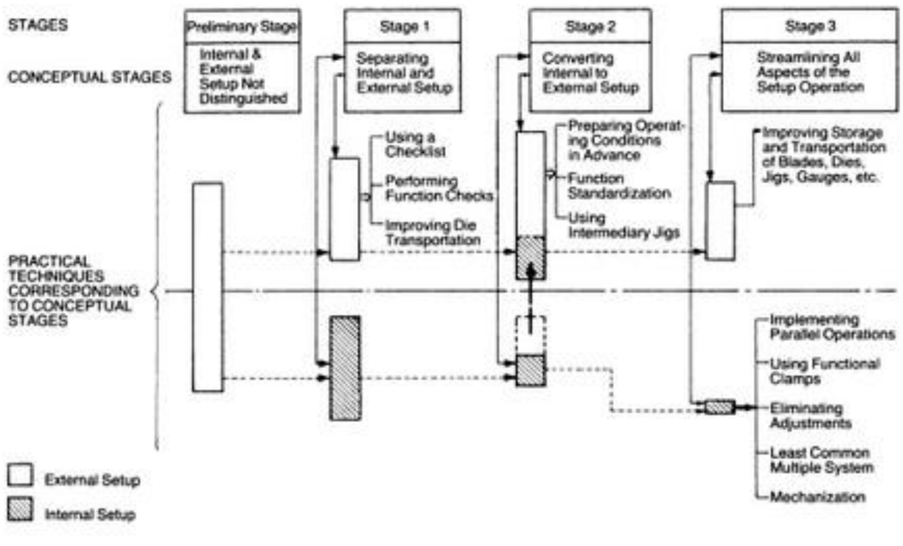


Figure 11 – Stages of SMED (Shingo, 1985, p. 92)

4.3 Effects of SMED

Implementation of SMED method has several positive impacts apart from time savings. These effects reflect in many spheres such as quality, logistics, ergonomics, safety, error prevention, economics (lowering expenses and costs), production flexibility etc. In fact, the most essential advantage of SMED is the possibility of more frequent changeovers, which leads to following effects:

- Batch sizes reduction
- Inventories reduction
- Increasing flexibility
- Reducing lead time
- Improving quality
- Reducing waste
- Increasing capacity

II. ANALYSIS

5 KOVÁRNA VIVA A.S.

Kovárna VIVA a.s. is a Czech forging shop specialized in closed die forgings from alloyed, micro-alloyed, carbon and structural steel. The weight of the products vary between 0,1 kg up to 20 kg.

Figure 12 – Company Logo

The company provides to its customers a complex production program for drop forgings, starting with forging construction proposal up to its final treatment – heat treatment, forging machining, surface treatment (staining, zinc and nickel coating) and the logistic services.

5.1 History

It is generally known that the forging shop used to be a plant which was a part of Bata's factory. The list below is a summary of VIVA's history.

1932 Establishment of the forging shop as a part of Baťa Company.

1992 27th of October the forging shop became independent as Kovárna VIVA Zlín

3 forming units

1993 The very first foreign customer

1995 Start of using CAD and CAM Unigraphics

Purchase of CNC machine for tool shop

Poclain Hydraulics project,

1997 ČSN EN ISO 9002 Certification

1998 Linde project

2002 ZF Boge Elastmetall project

2003 ČSN EN ISO 14001 certification

Creation of the Research & Development department

1st spindle press 2500 tons

Mechanization of the forging production for automotive industry

2005 Investments in Measuring & Control, 3D instruments, metallographic laboratory, spectrometer, magnetoflux

Crank press 2500 t unit

Development of new the forgings generation for Linde

SCANIA project

2006 ZF Sachs AG project

2007 New presses 1000 t and 1600 t

2008 Quenching line – 2nd unit

Spindle press 2500 t – 2nd unit

2009 Economic crisis - 50% decline of production

2010 TRW project

2011 260 Employees

New Forming 2500 t unit

2012 20th anniversary of the company Kovárna VIVA

2013 Construction of the cutting central zone for metallurgical material

5.2 Dislocation of Kovárna VIVA a.s.

Kovárna VIVA a.s. is located in Bata's factory area called Svit and owns several buildings belonging to this area.

Figure 13 – Dislocation of VIVA's buildings in Svit area (internal materials)

5.3 Processes

All processes in Kovárna VIVA a.s. are divided into three groups:

- Development
- Design
- Production

The Development Department deals with forming processes simulations. Using the latest versions of software support can guarantee the optimal technology forging's manufacture proposal and the possibility of reverse engineering as well.

Software support:

- CAD/CAM - NX6
- Technical Documentation Management - Team Center
- Forming Processes Simulation - Forge
- Data Formats - STEP, IGES

The Company is capable of designing and manufacturing needed tools itself. The production is realized on CNC machines with HSC technology. The input is vacuum hardened material with nitrated surface. The process of production includes the measurement control on 3D CND inspection post.

Hardware equipment:

- Machining centers—8 in total (Trimill, ZPS Tajmac, Hermle)
- Turning work - 3 in total (ZPS, MAS, YCM)
- 3D Measurement – Zeiss

The manufacturing of forgings consists of several operations until the final product can be shipped to the customer. All the operations belonging to the production are sequentially ordered in the following table:

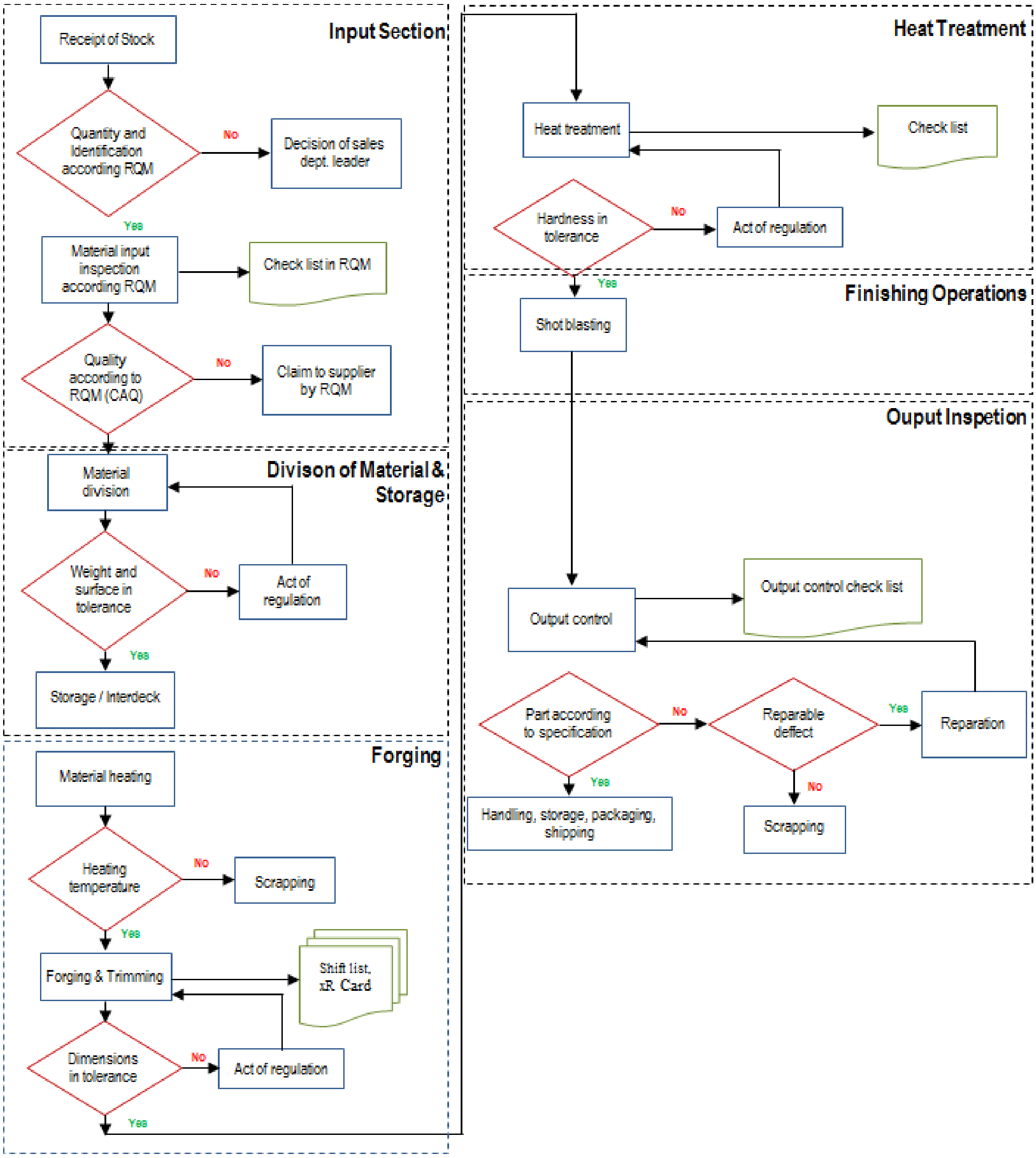


Figure 14 – Workflow in Kovárna VIVA a.s.

The workflow in Kovárna VIVA a.s. consists of many processes, all subject to ISO standards – ISO 9001:2008, ISO 14001:2004 and ISO/TS 16949:2009.

6 PROCESS ANALYSIS

VIVA owns 10 forging units, most of them are located in 92^nd building, including analyzed unit.

In the picture below the location of the chosen forging unit is highlighted with the red circle.

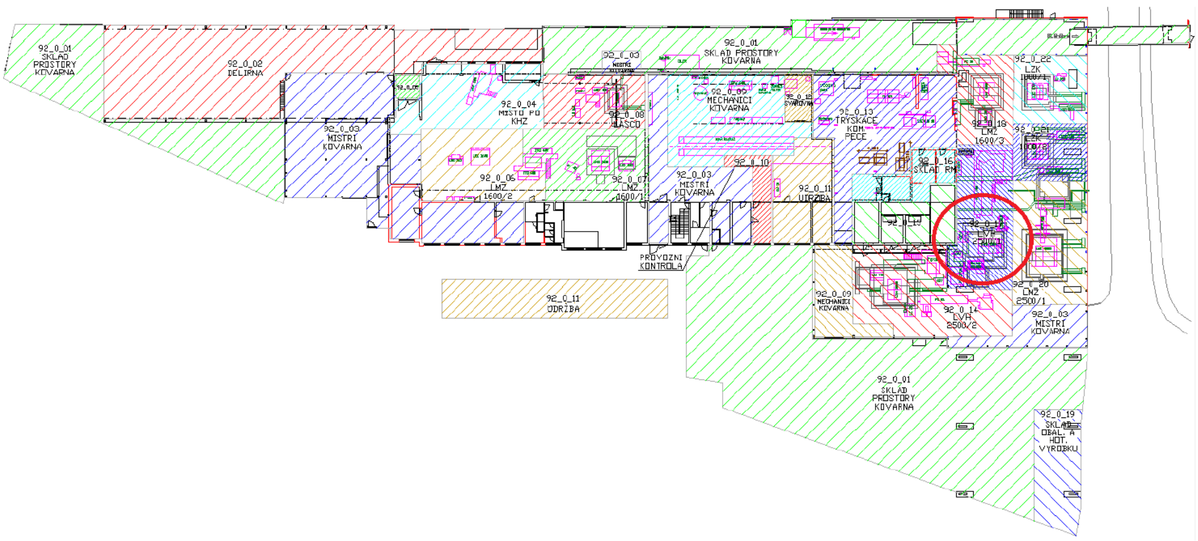


Figure 15 – Layout of 92^nd building (internal materials)

Following picture contains of the floor shop in 92^nd building. The analyzed forging unit is located in the left.

Figure 16 – Floor Shop (internal materials)

6.1 Die Forging on Screw Presses

In this process, the analysis is applied on screw press for die forging. This forging method has its specifics (tool clamping, trimming process, etc.) different of other methods.

The workflow is subordinated to the principle of forging in one-cavity die with one hammer blow (in exceptional cases it is possible to place at most one additional preparatory die – only in case the relocation of material is not too difficult). (Hašek, 1965, p. 344)

In this case of die forging with flash, the trimming press has to be well designed for precise flash trimming. (via chapter 6.1.2.)

6.1.1 Die Clamping

The clamping method differs from die clamping on other forming machines. With no big difficulties, the hammer dies and even the dies for crank forging can be clamped.

The lower die is clamped on the press table provided with parallel grooves in shape of "T" or "X". The upper die is clamped to ram provided with the same grooves.

Standardized die clamping has following main components: lower table plate, upper table plate, clamping shoe, clamping screws & nuts.

Figure 17 – Clamped tools on forging press (left) & trimming press (right) (own processing)

6.1.2 Trimming of Drop Forgings

According to the shape of forgings, the flash occurs on the external line of the forged piece. This flash has to be removed – the process is called trimming. In case of the complicated shaped forgings, only the hot trimming is realized; for these reasons:

- Less pressure when trimming
- Better separation of the flash

6.2 Description of the chosen process

The production process analyzed in this thesis is realized on forging unit, which consists of 2500 t crank press, the inductor and the trimming press. This forging unit produces the heaviest forgings, up to 25 kg.

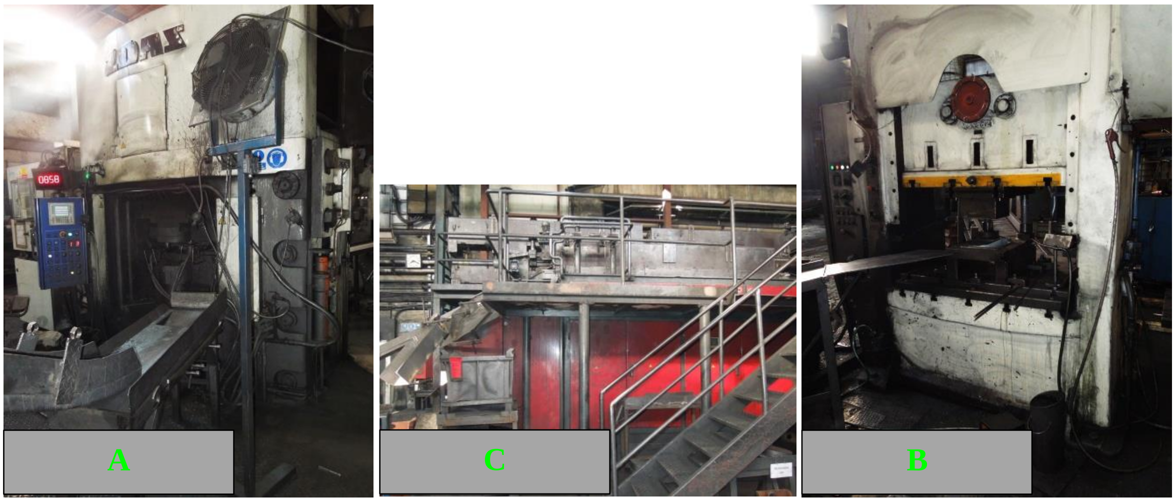


Figure 18 – Forging Press (A), Inductor (C) and Trimming Press (B) (own processing)

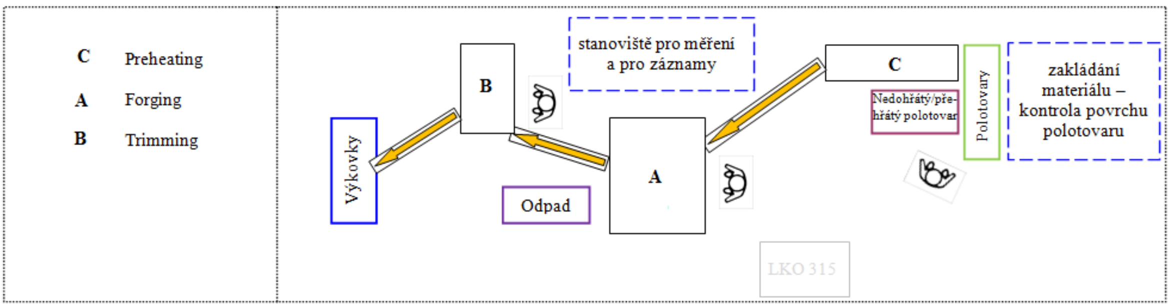


Figure 19 – Workplace Layout

The forging process starts with material preheating realized on induction preheating machine – **C**. After then the preheated material comes to first step of forming – hammering. The hammering process can be realized on the forging press or external on hammering press – in this case, the hammering die is clamped in the forging press. Next operation is forging itself on **A**. The first stage is pre-forging which gives a basic shape of the forged piece, followed by the second stage - finish forging, where the final shape is made. After the forming, the excess material had to be split apart from the forged piece – this operation is called trimming and it is realized on the cutting press - **B**. After the forming process the forgings are treated by controlled cooling.

The manufacturing process ongoing on this forging unit is continuous and production time is variable according to production charge. The time consumption for the production order is around 7 hours. There is a tool change among each production charge which takes up to 2 hours. During this setup time, the line is stopped and produces nothing. This is the biggest issue within this process, because every single minute, when the line is stopped, is a cost for the company.

6.3 Setup Operations

In the chosen process, the setup operations are realized on each machine (induction heating, forging press and trimming press) and their duration depends on skills of operators mainly. All these operations are performed as the internal setup. The setup times - standardized for each machine are listed in following table:

Table 2 – Setup Times (own processing)

Machine	Setup Time
Inductor	30 min
Forging press	90 min
Trimming press	50 min

There are three types of setup operations: Inductor exchange, Die exchange on forging press and Exchange on trimming press. All of them are realized as internal and consumed up to 2 hours.

6.3.1 Inductor Exchange

The exchange of inductor is realized if diameter of material changes out of the interval.

Table 3 – Inductor Diameters (own processing)

Inductor Diameter	Material Shape
60-80 mm	Square & Round
80-100 mm	Square & Round
100-120 mm	Square & Round
60-80 mm	Round
78-100 mm	Round
92-120 mm	Round

6.3.2 Die exchange on forging press

The manipulation with dies represents the most important and the most challenging operation of setup. This operation might be divided into 3 steps:

- Removing of old dies out of the press
- Cleaning and preparation of removed dies
- New dies mounting

When dies are fastened properly on the press, the process of preheating is performed. For this preheating of dies the operators use special burners (they are two in general – for pre-forging and forging couple of dies) which are inserted between each couple of dies. Then the operator releases valves for oxygen and gas and lights the burners, which rest in the press for cca 60 minutes. After this final procedure the press is ready for use. The time during which the dies are preheated is not included in setup time.

Figure 20 – Forging Die (internal materials)

6.3.3 Exchange on trimming press

The exchange of tools on trimming press is performed simultaneously with the exchange of dies on forging press. Exchange of trimming tools does not last as long as the exchange of dies; these tools are connected to one piece – the trimming tool. The handling with the trimming tool is quite easy and consists of release and removal of clamps followed by removal of the trimming tools itself. Next operations are fastening of new trimming tool and the setting-up. When the trimming press is adjusted properly, the production can start.

6.4 During the Shift

Each forging unit in Kovárna VIVA a.s. has three shift workers: the foreman, the smith and the smith assistant. Everyone has his own responsibilities and duties. The foreman has to control the process, to supervise the performance at work and to fill in the Shift list (via chapter 6.5), in which he registers during the shift, including the downtimes within the process (abnormalities, setups, repairs, etc.). The smith operates the forging press and the assistant operates the trimming press.

6.5 Shift Documentation

VIVA	SMĚNOVÝ KONTROLNÍ LIST	č. výkovku:
	Jakost materiálu:	č. zakázky:
	Tavba:	

Bezpečnost práce při všech pracovních úkonech dle směrnice BP 001/2005

Datum	Směna	Pracoviště	Odpracováno hodin: od: do:	Vykováno kusů	Zmetky celkem	Prostoje celkem

Pracovní zařazení	PŘEDÁK	KOVÁŘ	POMOCNÍK KOVÁŘE
PŘÍJMENÍ			

PŘEVZETÍ A UVOLNĚNÍ VÝROBY: Převzato a uvolněno: ☐ O.K.

☐ funkční stroj-zařízení ☐ nástroje a nářadí ☐ mazadlo, palety
☐ výrobní a kontrolní dokumentace ☐ měřidla ☐ předehřáté zápustky
☐ bezzávadné a uklizené pracoviště ☐ info z předchozí směny
☐ správné nastavení pyrometru ☐ správná funkce třídičky .... podpis předáka

Uvolnění výroby TK: ☐ UVOLNĚNO ☐ NEUVOLNĚNO .... podpis pracovníka TK

SAMOKONTROLA pracovníky výroby ☐ ANO ☐ NE

A Výměna kovacího nářadí, nahřívání

Varianta výměny	A	B	C	D	E	F	G	H

	od	do	min.	Norma výměny
Výměna				min.

Při překročení časové normy, uveď příčinu v poznámce.

Jiné výměny

	od	do	min.	
induktor				
prasklá zap.				

B Seřízení	od	do	min.	od	do	min.

PROSTOJE

	od	do	min.	od	do	min.	od	do	min.
C Broušení zápustek									
kov. vrch									
kov. spodek									
před. vrch									
před. spodek									
D Broušení	od	do	min.	od	do	min.	od	do	min.
Ostřihovačka									
Děrovačka									
E Údržba	od	do	min.	od	do	min.	od	do	min.
Strojní									
Elektro									
F Jiné	od	do	min.	od	do	min.	od	do	min.
Náhradní práce									
Úklid									
PŘESTÁVKA									

Denní údržba strojů a zařízení dle " Pracovní návodky - Denní údržba stroje obsluhou " provedena: ☐ ANO ☐ NE .... podpis předáka

Kontrola pracoviště, dodržování technologické kázně, BOZP a PO mistrem: čas: .... podpis: ....

Figure 21 – Shift List (internal materials)

The Shift list represents record of the shift. There are records concerning taking the shifts and conditions in the workplace at the beginning and the ending of the shift, but the very essential information is list of downtimes. The downtimes are divided into six groups: Exchange of the Dies (including forging and trimming press together), Setting (meaning setting of the machines), Die Grinding, Grinding in general, Maintenance and Others. The break is not included into the downtimes.

Based on the information from the Shift list, there is the analysis of the downtimes per month (December) below:

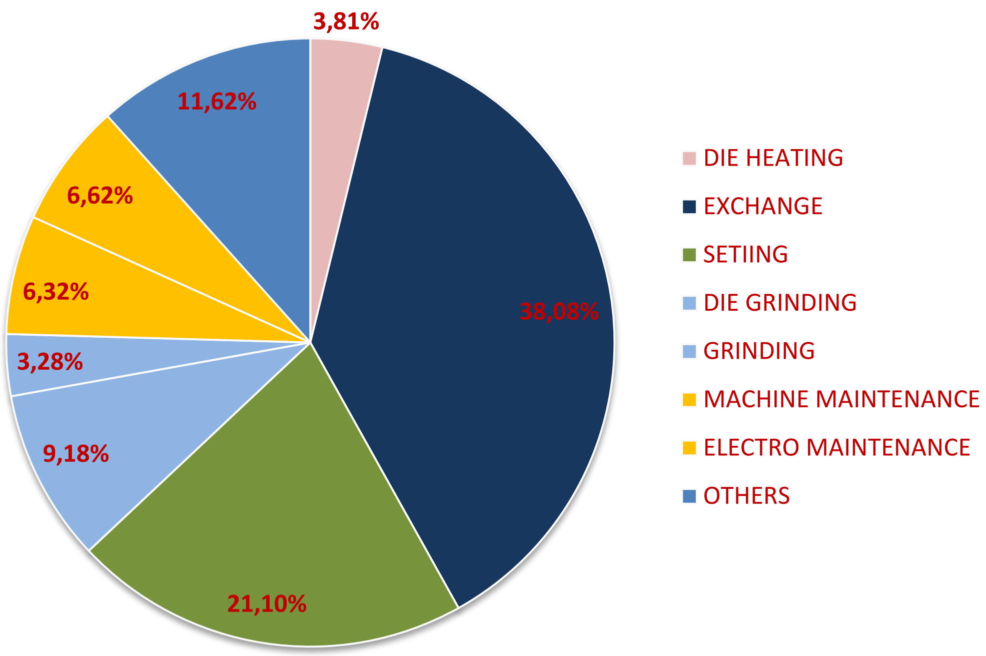


Figure 22 – Share of Exchange on total downtime (own processing)

The most significant is the Exchange downtime. It takes almost 38 % share on the total downtime during the shift. This waste was chosen to be eliminated using the SMED method.

6.6 SMED Implementation

In the analysis, the SMED method was implemented on the exchange of forging dies only because of the biggest impact of this type of exchange on the total setup time of the setup operation.

SMED (Single Minute Exchange of Dies, rychlá výměna nářadí)

Stroj A

ČINNOST:	DATUM:	STRANA:	Provedl
Výměna zápustek	3.9.2013	1	Paseková

N°	ČINNOSTI OBSLUHY	ČAS ZÁZNAMU			CELKOVÝ ČAS [s]	Přemistění	Nástroje	Poznámky
1	A - odhazuje poslední kus z induktoru B - vypíná induktor	8	1	51	5			
2	A - vypíná pás z induktoru?	8	1	56	5			
3	A - přechází k A a přesouvá ventilátor	8	2	1	8			
4	A - bere si nářadí z ponku vedle stroje A	8	2	9	12			
5	A - sjíždí beranem lisu dolů	8	2	21	20			
6	A - bere si nářadí z ponku vedle stroje A	8	2	41	154			
7	A - povoluje spodní díl lisu	8	5	15	35			
8	A - povoluje horní díl lisu	8	5	50	50			
9	A - baví se s kolegy (C+D), pak odchází bokem	8	6	40	45			
10	A - se vrací k lisu a povoluje C - ho pozoruje	8	7	25	16			
11	A - odkládá klíč a bere si jiný, povoluje s pomocí D	8	7	41	72			
12	A - jde si pro jiné nářadí D - stojí u skříně s nářadím a dívá se dovnitř	8	8	53	230			
13	A - povoluje zezadu stroje A D - jde za ním	8	9	5	10			
14	B - šplhá nahoru na pás z induktoru	8	9	15	21			
15	A - povoluje B - šel pryč	8	9	36	477			
16	B - přetipovává stroj A	8	10	38	32			
17	D - bere si klíč a vyjíždí beranem lisu nahoru, pak přechází k ostřihu	8	11	10	230			
18	D - povoluje lis na ostřihu	8	15	0	723			poškozený záznam
19	A+C - přichází zezadu	8	27	3	37			
20	A - ofukuje lis vzduchem B - přebírá nářadí ve skříni C+D - se baví	8	27	40	46			
		8	28	26				

ČINNOSTI OBSLUHY		ČAS ZÁZNAMU	CELKOVÝ ČAS [s]	Přemistění	Nástroje	Poznámky
21	A - dokončil čištění lisu vzduchem a začíná ofukovat okolí lisu B - si vybral nářadí a odchází C+D - jsou mimo záběr	8 29 33	67			
22	A - dofoukal podlahu a jde si pro smeták	8 30 0	27			
23	A - zametá	8 33 49	229			
24	A - přechází zametat dozadu stroje A	8 35 20	91			
25	A - přešel zezadu, s někým se baví, pak odchází	8 38 50	210			chybí cca 1 min záznamu
26	A - přichází, baví se s kolegou, popochází a baví se s B	8 39 45	55			
27	A+B - jdou pryč	8 40 0	15			
28	A - jde dozadu pro smeták a zametá tam	8 42 55	175			chybí cca 1 min záznamu
29	A - přesouvá věci zboku stroje A aby tam mohl zamést	8 43 50	55			
30	A - jde dozadu (mimo záběr kamery)	8 58 55	905			
31	A - ofukuje lis vzduchem B - přetipovává stroj A	8 59 36	41			
32	B - vrací se s papírem a podle dat na něm nastavuje stroj A A - stále čistí lis vzduchem	9 1 5	89			
33	A - přechází dozadu B - pořád přetipovává	9 2 12	67			
34	B - odchází pryč (mimo záběr kamery)	9 3 0	48			
35	A - bere si nářadí a přechází dozadu ke stroji A	9 11 29	509			
36	A - spouští beran a utahuje zápustky D - pomáhá A	9 12 0	31			
37	A - kontroluje dosednutí lisu	9 12 6	6			
38	A - umisťuje matky?	9 12 30	24			
39	A - dotahuje matky D - podává nářadí	9 13 17	47			
40	D - vyjíždí beranem nahoru A - dotahuje	9 14 0	43			

	ČINNOSTI OBSLUHY				CELKOVÝ ČAS [s]	Přemistění	Nástroje	Poznámky
41	A+D - jdou si pro nářadí do skříně	9	14	11	11			
42	A - vrací se zepředu ke stroji A a utahuje D - nic nevzal a jde pryč	9	14	44	33			
43	A - popochází a odkládá nářadí	9	14	50	6			
44	A - bere klíč a dotahuje spodní část lisu	9	15	23	33			
45	D - je zpátky a pozoruje A při práci	9	15	52	29			
46	A - podává si jiné nářadí dotahuje vrchní část lisu	9	16	28	36			
47	A - spouští beran D - odchází	9	16	55	27			
48	A - kontroluje dosednutí lisu a utahuje	9	17	27	32			
49	A - přechází utahovat dozadu ke stroji A	9	19	26	119			
50	A - odkládá klíč a přechází zepředu stroje A	9	19	34	8			
51	A - bere si jiný klíč, ten pak odkládá a jde s B a D pryč	9	20	10	36			
52	A - vyjíždí beranem nahoru, pak dotahuje B - podává nářadí	9	22	28	138			
53	A - spouští beran dolů	9	23	7	39			
54	A - vyjíždí beranem nahoru	9	23	12	5			
55	A - instaluje hořáky do lisu	9	24	14	62			
56	A - spouští beran dolů	9	24	38	24			
57	A - zhasíná osvětlení v lisu	9	24	50	12			
58	A - odklízí hadry z ponku	9	25	20	30			
59	A - jde pryč (pro oheň)	9	25	53	33			
60	A - vrací se s ohněm (hořící kus papíru?!) a zapaluje hořáky	9	27	0	67			
61	A - dolaďuje správnou pozici hořáků v lisu	9	27	2	2			
					5744			

Figure 23 – SMED Implementation (own processing)

The operators are listed in the form under A, B and C letters. The operator A is the smith, operator B is smith's assistant and operator D is the foreman. Operator C was worker from other forging unit, he shall not participate on the setup. Operators in the SMED form are named in order of appearance in the workplace.

The green highlighted lines are those activities which are correct (according to the setup) and which are realized as the correct setup (IED/OED).

The yellow highlighted lines are activities for which exists the possibility of raising efficiency by using 5S, adding more operators, using more effective hand tools, reengineering of the layout etc. There can be also included activities which are conducted as the wrong setup and which can be transformed from IED to OED. In the table below, the green, yellow and red lines are summarized in total times of each type of the working act.

Table 4 – Duration of the work activities (own processing)

s	min
4030	**67,2**
1360	**22,7**
354	**5,9**

The setup time in this case was about an hour and a half – the very last number in the SMED form is 5744 s which equals to cca 96 minutes. Actually the real setup time is extended by another 30 minutes – the die preheating with the burners. In total, the setup time for die exchange is 120 minutes. If the yellow and red activities are eliminated, the setup time is reduced by half an hour.

The output form the SMED application is the Exchange plan.

6.7 Exchange Plan

This document serves operators for better work standardization and it is also used as an instruction accompanied by visualization elements.

VIVA	PRACOVNÍ NÁVODKA **Výměna nářadí A** **Hranaté / Hranaté**	Číslo:	VR 010
		Datum:	16.9.2013
		Index:	01

Krok	Název kroku změny	Obrázek	Čas Ext.	Čas Int.
1	Příprava ručního nářadí na výměnu			
2	Nastudování dokumentace nové zakázky			
3	Pomocí klíče na ovládacím panelu přepnout kovací lis do režimu "SEŘÍZENÍ" - klíč přepnout do pravé polohy	4		
4	Beranem lisu sjet do ***dolní úvratě*** lisu (horním držákem zápustek na spodní)			
5	Pomocí klíče na ovládacím panelu přepnout lis do režimu "VYPNUTO" - klíč přepnout do prostřední polohy označené "0"	3		
6	Povolit a vyjmout 4x ***upínací šrouby spodního držáku zápustek*** pomocí klíče č.46	1		
7	Povolit a vyjmout 4x upínací ***šrouby horního držáku zápustek*** pomocí klíče č.46	2		
8	Pomocí klíče na ovládacím panelu přepnout lis do režimu "SEŘÍZENÍ" - klíč přepnout do pravé polohy. Beranem vyjet do ***horní úvratě*** lisu.	4		
9	Pomocí VZV vyjmout z kovacího lisu ***spodní i horní držák zápustek*** (u 2LVH 2500 použít přípravek s kuličkami)	6		
10	Očistit a vzduchem ofoukat ***spodní i horní pracovní prostor*** kovacího lisu (dosedací plochy spodního i horní držáku zápustek)			
11	Pomocí VZV ustavit do pracovního prostoru lisu ***spodní i horní držák zápustek*** (u 2LVH 2500 použít přípravek s kuličkami)	6		
12	Pomocí klíče na ovládacím panelu přepnout lis do režimu "SEŘÍZENÍ" - klíč přepnout do pravé polohy.	4		
13	Beranem lisu sjet do ***dolní úvratě*** lisu (beranem na horní držák zápustek).			
14	Pomocí klíče na ovládacím panelu přepnout lis do režimu "VYPNUTO" - klíč přepnout do prostřední polohy označené "0"	3		
15	Ustavit a utáhnout 4x upínací šrouby ***spodního držáku zápustek*** pomocí klíče č.46.	1		
16	Ustavit a utáhnout 4x upínací šrouby ***horního držáku zápustek*** pomocí klíče č.46.	2		
17	Pomocí klíče na ovládacím panelu přepnout lis do režimu "SEŘÍZENÍ" - klíč přepnout do pravé polohy. Beranem vyjet do ***horní úvratě*** lisu.	4		
18	Seřídit výšku pěchování vyjmutím, popřípadě přidáním podložky pod ***spodní pěchovadlo***. Výška pěchování je udána v návodce pro operaci "kování, ostřihování, BY - ochlazování", při přidání či odebrání vycházet od výšky pěchování předešlé práce.	7		
19	Ustavit a uvézt do provozu (v pořadí - 1. plyn, 2. oheň, 3. vzduch) hořáky zápustek.	5		
20	Na kovacím lisu nastavit recepturu kování. Receptura kování je udána v návodce pro operaci "kování, ostřihování, BY - ochlazování".			

Vypracoval: P. Paseková
Dne: 16.9.2013

Figure 24 – Exchange Plan (own processing)

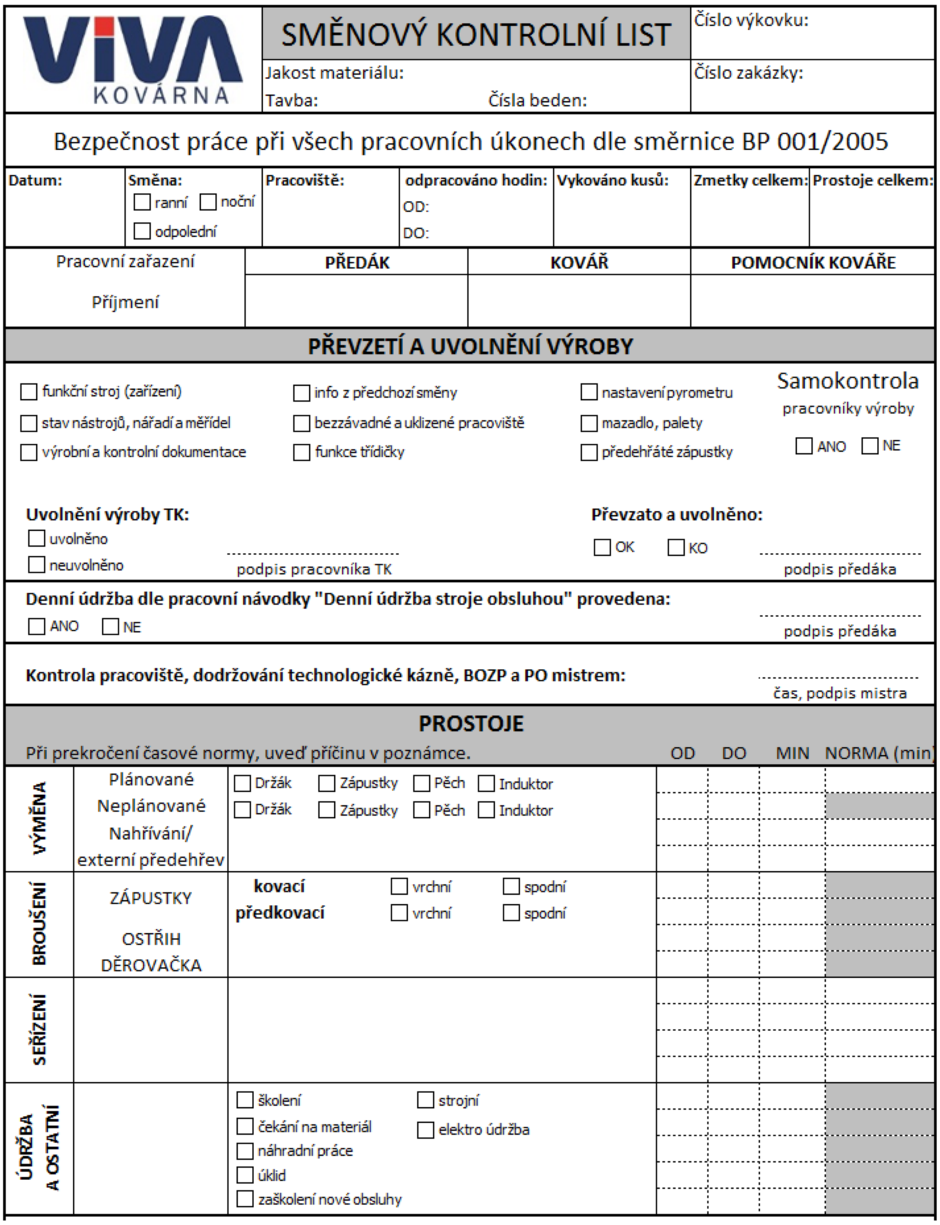
This document contains sequence of working acts which are color-coded into external and internal setups – green represents external setup, red represents internal setup. For better understanding and visualization on the part of operators, majority of the activities is supplemented by pictures.

7 OPTIMIZATION PROPOSAL

After analysis of the setup operations, several possibilities for improvement were discovered. Firstly it is the layout and purpose of the shift list, secondly reorganization within the die exchange itself and finally it is video instruction based on the exchange plan.

7.1 Shift List

The layout of the document is quite confusing and operators have problems with its proper fulfillment. Also the division of the downtimes into six groups is not logical. The user-friendly document should be more structured and easy to understand.



VIVA KOVÁRNA

SMĚNOVÝ KONTROLNÍ LIST

Číslo výkovku:

Jakost materiálu:

Číslo zakázky:

Tavba: Čísla beden:

Bezpečnost práce při všech pracovních úkonech dle směrnice BP 001/2005

Datum:	Směna: ☐ ranní ☐ noční ☐ odpolední	Pracoviště:	odpracováno hodin: OD: DO:	Vykováno kusů:	Zmetky celkem:	Prostoje celkem:

Pracovní zařazení	PŘEDÁK	KOVÁŘ	POMOCNÍK KOVÁŘE
Příjmení			

PŘEVZETÍ A UVOLNĚNÍ VÝROBY

☐ funkční stroj (zařízení) ☐ info z předchozí směny ☐ nastavení pyrometru

☐ stav nástrojů, nářadí a měřidel ☐ bezzávadné a uklizené pracoviště ☐ mazadlo, palety

☐ výrobní a kontrolní dokumentace ☐ funkce třídičky ☐ předehřáté zápustky

Samokontrola pracovníky výroby ☐ ANO ☐ NE

Uvolnění výroby TK: ☐ uvolněno ☐ neuvolněno .... podpis pracovníka TK

Převzato a uvolněno: ☐ OK ☐ KO .... podpis předáka

Denní údržba dle pracovní návodky "Denní údržba stroje obsluhou" provedena: ☐ ANO ☐ NE .... podpis předáka

Kontrola pracoviště, dodržování technologické kázně, BOZP a PO mistrem: .... čas, podpis mistra

PROSTOJE

Při prekročení časové normy, uveď příčinu v poznámce.

			OD	DO	MIN	NORMA (min)
VÝMĚNA	Plánované	☐ Držák ☐ Zápustky ☐ Pěch ☐ Induktor				
	Neplánované	☐ Držák ☐ Zápustky ☐ Pěch ☐ Induktor				
	Nahřívání/ externí předehřev					
BROUŠENÍ	ZÁPUSTKY	**kovací** ☐ vrchní ☐ spodní				
		předkovací ☐ vrchní ☐ spodní				
	OSTŘIH DĚROVAČKA					
SEŘÍZENÍ						
ÚDRŽBA A OSTATNÍ		☐ školení ☐ čekání na materiál ☐ náhradní práce ☐ úklid ☐ zaškolení nové obsluhy ☐ strojní ☐ elektro údržba				

Figure 25 – Proposal of new Shift List (own processing)

Another advantage of the proposed document is the possibility of online fulfillment thanks to check boxes. This type of registering is easier and clearer.

7.2 Die Exchange

The exchange of dies lasted almost 90 minutes (with die preheating included). This time can be eliminated by reorganization of operators and transformation of several internal activities into external. The die preheating is realized as internal after the exchange is done and lasts almost 30 minutes. This operation can be performed as an external setup as well, using external preheating in furnace. Only because of utilization of the furnace, the setup time can be shortened by 30 minutes (the time when the burners heat the dies). With the work reorganization it is possible to reach another 10-15 minutes of time savings.

Figure 26 – Furnace for external preheating (own processing)

7.3 Exchange Plan

The Exchange plan is good essentially. For better visualization of the exchange (it is quite difficult and challenging operation) the short video instruction can be used. Before the SMED application, the video record is taken and then it is analyzed and based on this record the SMED form is fulfilled. This record can be used as an instruction as well. Thanks to the software Pinnacle Studio 16, the very essential steps of the setup operation can be left and these steps could be interspaced by working act description form the Exchange plan. This video-instruction can serve new employees in their training.

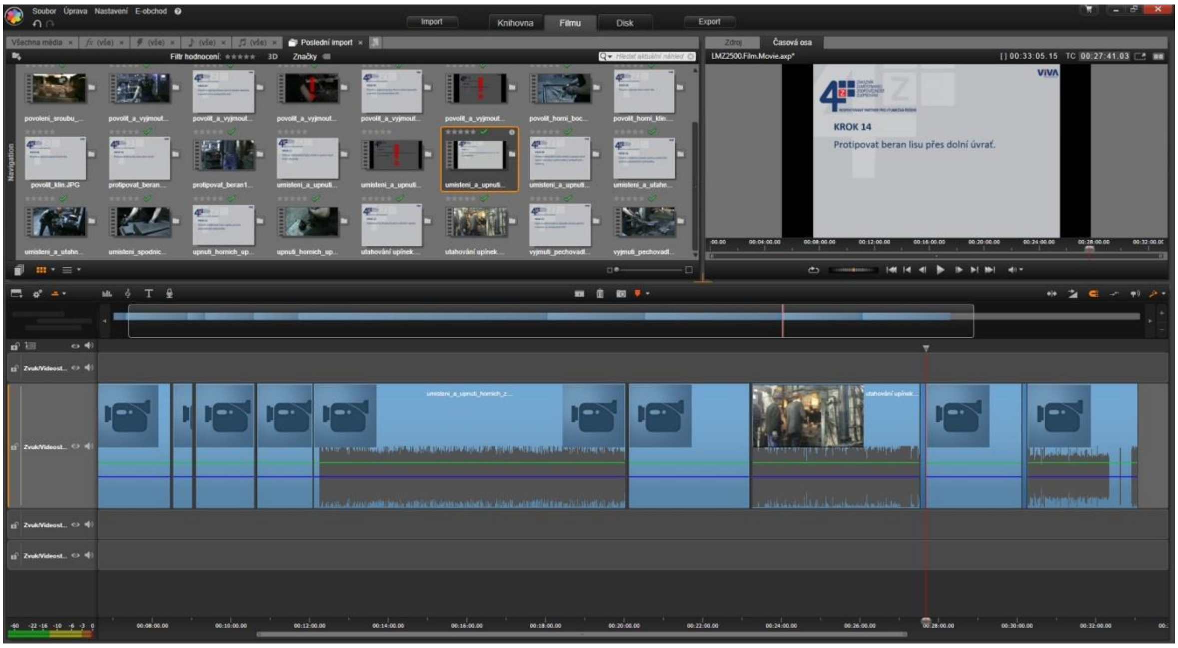


Figure 27 – Video making in Pinnacle Studio 16 (own processing)

7.4 Economic evaluation and benefits

After shortening of the setup time of die exchange (including utilization of preheating furnace) the whole setup operation can be performed in less than 60 minutes – meaning the productivity of the forging unit will get higher because of shorter setup operations.

The economic benefits are the time savings converted to CZK using Machine Hour Rate (MHR). The value of this indicator is 65 CZK per minute. The results are listed in table below:

Table 5 – Economic benefit of shortening the Setup Times (per year) by using SMED (own processing)

MHR [CZK/min]	Setup Time [min]	Exchanges per year	Total exchanges [min]
65	90	420	37800
65	60	420	25200
Time Savings (min)	**12600 min**		
Time Savings (CZK)	**819 000 CZK**		

The Time Savings gained by shortening the Setup time of the die exchange is the 819 000 CZK. This number is used in following formula as the revenues. The cost value is represented by purchase price of the furnace for external preheating.

ROI – Return of Investments

$$ROI[\%] = \frac{revenues - costs}{costs} * 100$$

$$ROI = \frac{819000 - 592900}{592900} * 100 = 38{,}3\ \%$$

The Return of Investments is equal to 38,3 %. It means that the investment brings 38,3 % of profit per year. This value can get higher if the company use the furnace for more than one forging unit, than the revenues will be multiplied (according to number of forging units).

CONCLUSION

Elaboration of this Bachelor's thesis had the purpose of identification and elimination of waste in setup operations. Concerning the characteristics of the process, that was quite challenging intention.

It was necessary to get familiar with the process in general. I had to get in touch with the general terminology of the forging process as well as with the sequence of operations within the exchanges of dies. This learning process took roughly three months after which I was able to describe the process and identify any issue. Then I started my analysis which took hours of observation in the floor shop with stopwatch and camera recording the operators performing the setup operation. After I got enough information from the process I started my analysis using SMED. In this stage I discussed the process with the masters who helped me to understand the specifics of the setup (e.g. why they use this tool instead of another one etc.). They also played a significant role in the moment when I needed to choose those important operations which can be included into the exchange plan. When I had this work done, the setup operations started to be performed according to new exchange plan and it showed up that the setup operation is performed in the shorter time than it was before SMED implementation because of time reductions of yellow and red highlighted activities from the SMED form (those which can be performed as an external setup or eliminated at all). The next option how to reduce the setup time is to use external preheating furnace – this improvement will shorten the setup time by another 30 minutes.

In total, after implementation of SMED system, the company can reach time reductions from 120 minutes to 60 minutes. This is not the ending value, there are still options how to eliminate waste in the setup operations, but the SMED application has shown the most significant weaknesses in the setup operations.

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LIST OF ABBREVIATIONS

IE	Industrial Engineering
IED	Inner Exchange of Die (Internal Setup)
JIT	Just-in-Time
OED	Outer Exchange of Die (External Setup)
PDCA	Plan-Do-Check-Ask
SMED	Single Minute Exchange of Dies
TPS	Toyota Production System

LIST OF FIGURES

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