OPTIMIZATION OF EQUIPMENT´S CHANGEOVER AND ITS IMPORTANCE FOR OVERALL EQUIPMENT EFFICIENCY AND FLEXIBILITY OF WHOLE SYSTEM

OPTIMIZATION OF EQUIPMENT´S CHANGEOVER AND ITS IMPORTANCE FOR OVERALL EQUIPMENT EFFICIENCY AND FLEXIBILITY OF WHOLE SYSTEM

Dárius DYSKO

Abstract
The paper contains definition of equipment´s changeover and brief analysis of its activities. It explains the importance of equipment´s changeover optimization what reflects in increasing of overall equipment efficiency (OEE) and flexibility of whole system. The core of paper describes practical application of equipment´s changeover optimization and its process flow. At the end paper summarizes some practical benefits reached through optimization of equipment´s changeover.

Key words
Capacity, Changeover, Equipment, Flexibility, Optimization, OEE (Overall Equipment Efficiency), Planning and Scheduling, Production Batch, Setup, SMED (Single Minute Exchange of Dies), Standardization, Waste Eimination.

Introduction

Capacity utilization, productivity, efficiency, flexibility and so on are the terms which were used sporadically not so long ago when a new "lean wave" began to promote. But presently, these terms have become the parts of our daily routine lives. Everyone is aware about their importance and need of their optimization. It is important due to changes (and increase) in customer demands, competitiveness and profitability. For example, whereas production philosophy was formerly built on a big amount of same products produced in a row, nowadays this could mean "suicide" of whole production system. Consequently, also based on this, system of production has also to be changed and continually improved as much as possible. Of course, without any doubts, there exists a quantum of literatures with described tools, method, approaches and so on for optimization of whole systems and also their parts. But I would like in this paper focus on one (I guess very easy) optimization method aimed directly to the equipment and its changeover. This method is built on couple of basic, logical ideas and using a common sense without the need of any complicated calculations and super technologies.

Definition of equipment´s changeover and its activities

Every single equipment is intended for certain work(s). So it means that in some defined time it has to produce some capacity. But we know that any equipment will not work for 100 percent forever. There always may occur various losses related to availability, performance,

and quality. Especially changeover as predictable, measurable and even be able to optimized availability loss will be interest in the rest of paper.
Changeover - the installation of a new type of tool in a metal working machine, a different paint in a painting system, a new plastic resin and a new mold in an injection molding machine, new software in a computer and so on. The term applies whenever a production device is assigned to perform a different operation [9]. Other definitions speak that changeover is defined as time interval between the last good piece of one type of product and the first good piece of the next type of product (Figure 1).
Total setup during changeover is divided to two groups (Figure 1):

1. Internal setup - all activities that can be done only when equipment is turned off.
2. External setup - all activities that can be done during equipments work.

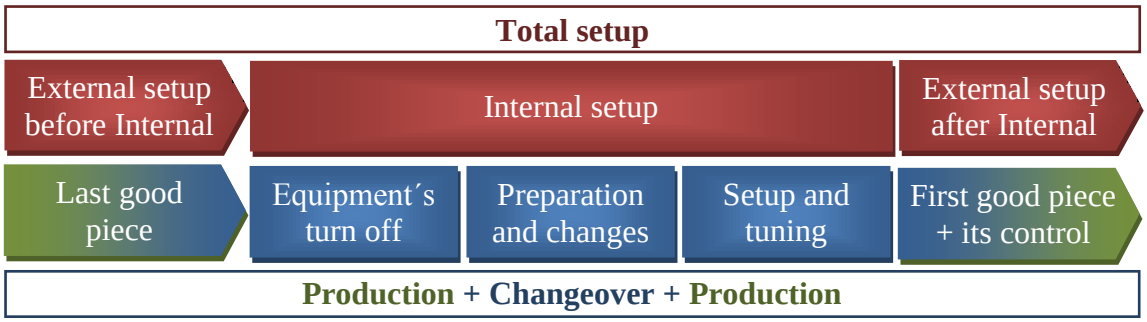

Figure 1 Relation between setup, changeover and production

The principle of changeover optimization is tasked to reduce setup times between manufacturing of two consecutive batches of different types of product.

Influence of equipment´s changeover to overall equipment efficiency (OEE) and flexibility of whole system

Logically, all equipment´s losses negatively influence its capacity utilization. The longer downtime means the greater loss, so the task is to reduce and optimize all losses and eliminate (or minimally reduce) all waste (muda) related to equipment. If you want to optimize something, firstly you should know how to measure its current status.
Capacity can be difficult to measure because it depends on activity mix, the duration over which output is required and any changes in the actual specification of the output. Overall equipment effectiveness (OEE) measure is one method of judging the effectiveness of capacity that incorporates the concept of capacity "leakage". It is calculated by multiplying an availability rate by a performance (or speed) rate multiplied by a quality rate. [8].
Studies say that "ordinary system" achieves OEE in range from 30 to 60 percent and "top system" with implemented total productive maintenance methodology (TPM) around 85 percent.
If the level of OEE will be increased by its optimization, it means that equipment´s capacity will be higher (in the same time period as before). And that, in conjunction with decreased time of changeover, can be transformed to production of smaller batches for each type of product for every production time period. That means also shorter lead times which ensure more flexible system which can meet customer demands and enhance their satisfaction. And that "small optimization" of changeover should result to higher competitiveness, stability and profitability of whole system (more information in chapter about benefits).

Practical application of equipment´s changeover optimization and its process flow

As I mentioned, always, when you go to solve or optimize something, you need to do a measure and a good analysis of status. Also for changeover and setup optimization you need sufficient data. The best way how to get them, is to go to the shop floor (gemba) and take them by tracking of real changeover. Very good is when you are minimally two (or even more - depends on changeover difficulty) and you can divide your roles. The first one will be responsible for recording of whole changeover with camera and tracking details of changeover (movements, what operator does with his hands, where he needs to look, layout, etc.). The second one will be responsible for drawing movements to the layout, counting operator´s steps during changeover and also tracking the system of work and looking for waste (muda). One recommendation before you will start to do that. Explain to the operator(s) and/or toolmaker(s) what are you going to do and why. It is good because they are sometimes scared when they become a part of some action and they can start to do something differently as they usually do. If the changeover is more complicated (it does in big area, more people participate, etc.), you need to divide your roles in order to get the most data - it makes easier further work.

Than follows a changeover analysis. The best here is to invite directly that operator(s) and/or toolmaker(s) that made that changeover. Good is to have here also lean specialist, process specialist, service man and eventually people from other positions if you think that they are important. You will go here through video step by step, operation after operation, movement after movement. You will analyse what operator did, how, in which sequence, why, you award if it is internal or external activity and so on. Here is good to have electronic form (totally sufficient is everywhere available Microsoft Excel) where you will write the notes from ongoing analysis. The form can look like in Figure 2, but of course, you can change it and adjust according your needs.

Item #	Description of item / activity / operation	Time in the end of item from videorecord (start from 0)	Duration of activity in videorecord (automatically calculated)	External setup	Internal setup	Analysis / Comments / Problems / Waste	Actions / Proposals (Removing, elimination, reduction, optimization, simplification, replacement, interconnection, cancelation)	Benefits from external actions	Benefits from internal actions
1.									
2.									
. . .									
n									
			X					Y	Z
								Y + Z	
			Analysis				Optimization		

Figure 2 Example of changeover analysis form

In this analyzing part is very good to use support tools like for example "5W1H" or "5Whys". 5W1H is methodology which during analysis tracks basic questions: who?, what?, where?, when?, why? and how?. The name 5W1H comes from the initials of the question.

5Whys is a simple analytical tool to determine the root cause of the activity, problem, defect, etc. to which you repeatedly ask more times "why". Mostly, you get the root cause after the fifth question "why" and from this idea the name of this methodology was created.
A bit more difficult is step after analysis - changeover optimization and waste elimination. It is good to go through filled analytical part of form (Figure 2) second time row by row and propose actions for improvement and fill them to the optimization part of mentioned form. Of course, many times is changeover set wrong and a lot of external activities are in real happen after equipments turn off. And that is the big waste. Accordingly, the first rule here which has to be implemented is transfer of all possible activities from internal setup to the external (Figure 3). For example pretreatment, preset, preparation and bringing of tools next to the equipment/machine/line, transport, unpack and preparation of material for next product, preheating molds, preparation of tools and workstation, etc. All these activities can be physically made before equipment is turned off. Except activities transfer from internal to external setup is necessary to check the details of internal activities, simplify and standardize them. For example by using jigs, backstops, guiding strips, wing nuts, quick couplers, holders, unification of screws, the same clamping heads of tools, clamping systems per one turn, systems of one movement, etc. Also important is to eliminate/reduce all unnecessary and lengthy activities as much as possible. All these things cause increasing of added value and efficiency of internal activities. Something similar is necessary to do also with external setup.

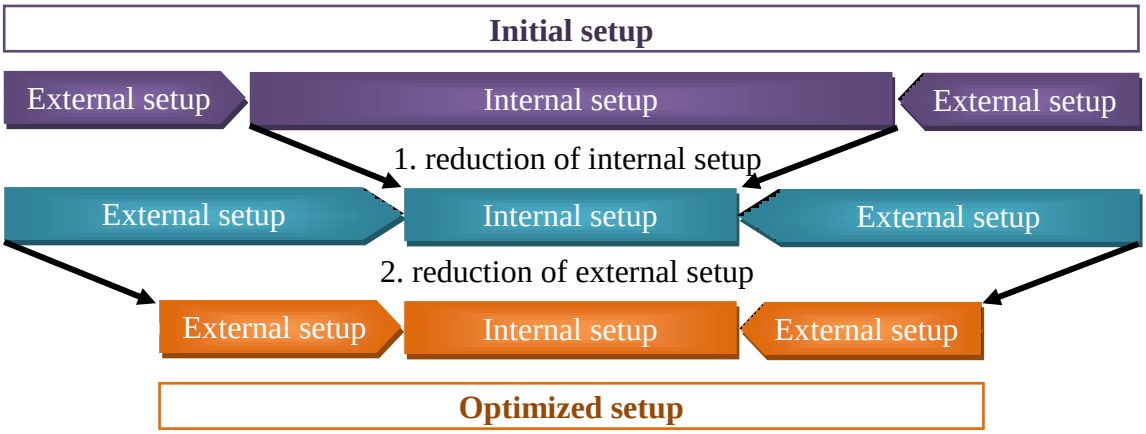

Figure 3 Principle of setup optimization

After transfer proposal of activities from internal to external setup, fill in other improvements actions and possible benefits to the "optimization" part of form (Figure 2). At the end of the filled form you will get potential benefits from external (Y) and internal (Z) actions and total result (Y+Z). You can compare it with initial changeover time (X) and so you get theoretical saving of changeover optimization. If you are not satisfied with your potential result, you will continue to work on further proposals.
Then you have to go to the shop floor to the equipment/machine/line and start verification of proposed ideas, followed by physical improvement actions.
According to all done activities is necessary to create checklist for new changeover and then perform new changeover to verify how it will work in practice. Checklist is a list of all activities which have to be done during changeover with chronological sequence. It starts with activities in external setup before internal, then internal activities and at the end with activities from second external setup. For each activity has to be defined human resource.

You should not forget that with external setup after internal and with first good piece of a new product relates control of its parameters. With that relate things like calibres, gauges, etc. This quality part should not be forgotten within optimization of changeover.
So, if we get to the test of new changeover in practice, above mentioned checklist serves as navigation for person/people who does/do changeover. During the changeover is the whole process with improved things tracked, the time of changeover is measured and the number of steps the operator(s) are counted. Also insights and observations are noted and then have to be resolved.
Subsequently make the final evaluation of whole change and calculate the savings in times and movements of operator(s) during changeover.
Finally stays one important step - standardization and training of employees. It helps to sustain achieved improvement. But even then, it is still good to track the duration of the changeover through form for its monitoring. This form can easily look as table with data from changeovers, column chart for easier visualization of status, with defined target for changeover time and with some place to write notes that can be helpful for further optimization. This form put directly to the equipment/machine/line and fill it after each changeover.
Globally we can say that we went through procedure for changeover and we could summarize it to the process flow (Figure 4).

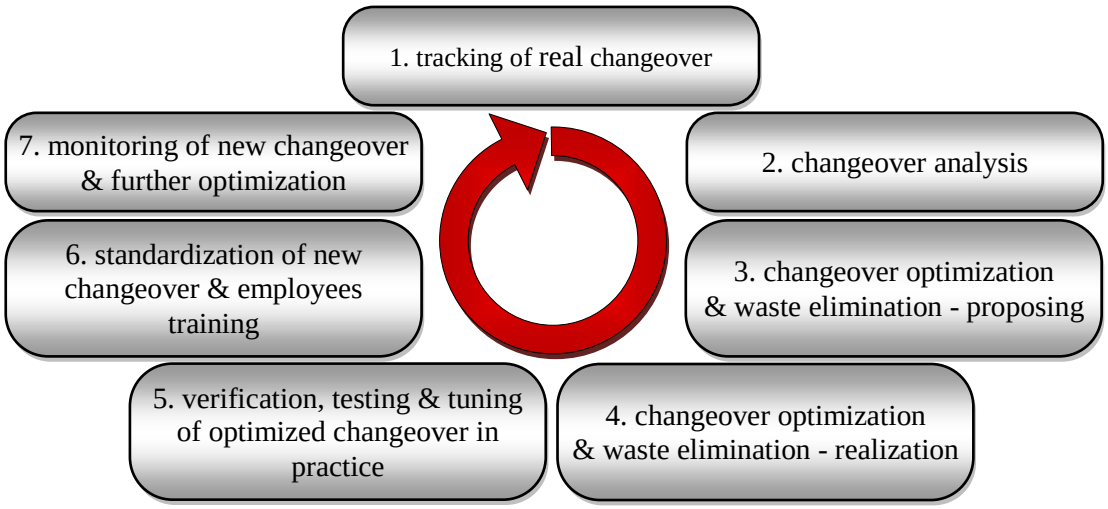

Figure 4 Process flow of changeover optimization

The red arrow in Figure 4 does not mean only direction and sequence of tasks. It is in circle because it is not over after the task nr.7. You can still continue with optimization. If we speak about one equipment, you should do another changeover optimization in some time. If we speak about line, you should continue with changeover optimization in the next equipment (which has now the worst changeover time) and so on continue through all equipments in line or directly optimize changeover of the whole line at once. Here you can meet for example with question of how many employees have to do the changeover or how to work with matrix of changeover difficulty between all products, etc. But on the other hand, you can immediately use a lot of your solutions to other similar/same equipments/machines/lines without need of former analysis and generation of ideas just work on changes.
I can also recommend (from personal experiences) solving the changeover optimization in team of people through gemba kaizen workshop execution.

For changeover optimization you can use also other support approaches like: 6S, visualization, ergonomics, poka-yoke (fail-safing), parts of TPM, etc.
Higher level of changeover optimization (as I have already indicated) is about special tools and technical modifications of tools and machines; standardization of parts, segments, tools, fixtures; special transport and manipulation devices; etc. what is moving towards total automation without need of changeover. But this idea is about big input costs and here is necessary to consider the profitability of such a "high-tech" solution.

Benefits from implementation of changeover optimization

If we want to summarize importance of changeover, we can look to benefits to which its optimization leads to: decreased setup and changeover times and its difficulty, production batches, quantity of raw, WIP and finished goods material, costs and bound money, lead times, space, transports and personal staff; reduced/eliminated waste (waiting, manipulation, movements, searching, adjusting and tuning, etc.); standardized changeover; balanced production; increased capacity, performance, OEE, productivity, flexibility and customer satisfaction.
Literature shows that by implementation of fast changeover is possible to reduce changeover time up to 75%. From my personal experiences I can confirm that real benefits (for example in company which is more than 10 year old and around 2 years actively goes by Lean philosophy way with primarly focus on low cost solutions) can be:
- changeover reduction of the production lines from 31% to 63% (movements up to 74% - example of spaghetti diagrams of movements during changeover is in Figure 5)
- changeover reduction of the machines from 29% to 100% (movements up to 68%)

Average summarization of benefits per 1 changeover optimization is: reduced changeover about 51%, increased productivity about 2% and the input costs represented only 2% from the overall financial savings.

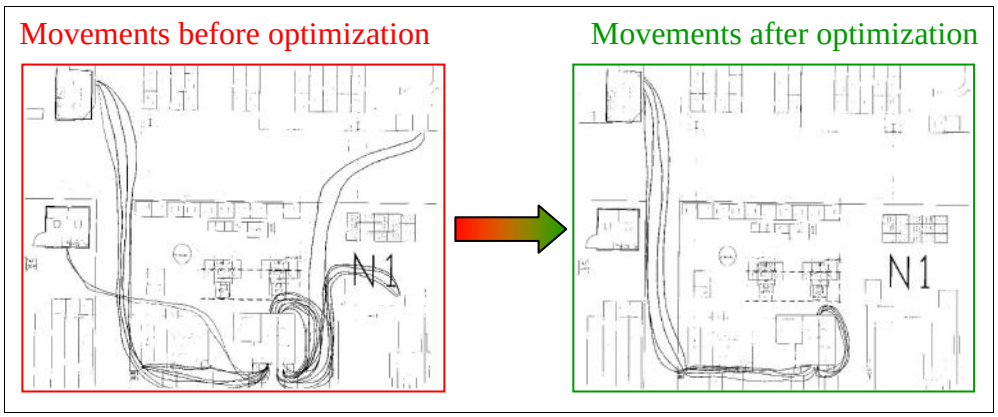

Figure 5 Spaghetti diagrams of movements before and after changeover optimization

Methods for changeover optimization

One of the best known methods for changeover optimization is Single Minute Exchange of Dies (SMED). Its purpose is to achieve the duration of changeover in single digit amount of time (thus to 9 minutes and 59 seconds).
If you are not able to reduce changeover time to less than ten minutes at first time, do not worry. Never mind. It is known that changeover optimization to single digit value lasts in some companies for several years.

Other "more sophisticated" methods of fast changeover are for example One Touch Exchange of Dies (OTED) or No Touch Exchange of Dies (NOTED). Their principle is that changeover will be made with a single touch or without touch [5]. One-touch setup is the term applied when changeovers require less than a minute. Obviously, the long-term objective is always zero setup, in which changeovers are instantaneous and do not interfere in any way with continuous flow [9]. Of course this idea is achievable but by various modifications, transformations and sophisticated solutions and that has to reflect in the costs.

Conclusion

If we look to all those benefits to which has changeover effect, we can say that it is a very needful part of system. But one important thing related to changeover still has not been mentioned here. It is planning and scheduling.

One of the best known methods for production smoothing is Mixed Model Scheduling Method (MMSM). It solves the problem of determining the minimum number of units/pieces of each product in the production sequence for a given production plan. In conjunction with smooth production begins to use the term Every Product Every Interval (EPEI), which means the possibility of each product produce at each time interval of production. For ensuring the requirement of simplicity in planning and managing of production is used Heijunka, which schedules products batches and simultaneously products mix in defined time frame and visualizes it to the planning board [4].

Thus, if solving of problems and smoothing of production depends on stability of product mix and flexibility of system, we are again returning to the fast changeover but from the opposite site.

This was further argument how important are for production fast changeovers. But also we saw that principle of changeover optimization is very easy, common sensed and can be also low cost. So there cannot be problem to start with its optimization. And when the company combines that with doing other improvements and waste eliminations within equipments, lines or whole system, result in moving of system forward will surely come.

Key words

Capacity, changeover, equipment, flexibility, optimization, OEE (overall equipment efficiency), planning and scheduling, production batch, setup, SMED (single minute exchange of dies), standardization, waste elimination

Literature

[1] GREGOR, M. et. al.: Plánovanie výroby. EDIS - vydavateľstvo ŽU, Žilina 2005, ISBN 80-8070-427-9.

[2] GREGOR, M. - KOŠTURIAK, J.: Just - in - Time. Výrobná filozofia pre dobrý management. Elita, Bratislava 1994, ISBN 80-85323-64-8.

[3] GREGOR, M. - KOŠTURIAK, J. - KRIŠŤÁK, J.: Meranie a zvyšovanie produktivity. Jozef Blaha, Žilina 1998, ISBN 80-966996-9-5.

[4] GREGOR, M. - MATUSZEK, J.: Štíhly podnik a štíhle myslenie. In: Produktivita. Žilina 2004, 1, s. 14-15.

[5] IPA Slovakia: IPA slovník [online], Žilina 2013, Available on the internet: http://www.ipaslovakia.sk/sk/ipa-slovnik/smed

[6] KRAJČOVIČ, M. et al.: Priemyselná logistika. EDIS - vydavateľstvo ŽU, Žilina 2004, ISBN 80-8070-226-8.

[7] MIČIETA, B.: Prosperujúci podnik. Postupy podporujúce zvyšovanie produktivity a konkurenčnej schopnosti podnikov. Slovenské centrum produktivity, Žilina 2000, ISBN 80-968324-0-9.
[8] SLACK, N. et al.: Operations and process management - Principles and practice for strategic impact. Prentice Hall, Harlow England 2006, ISBN 0-273-68426-4.
[9] WOMACK, P. J. - JONES, T. D.: Lean thinking. Banish Waste and Create Wealth in Your Corporation, 2003, ISBN 0-7432-4927-5.

Contact
Ing. Dárius Dysko
e-mail: darius.dysko@gmail.com