SMED

Reduction of technological machines setup time and time of service operations

Single Minute Exchange of Die

Education and Culture DG
Lifelong Learning Programme

SMED

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LLA

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1. What is setup?

Setup of technological machine consists in preparing a machine for a next production task (next technological operation)

Source: http://i.eurosport.pl/2010/03/11/589071-7254854-317-238.jpg

1. What is setup?

Setup consists of the following groups of activities:

1. Setup preparation

- taking a technological documentation of operations
- taking tools and workshop aids (holders, tools, instruments)

2. Setup execution

- assembling workshop aids on machine
- setting up tools

3. Fine tuning

- making a first piece and measuring it

4. Aftercare

- disassembling workshop aids after technological operation finishing and returning them to a tool room
- cleaning, protecting and storing tools

2. Setup time

Setup time (C/O) is a time for activities connected with technological machine setup.

Setup time is most often established by calculations and it is based on standards.

Long setup time is expensive. That is why majority of companies realize their production in big batches, which causes:

- increasing an inventory of production in process
- lengthening a production cycle
- decreasing a quality of production

2. Setup time

Traditionally, problem of long setup time was solved as follows:

- strategy based on skills - well skilled worker does setup (tool setter)
- strategy based on big batches – increasing a number of pieces in batch (table 1)
- strategy based on economical or optimal size of batch - size of batch is chosen as most economical or optimal

2. Setup time

Table 1. Relations between setup time and size of batch

Setup time	Size of batch	Processing time per 1 piece	Operation time	Indicator [%]
4 h	100	1 min	$1\text{min}+\frac{4\times 60}{100}=3{,}4\,\text{min}$	100
4 h	1000	1 min	$1\text{min}+\frac{4\times 60}{1000}=1{,}24\,\text{min}$	36
4 h	10000	1 min	$1\text{min}+\frac{4\times 60}{10000}=1{,}024\,\text{min}$	30

Source: Shingo S., A Revolution in Manufacturing: The SMED System, Productivity, INc. 1985

2. Setup time

Estimated or calculated setup times in machine building industry is from ten minutes for machining centres to ten hours for machines for plastic working.

Setup time influences economical size of production batch ***n*** (1)

$$n = \frac{\sum C/O}{q \cdot \sum C/T} \qquad (1)$$

where: ΣC/O - sum of setup times
ΣC/T - sum of cycle times
q – coefficient (q = 0,02÷012)

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3. SMED method

Introducing in enterprise production management system based on Lean Manufacturing rules is necessary to decrease size of production batch *n* and to increase flexibility of production system.

It can be achieved by setup times reduction using SMED method (Single Minute Exchange of Die).

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3. SMED method

SMED (*Single Minute Exchange of Die*) method is used for shortening the setup times.

It is a set of techniques, used in 3 steps, which enable the changing a technological instrumentation or the setting up a production line in less than 10 minutes (although it is not always possible).

3. SMED method

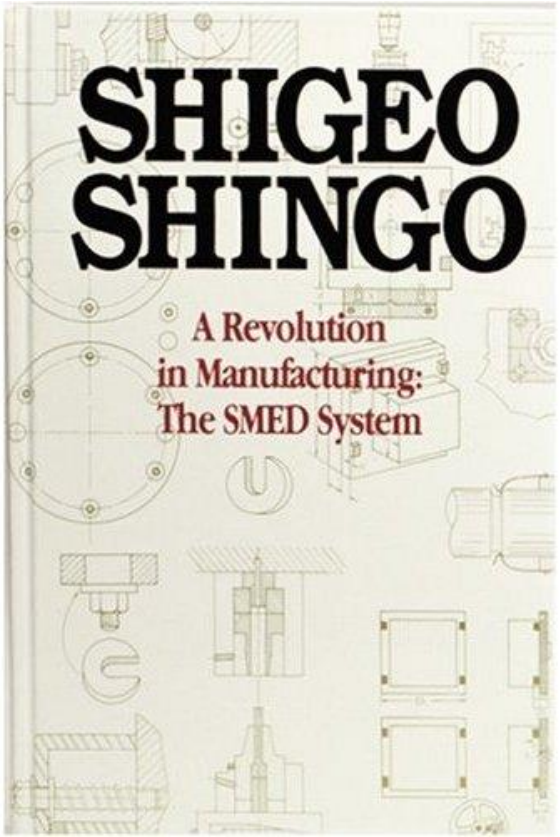
Author of SMED method is Shingeo Shingo, Japanese engineer specialized in production process rationalizing.

In 1950 Shingeo Shingo was conducting researches on rationalizing of work organization in Mazda factories in Hiroshima

Source: http://totalqualitymanagement.wordpress.com/2008/10/28/lean-production-system/

3. SMED method

Shingeo Shingo presented the essence of SMED method in the work: *„A Revolution in Manufacturing: The SMED System"*



Source: http://www.amazon.com/Revolution-Manufacturing-SMED-System/dp/0915299038/

3. SMED method

In SMED method Shingeo Shingo was using traditional tools for work investigating and standardizing, such as:

- time study,
- spaghetti diagram.

He proposed:

- new way for analyzing the results obtained after time study,
- new way for organization storage and delivering workshop aids.

4. The essence of SMED

Shingeo Shingo said, that operations connected to setup of machine can be divided into three fundamental different groups:

- internal operations, such as assembling and disassembling of holders, tools, dies, that can be done only when machines don't work,

- external operations, such as transport of holders, tools, dies to storing places or delivering new workshop aids in the vicinity of machines, that can be done, when machines work,

- needless operations, such as incorrect actions were done during setup process, fabrication of connection elements (screws, nuts)

4. The essence of SMED

SMED method is realized in four steps:

Step 0 – It is a registration of setup operations to know how setup process is realized

Step 1 – Dividing setup operations into external, internal and needless operations

Step 2 – Converting internal operations into external operations

Step 3 – Improving setup operations
(setup preparation and execution)

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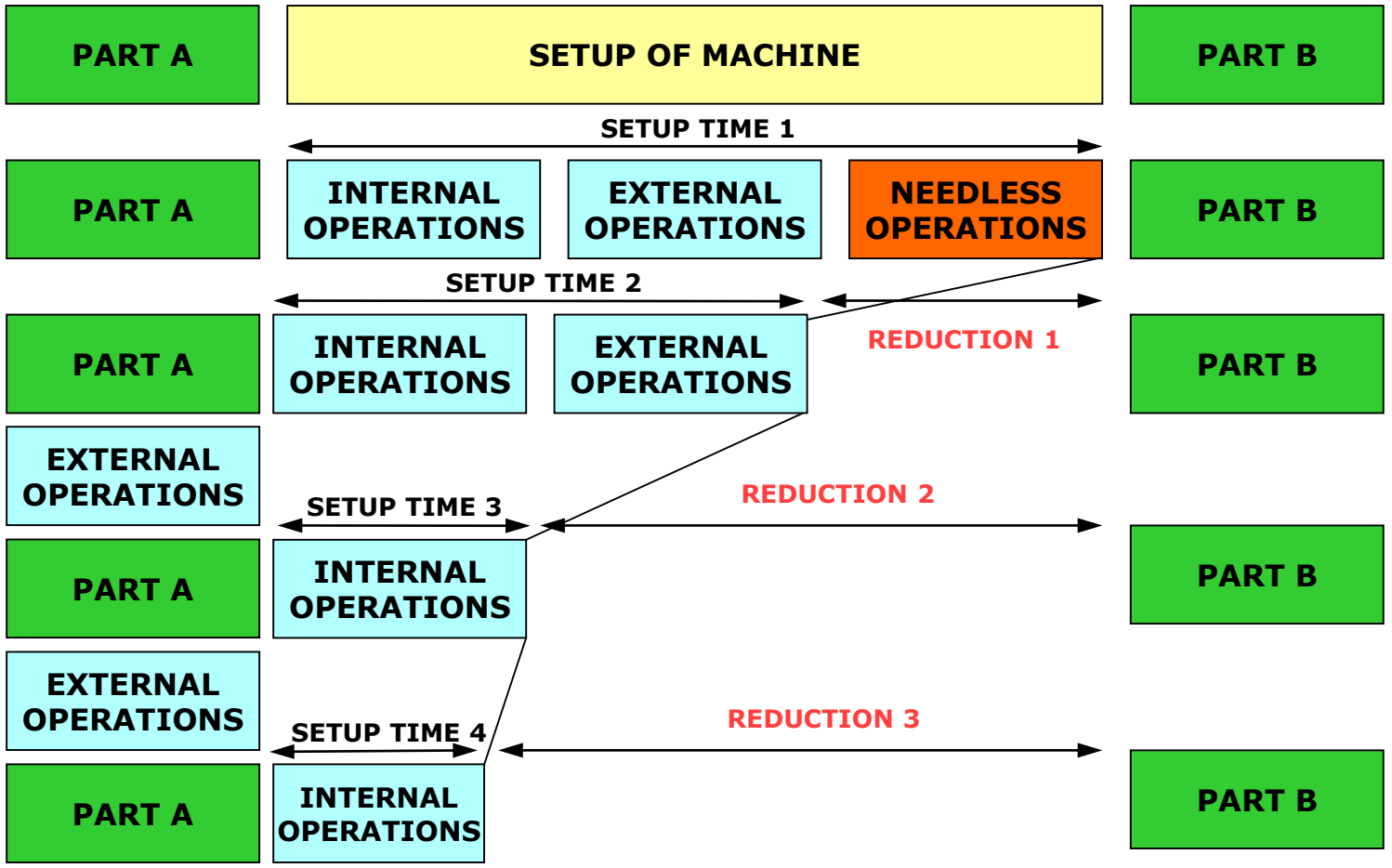
4. The essence of SMED



STEP 0
Measurement of setup time

STEP 1
Dividing of setup time

STEP 2
Elimination of needless operations

STEP 2
Transferring of external operations

STEP 3
Shortening of internal operations by technical development

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5. STEP 0
- registration of setup operations

In this step we try to register all operations executing during setup process of technological machine (without diversifying them into external and internal operations).

We can record setup process by:
- film
- time study
- spaghetti diagram
- pedometer

It is a basis for use the SMED method.

5. STEP 0
- registration of setup operations

Time study – is a method for determining a standard time for operations

The goals of time study are investigating and settling:

- an operation time,
- the best work method,
- correctness of standards established using other methods.

The whole investigation concerning time measurement is divided into three stages:

- preparatory,
- observation and time measurement,
- results analysis

5. STEP 0
- registration of setup operations

1. Preparing for time study includes:

- meeting a worker, whose work will be investigated
- preliminary division of operations into elements
- identification of equipment and work conditions on the work stand
- defining the worker's competences
- settling necessary number of observation, which should be done

2. During observations and measurements the following actions can be done:

- only measurement of operation time,
- measurement of operation time and estimation of operation speed

5. STEP 0
- registration of setup operations

3. Analyzing data from observations includes:

- rejecting results, which are obtained in special cases (machine failure, breaks in energy supply)
- calculation of the coefficient *kz*

$$k_z = \frac{t_{\max}}{t_{\min}} \leq 1{,}30$$

- calculation of average time $T_m = \frac{\sum T_i}{n}$
- determining accuracy of average estimating $e\% = \pm \frac{S}{T_m} B_{pn}$

where: $S = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (T_i - T_m)^2}$ - calculation of variance

Bpn – coefficient selected from table for *n*-measurements

5. STEP 0
- registration of setup operations

Spaghetti diagram is a lean tool, which allows for the observation of a production or worker motion according to spatial arrangement of work stands in a production unit.

We do spaghetti diagram by drawing paths of product motions or people movements in successive production stages on production unit plan.

5. STEP 0
- registration of setup operations

Application of spaghetti diagram:

- observation of product motion
- calculation of real length of paths
- calculation of flow speed of product
- looking for waste

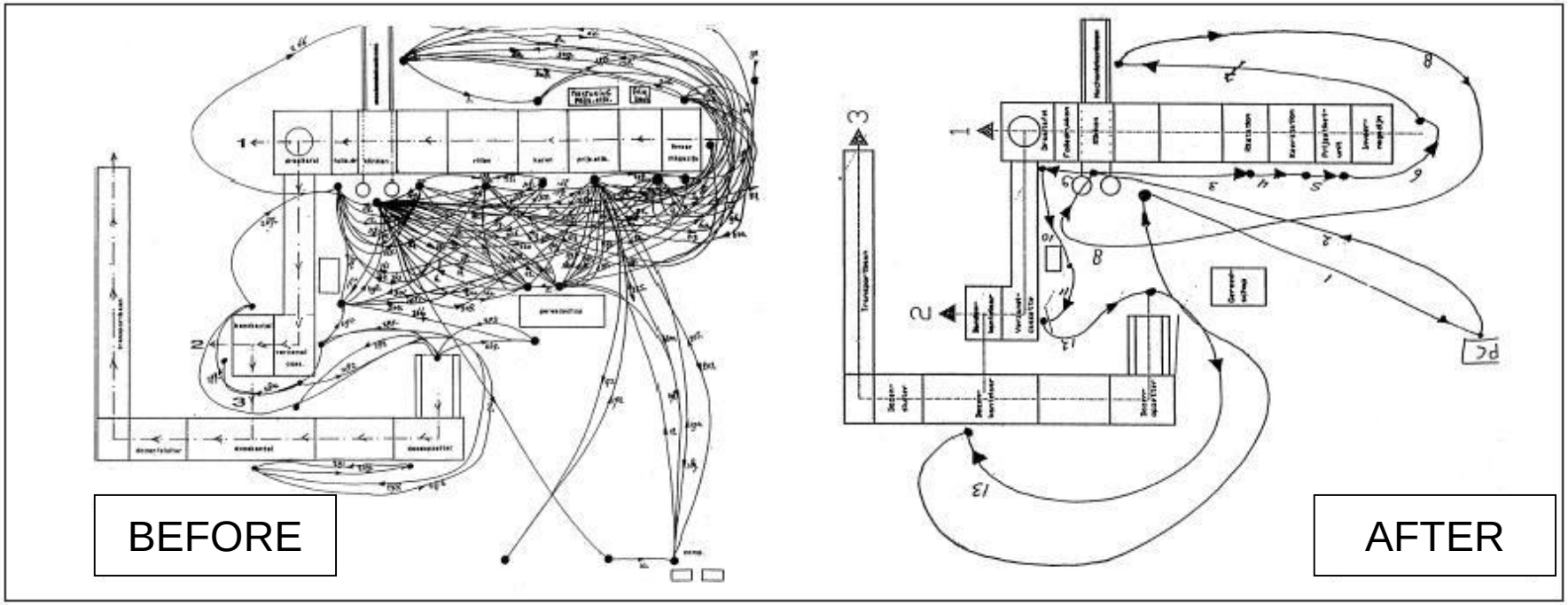
5. STEP 0
- registration of setup operations

Advantages of spaghetti diagram:

- simple and effective tool
- fast and cheap in use
- easy in understanding (natural approach path shortening)
- direct indication of fields where inefficiency arises
- use of intuition
- facilitates understanding of ineffectiveness causes
- is an input for follow-up actions concerning the improvement of flows in a factory

5. STEP 0
- registration of setup operations

SPAGHETTI DIAGRAM



Analysis of worker motions during set up actions of production line

Source: Dirk Van Goubergen, Hendrik Van Landeghem: Role and responsibility of the equipment design engineer in the set-up reduction effort. *Flexible Automation and Intelligent Manufacturing Conference FAIM 2001, Dublin, Ireland (16-18 July 2001)*

6. STEP 1
- dividing operations on external, internal and needless

It is the most important step in SMED method.

It lets identify external activities
(preparatory activities, transport of workshop aids, repair of workshop aids),
which can be done before machine is stopped.

This way we can shorten setup time by about 30-50%.

6. STEP 1
- dividing operations on external, internal and needless

Step 1 allows:

- to identify needed workshop aids, values of setting, process parameters, with the use of checklist
- to arrange items on a work stand with the use 5S method
- to check condition of instruments, tools, materials and repair them before setup
- to deliver workshop aids on a work stand before setup, during machine works

6. STEP 1
- dividing operations on external, internal and needless

CHECKLIST

CARD OF WORKSHOP AIDS			
Card number: 1		**Work stand: lathe**	
Operation: MEASUREMENT OF MACHINE-HOLDER-WORK PIECE-TOOL SYSTEM RIGIDITY			
List of workers, who are right to do setup process			
1	First name and surname: Piotr Kozioł		
List of tools and instruments using in operation			
Name of tool / instrument		6.	Holder of sensors
1.	Mandrel	7.	Sensors (3)
2.	Sleeve	8.	Bow force gauge STR-300kg
3.	Arm	9.	
List of tools and instruments using in setup			
Name of tool / instrument		4.	Double-ended flat wrench 8x10
1.	Block	5.	Tubular wrench
2.	Flat spanner 38x40	6.	Note
3.	Quadruple wrench	7.	Ball pen
Made by: Katarzyna Kaliszczuk **Date:** 5.03.2008		**Approved:** _____ **Date:** _____	

GO TO MODULE 8

6. STEP 1
- dividing operations on external, internal and needless

Tools arrangement - 5S method

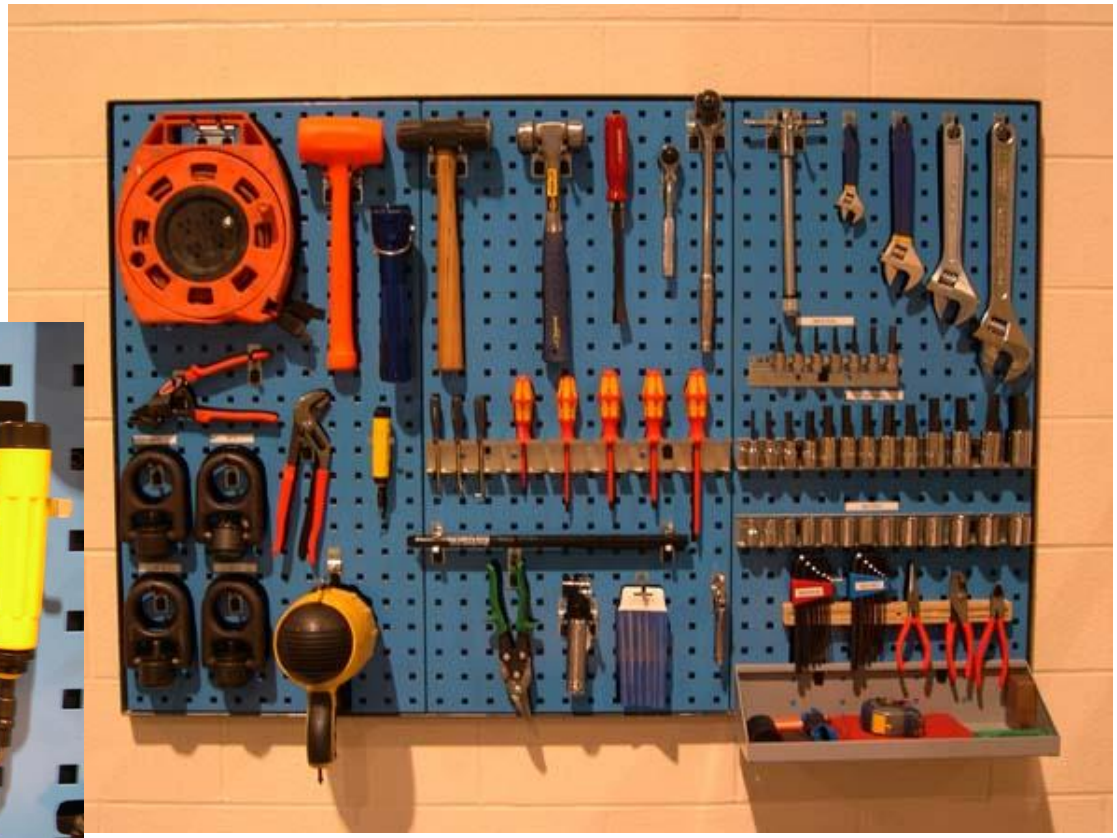
Tools in drawers with profile insert

GO TO MODULE 8

6. STEP 1
- dividing operations on external, internal and needless

Tools arrangement – 5S method

Tools on shadow table

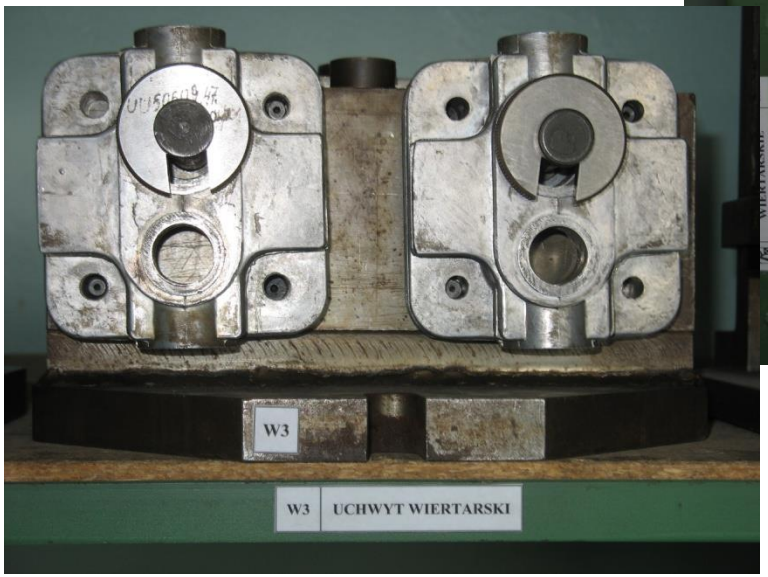


GO TO MODULE 8

6. STEP 1
- dividing operations on external, internal and needless

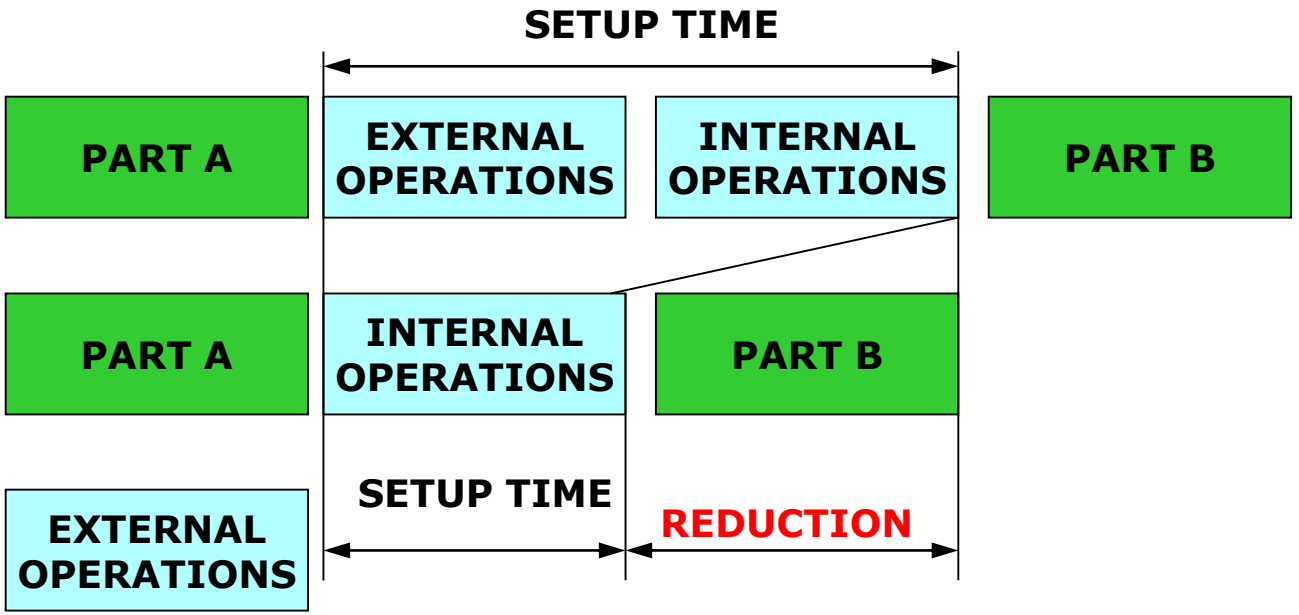
Holders storing – 5S method

Storing holders on cabinets



7. STEP 2
- transforming internal operations into external operations

In this step we try to transform internal operations into external operations, when it is possible.



7. STEP 2
- transforming internal operations into external operations

Techniques, which can help in transforming internal operations into external operations:

- **early preparing of a work stand** – delivering needed instruments and tools and their preparation before setup (e.g. injection mould heated to work temperature with the use of external heater)
- **standardization of functions** – standardized parameters of operations executing on the machine
- **using indirect devices** – using standard holders, in which tools with variable geometry are fixed

7. STEP 2
- transforming internal operations into external operations

Holders used in CNC machines, which enable fixing and next fast changing a tool

Source: http://www.venture.com.pl/images/kintek_products.jpg

8. STEP 3
- improving preparation operations

In this step we optimize both, internal and external operations.

Improving external operations is about storing and transport of workshop aids by using packets in storing and transport, and marking places of their storing.

Improving of internal operations is about parallel realization of operations, using fasten clamps, eliminating regulations and using mechanization.

8. STEP 3
– improving preparation operations

Improving of storing and transport of workshop aids

Shingeo Shingo proposed to deliver all necessary tools and connection elements in sets (in transport and storage) on work stands.

Source: http://www.hkpom.suwalki.pl/pl/meble_metalowe/system_narzedziowy

8. STEP 3
– improving preparation operations

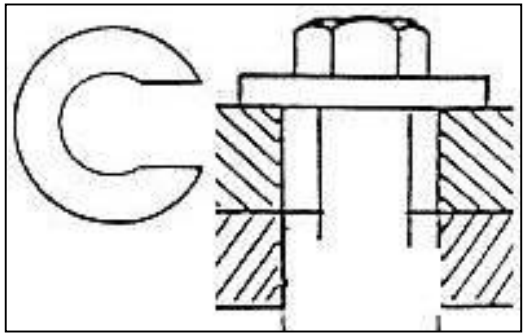
Parallel realization of operations more often is used in setup process of big machines (presses, injection moulding press), which needs setup operations from two sides of machine.

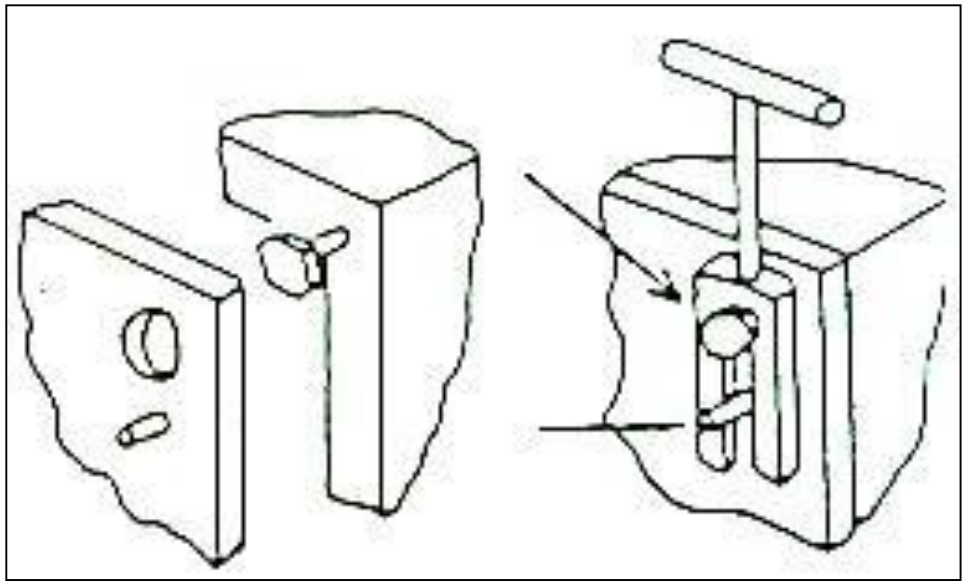
Setup operations can be done by two persons doing setup on each side of machine.

8. STEP 3
– improving preparation operations

CLAMPS

Using washer with cut-out



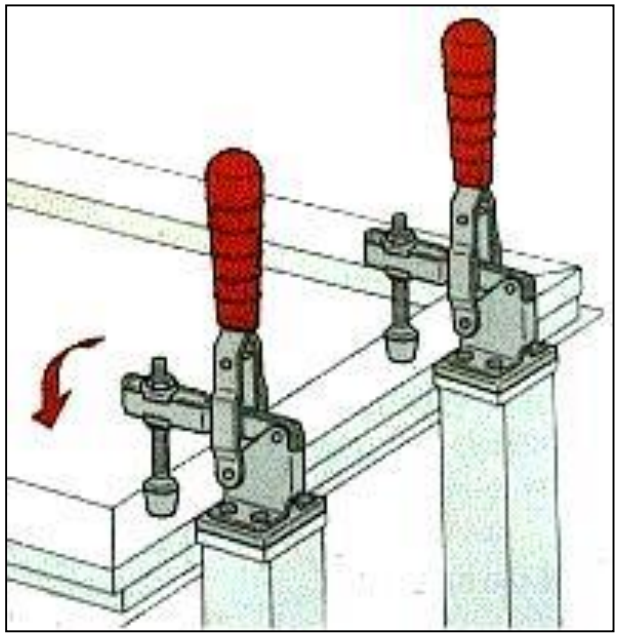


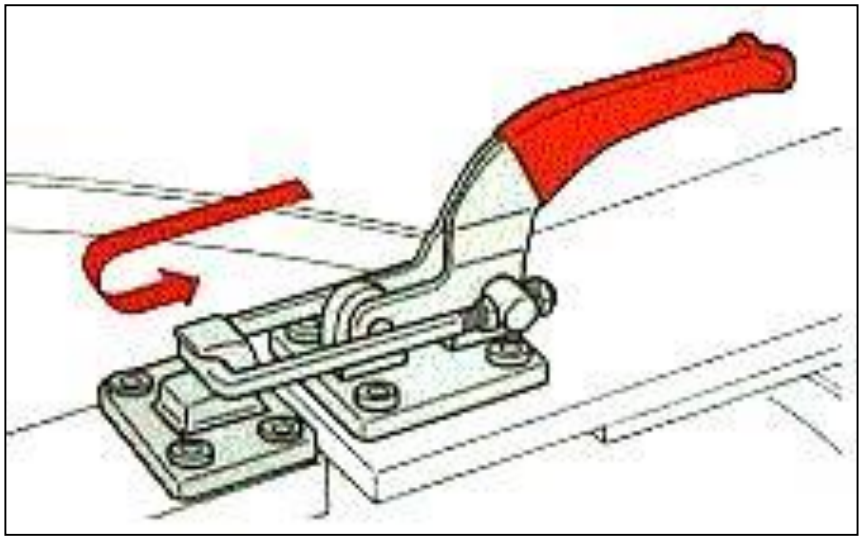
Source: Shingo S., A Revolution in Manufacturing: The SMED System, Productivity, Inc. 1985.

8. STEP 3
- improving preparation operations

CLAMPS

Using link mechanism

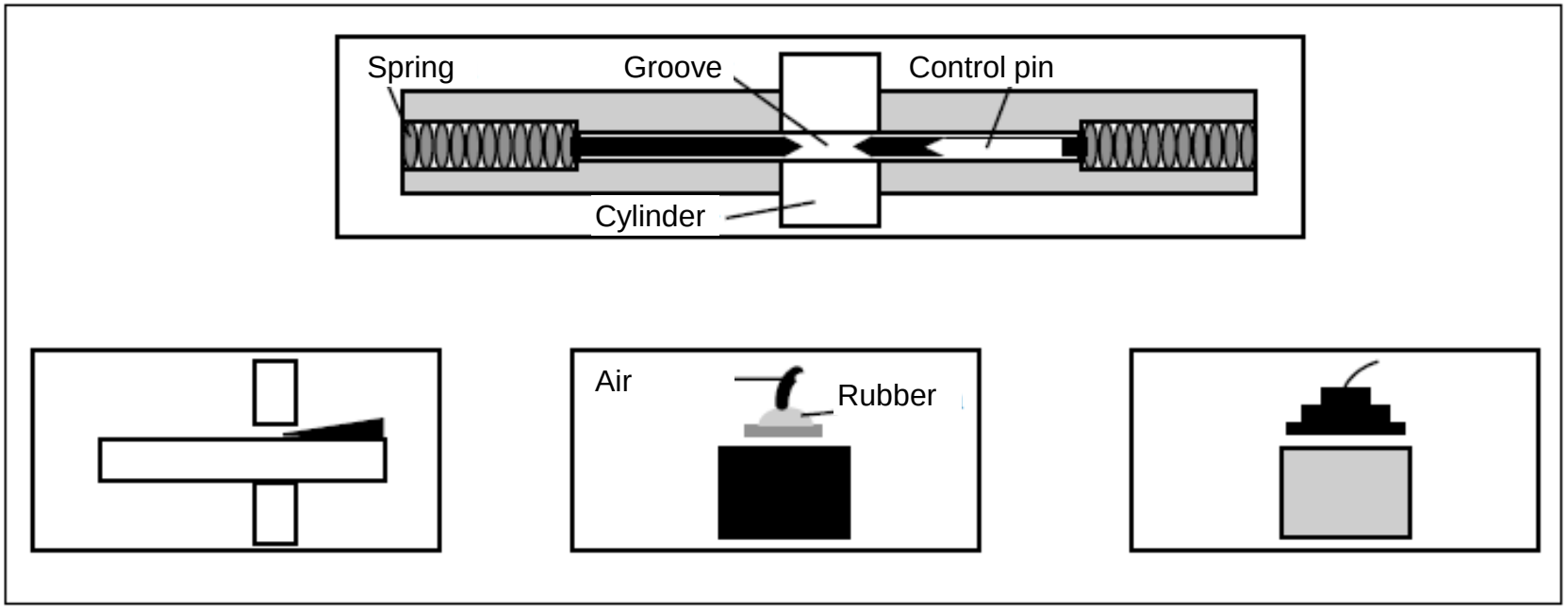




8. STEP 3
- improving preparation operations

CLAMPS

Using spring clips, wedge grips, air clamps, magnetic clamps



Source: Productivity Press Development Team, Quick Changeover for Operators: The Smed System, Productivity, Inc, 1996.

8. STEP 3
- improving preparation operations

CLAMPS

Using tables with T-slot grooves and kits of holding lugs

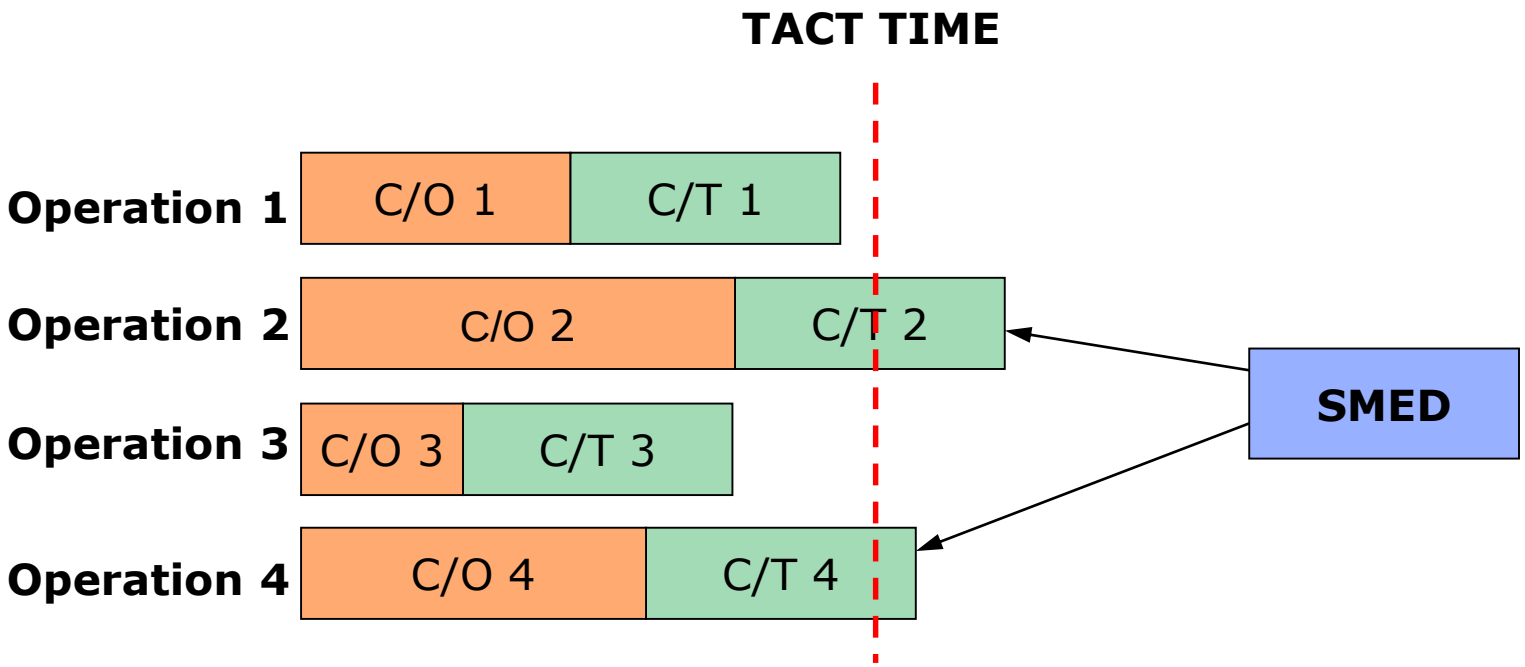
9. Methodology of SMED

Rationalisation of technological machines setup is realised in the following stages:

1. Selection of operation, for which setup time should be shortened: bottleneck operations
2. Reviewing setup instruction or scheme of instruments arrangement on machine
3. Registration of actual way of machine setup
4. Elimination of needless activities
5. Dividing of activities on internal and external
6. Designing a container for storing and transportation workshop aids, which is used during the setup process
7. Realisation of setup after using SMED method and evaluation of effects
8. Developing of instrumentation construction for continuous rationalisation of setup process

10. Selection of operation

We use SMED method usually for the operations, for which a time of operation is longer than tact time



11. Advantaged of SMED

1. Increase of flexibility – an enterprise can react to the changeable needs of clients without incurring costs for additional stocks

2. Faster deliveries – increasing of production batch size lets to increase a time of production cycle, and reduction of time of order realization and delivery

3. Higher quality – proper preparation and organization of setup process lets to increase nonconformities coming from mistakes in setup process and lets to eliminate a need for tests run realization for a new product

11. Advantaged of SMED

4. Increase of productivity – shorter setup time reduces time of machine shutdown, which means higher coefficient of equipment productivity

5. Increase of setup safety – thanks to simplifying rules of tools changing, setup process doesn't need much effort and it is less risky

6. Work stand ordering – setup is a standard process and it is simplified, which means less tools for changing, which gives less items on work stand

12. A example of SMED using
Scheme of workshop aids arrangement

Scheme of arrangement of devices for rigidity measurement in system machine-work piece-tool

12. A example of SMED using Registration of setup

During registration of machine setup process we should use:

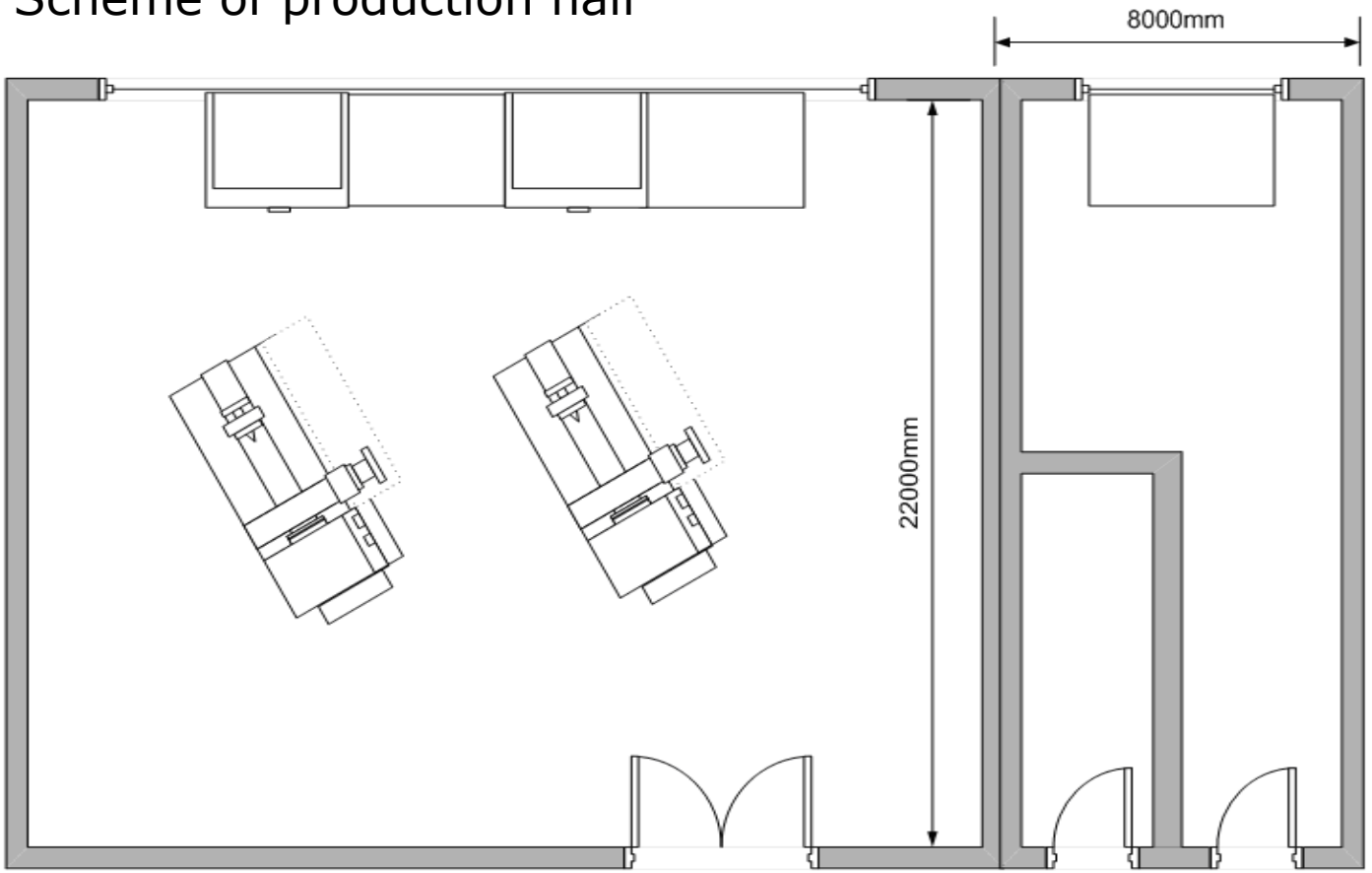
1. Observation sheet, on which we can write all activities, which are done by the worker, time of the activities and we can qualify them into groups of activities: internal, external, needless
2. Checklist, on which we can write all devices and tools used in technological operations, instruments, materials and instructions used during setup process
3. Scheme of production hall, which allows to prepare a spaghetti diagram
4. Pedometer, which allows to estimate length of distance walked by worker during machine setup

12. A example of SMED using Registration of setup

SHEET OF OBSERVATION - BEFORE USING SMED METHOD							
Stand: LATHE STAND				**Operation: MEASUREMENT OF MACHINE-HOLDER-WORK PIECE-TOOL SYSTEM RIGIDITY**			
Team: **1.** Katarzyna Kaliszczuk, **2.** Marta Czapłygin, **3.** Piotr Kozioł							
Date of observation: 15.04.2009				**Page: 1**			
Lp	**Description of activities**	**Start**	**End**	**Duration time**	**Internal**	**External**	**Remarks**
1	Going for equipment (taking a key)	0:02	1:39	01:37		x	
2	Going for equipment (measurement sensors)	1:39	3:00	01:21		x	
3	Going for equipment (force gauge)	3:00	4:18	01:18		x	
4	Mandrel installing	4:18	4:22	00:04	x		
5	Sleeve installing	4:22	4:49	00:27	x		
6	Installing of sensors holder	4:49	4:59	00:10	x		
13	Talk with a colleague	9:59	10:21	00:22			Needless activity
14	Preliminary measure of rigidity	10:21	15:28	05:07	x		
			Sum	15:26			

12. A example of SMED using
Registration of setup

Scheme of production hall

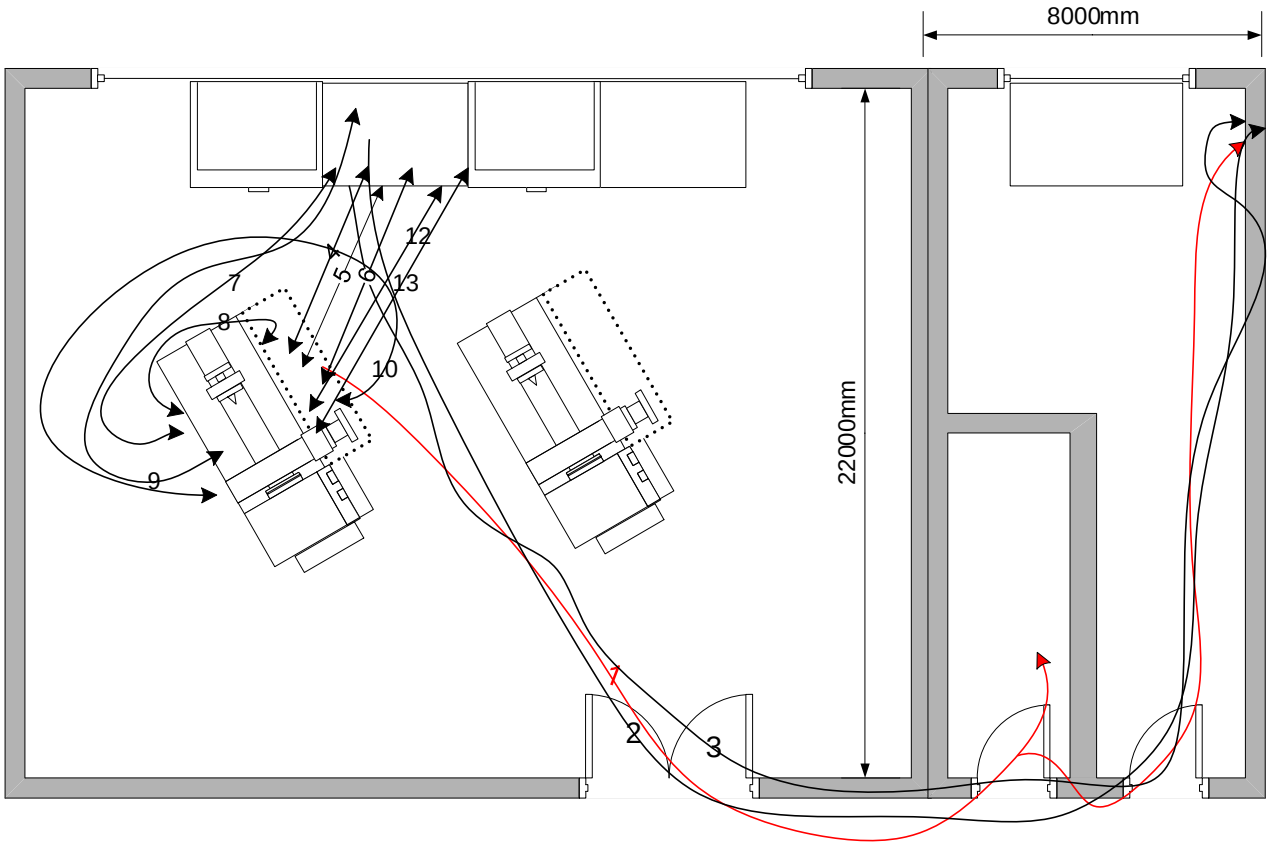


12. A example of SMED using Evaluation of SMED effects

COMPARISON PARAMETER	BEFORE USING SMED METHOD	AFTER USING SMED METHOD
Setup time	**15 min 26 s**	**7 min 16 s**
Number of tools and devices used in operation and setup	**15**	**13**
Number of worker's steps counted by pedometer	**287**	**93**

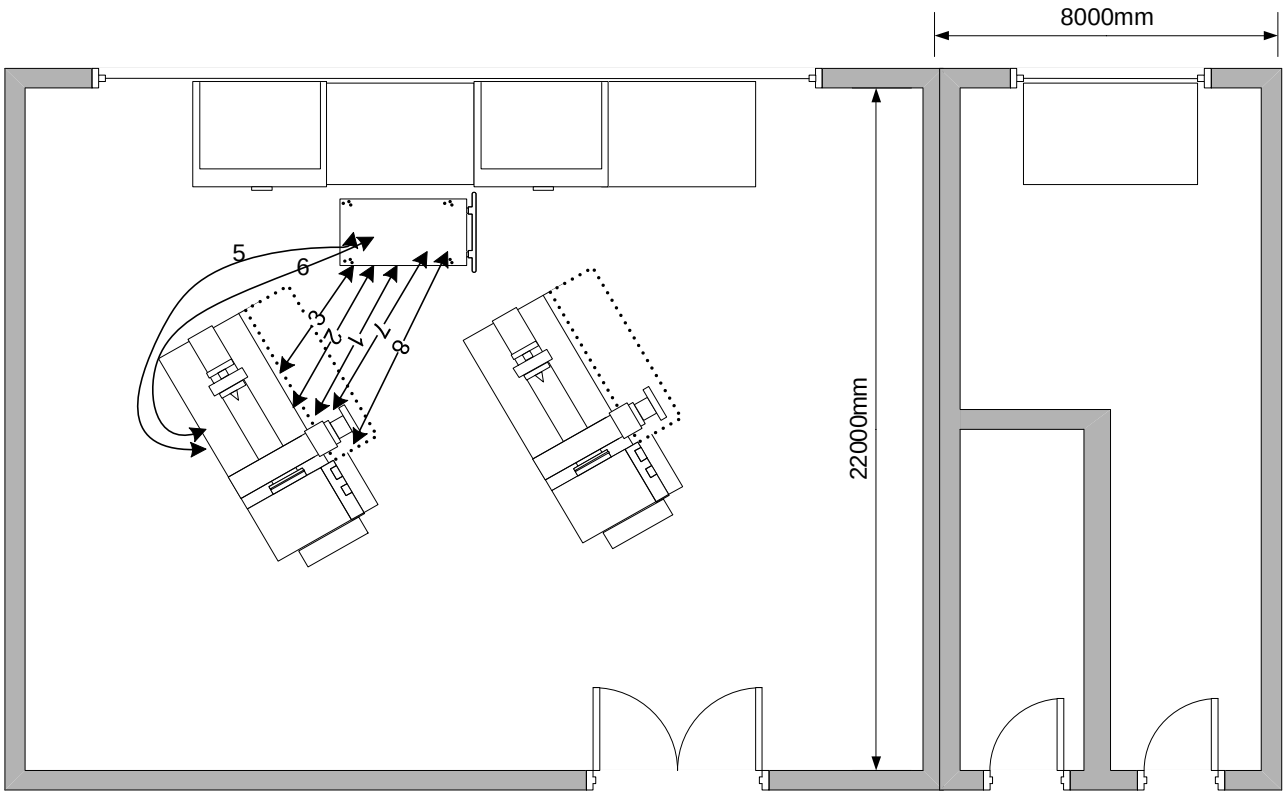
12. A example of SMED using
Evaluation of SMED effects

SCHEME OF WORKER MOTIONS – SPAGHETTI DIAGRAM (BEFORE USING SMED METHOD)

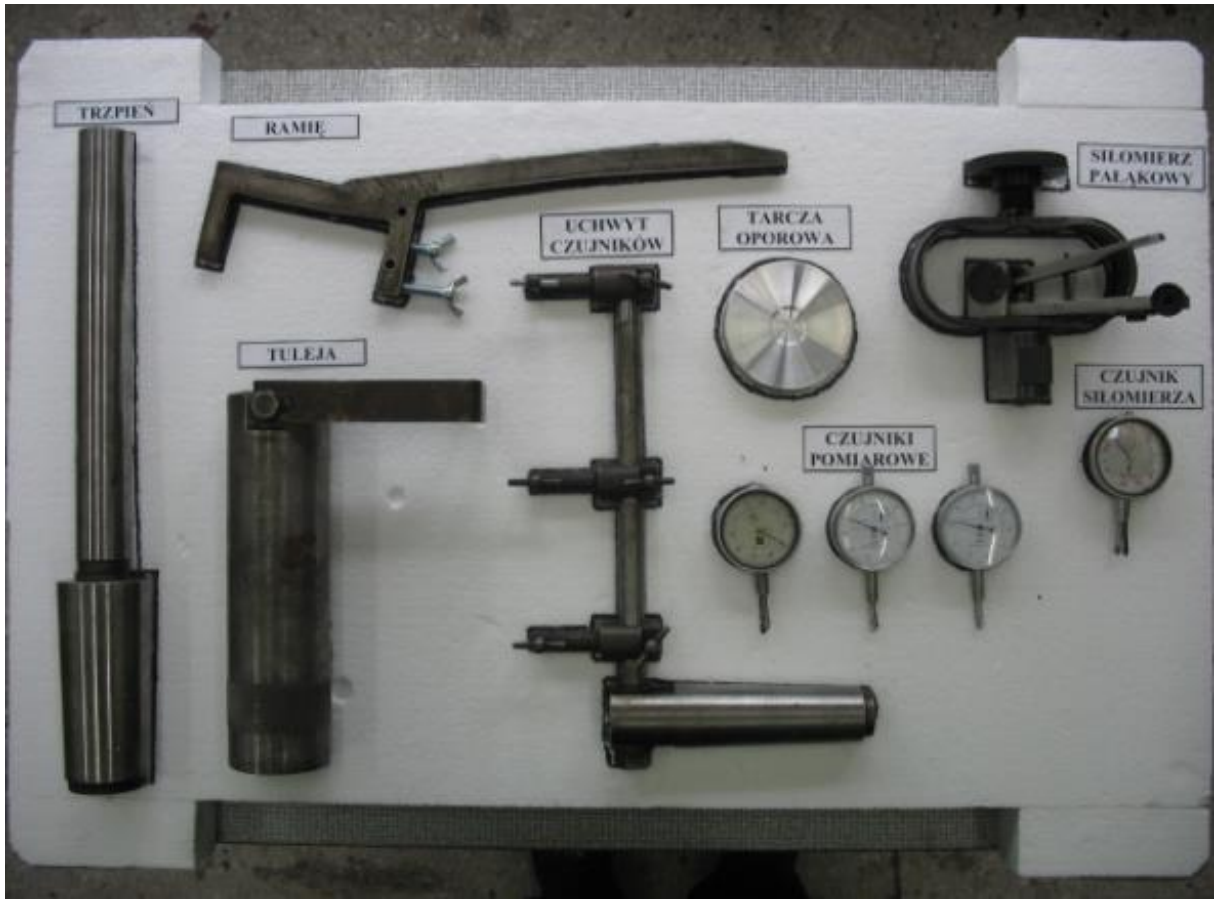


12. A example of SMED using Evaluation of SMED effects

SCHEME OF WORKER MOTIONS – SPAGHETTI DIAGRAM (AFTER USING SMED METHOD)

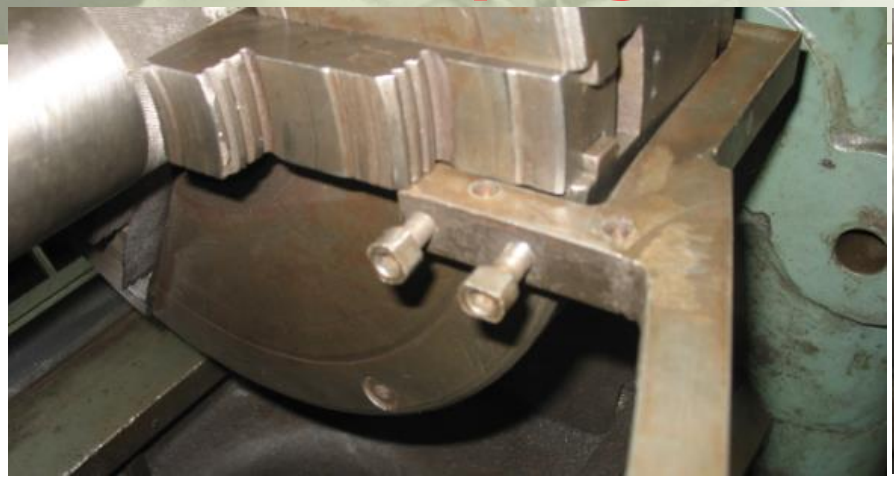


12. A example of SMED using
Design of pallet



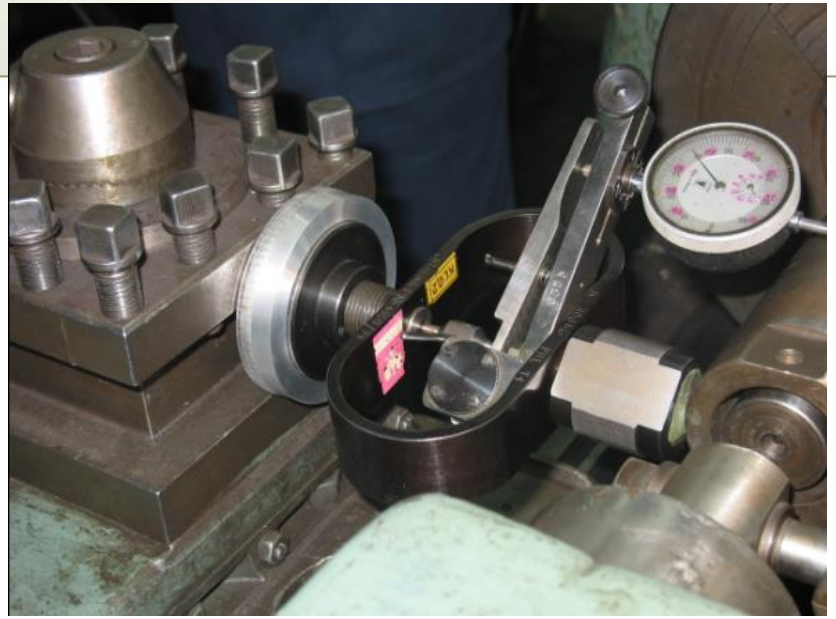
Pallet for storing and transportation of workshop aids

12. A example of SMED using Developing of instrumentation design



BEFORE RATIONALIZATION	AFTER RATIONALIZATION
Installing of arm with the use of screws	Installing of arm with the use of butterfly screws
Activities: 1. Arm installation - 0,38 min	Activities: 1. Arm installation - 0,23 min
Tools: 1. Spanner	Tools: -

12. A example of SMED using Selection of operation



BEFORE RATIONALIZATION	AFTER RATIONALIZATION
Basing a force gauge on locking fastener installed in cutter holder	Using a keep plate
Activities: 1. Installing of locking fastener - 0,21 min 2. Installing of force gauge - 0,41min	Activities: 1. Installing of force gauge with keep plate - 0,33 min
Tools: 1. Tubular spanner 2. Locking fastener	Tools: 1. Keep plate

Literature

1. Shigeo Shingō: A revolution in manufacturing: the SMED system. Productivity, Inc. 1985
2. Shigeo Shingō: Quick changeover for operators: the SMED system. Productivity Press, 1996
3. Clauch J.: Set-Up-Time Reduction. McGraw-Hill, 1996
4. Leschke J. The Setup-Reductio Process. Production and Inventory Management Journal, Firs Quarter, 1997
5. http://membres.multimania.fr/hconline/smed_us.htm#4etapes

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End

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