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< Operational excellence >

Introduction to Operational Excellence

IAMC Toolkit

Innovative approaches for the Sound Management of Chemicals and Chemical Waste

Introduction to Operational Excellence

SMEs manufacturing chemical products often face challenges in improving productivity, controlling production costs and providing customers with value in time.

Operational Excellence is an integrated programme or management system for continuous improvement and creating long-term value in a safe and responsible way. It is a way in which an organization can achieve its objectives more effectively.

The reader will learn how to use Operational Excellence tools (mistake proofing, SMED, statistical quality improvement, design of experiments) to continuously improve company performance in the areas of waste reduction and productivity improvement.

Contents

1. SMED (Single-Minute Exchange of Dies) technique
2. Mistake proofing
3. Statistical process control
4. Design of experiments
5. Key messages

SMED (Single-Minute Exchange of Dies) Techniques

- SMED (Single-Minute Exchange of Dies) techniques
- Mistake proofing
- Statistical process control
- Design of experiments

SMED Applied to the Chemical Industry

- SMED was designed for mechanical manufacturing systems: it is applicable to chemical systems (e.g. densification of polymer granules using pelletizing dies). SMED is:
- A tool for reducing waste (time (labor, equipment), materials) in a manufacturing process
  - Value stream mapping (future state) typically identifies where SMED can be applied
- A rapid and efficient way to change manufacturing process from producing one product to another.

Think NASCAR racing:

Quick and efficient pit stops!!

5 Key Components of the SMED Approach (1)

1. Separation of activities: reduce time that equipment of operation; separate the work of servicing or reconfiguring into:
   - Internal tasks: done while equipment is out of production
   - External tasks: can be done before or after equipment stops and restarts

   ⇨ Prioritizes and limits time done during downtime

2. Modification of internal activities: minimize period of production outage by modifying internal activities. For example,
   - Analyze large internal task to see if parts can be done externally
   - Remove waste from work to perform it faster (e.g. prepare tools and perform in teams)
   - Subdivide work so that it can be done simultaneously
3. Modification of equipment: evaluate how equipment can be (simply) modified to service or reconfigure more quickly

5 Key Components of the SMED Approach (2)

4. Modification of the work team: utilize an appropriate team rather than just a single individual (as is often the case in SMEs)
   - Can often decrease downtime in a way that outweighs increase in workforce
   - Modifications of internal work increase team work done in parallel
5. Preparation for each event: Incorporates all previous 4 elements. The frontline team (operators) can develop the optimum plan and execute work precisely

Mistake Proofing

- SMED (Single-Minute Exchange of Dies) techniques
- Mistake proofing
- Statistical process control
- Design of experiments

Mistake Proofing: Introduction

Everybody knows how to mistake proof, most SMEs do it only informally and periodically

Mistake proofing is a simple but powerful tool for continuous improvement when formalized for frontline personnel (operators).

Concept: mistakes come in two parts:

- A mistake occurs and something in the plant or process is not as it should be
- The situation created by the mistake leads eventually to a bad consequence
- Two opportunities: 1) don‘t make the mistake, 2) correct the mistake before bad consequence occurs

Mistake Proofing: 4 Types of Warning Systems

- Physical separation: physically separate mistakes from consequences
- Visual signals: Using color and shape to display information about the state of the plant.
- Pattern recognition: provide operators with chance to arrange their processes so patterns of correct and normal operating conditions are clear.
- Simple physical devices: actively encourage operators small change improvements.

Mistake Proofing: Additives Example (1)

Compounding of additives in polypropylene production:

- Polymer production typically incorporates a wide variety of additives during the last production step. Process is state-of-the art
  - However: product quality problems discovered to occur in the additive compounding (measuring and mixing in a batch) stage

- Compounding of additives is done by adding 6x500g scoops (3kg) of a particular ingredient to the batch (low tolerance required)
  - Operator was often interrupted and lost track while counting leading to +/- 500g (outside of tolerance)

Mistake Proofing: Additives Example (2)

Solution:

- Scale-accuracy not required (and would add too much time)
- Acquired a small bucket marked to different levels for different ingredients and recipes. Scooped from bulk to bucket removing possibility for error

This simple mistake occurs often in chemical industries.

Statistical Process Control

- SMED (Single-Minute Exchange of Dies) techniques
- Mistake proofing
- Statistical process control
- Design of experiments

Statistical Process Control (1)

Many chemical plants are designed to be resource efficient when operating perfectly (e.g. at full capacity, design specifications)

BUT: Chemical plants rarely operate perfectly or as designed

Many chemical plants have <u>process and product variability</u> that can lead to:

- Off-spec product (waste material, time, equipment)
- Damage of process equipment

Statistical Process Control (2)

⇨ **Improving the control of processes and quality of products is:**

- a key business operation
- a pillar for continuous improvement to improve resource efficiency and decrease waste

Customer specifications are often made by product designers without knowledge of the chemical company's processes:

- RECP opportunities possible by working with customer to jointly define the optimum (most resource efficient) chemical product specification.

Statistical Process Control (3)

Statistical process control is:

- A method of quality control using statistical methods
- Applied to monitor and control processes
- Used to ensure full capability of process (maximum product, minimum off-spec/waste)
- Suitable for any process where a product must conform to customer specifications and can be measured
- An analytical tool for structured and widespread process improvement (through detailed analysis and experimentation)

Key features:

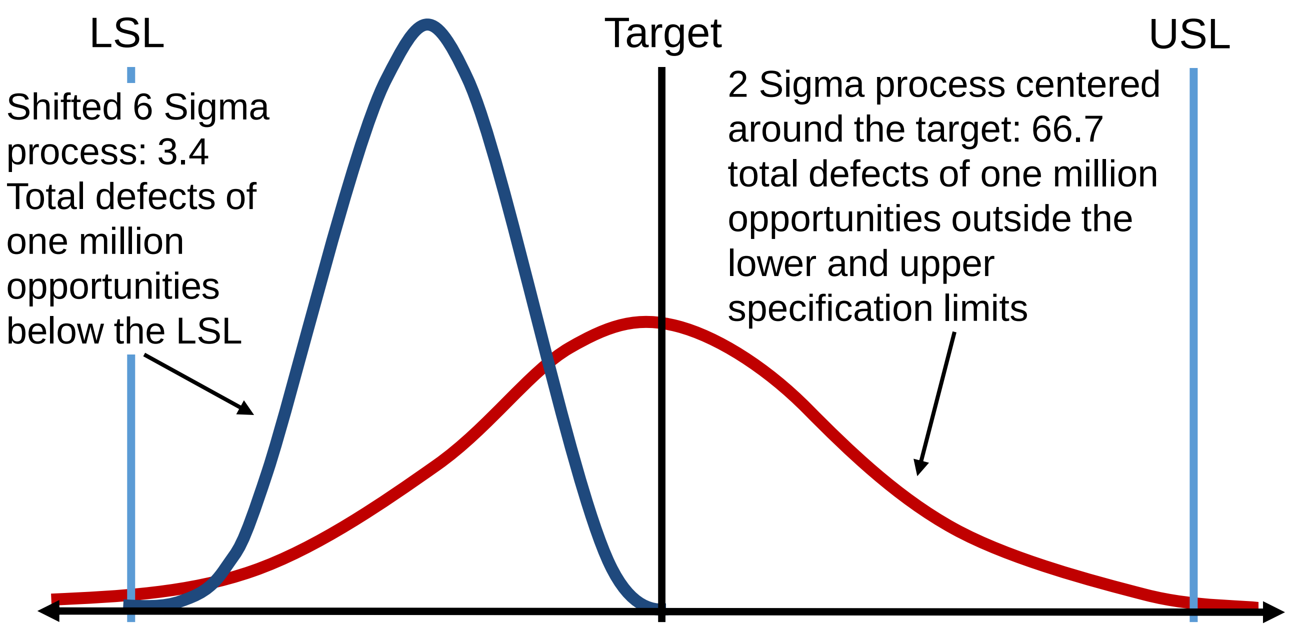
- Six-Sigma quality
- Control charts
- Continuous improvement
- Design of experiments

Six Sigma Concept

Customers have specific targets with upper and lower specification limits (LSL, USL).

A Six Sigma process is one in which 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects (i.e. meet customer specifications)

⇨ 3.4 defective features / million opportunities



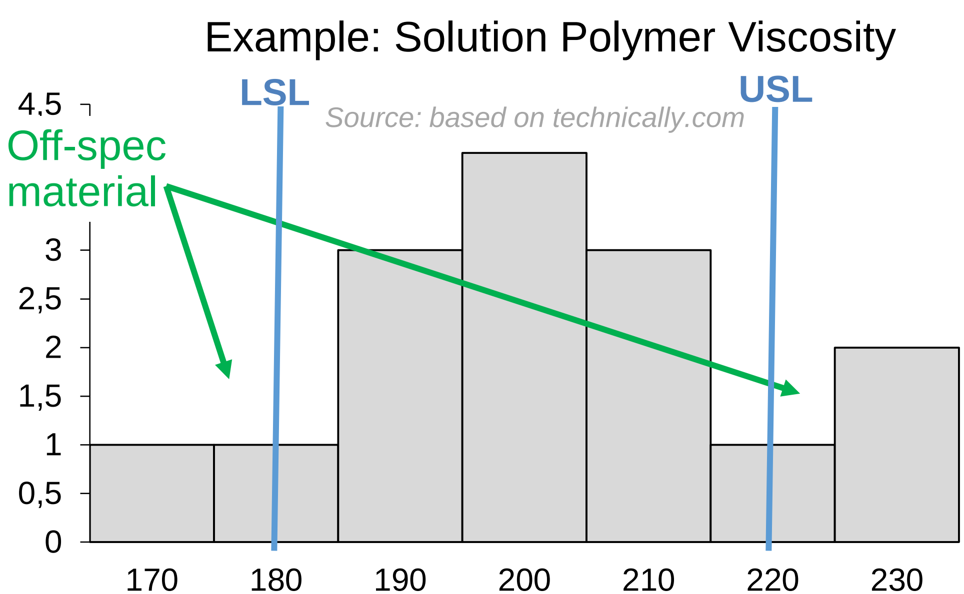
Source: issppro

Six Sigma quality: align the mean value of output with the product specification.
⇨ All natural process variation meet the tolerance range of product specification

Six Sigma Concept - Example

Example: Customer of solution polymer manufacturer

- Product specification range (LSL-USL) for viscosity: 180-220cp (Target specification solution polymer viscosity: 180-220 cp)
- Statistical distribution shows 25% of product is unacceptable ⇨ WASTE
- Solution: manufacturer ran experiments to narrow distribution and decrease waste



Measuring process capability:

"process capability" is term to describe how capable a process is of operating "perfectly" :

Cp = tolerance range/(6*sigma)

= (220-180)/(6*16.5) = 0.4

Good Cp > 2.0.

⇨ Inefficient process.

Example - How SPC Can Improve Resource Efficiency (1)

Company: A polymer company produced vinyl flat sheets for the automotive industry. The flat sheet was vacuum formed for instrument panel pads.

Customer specification: thickness of flat sheet vinyl = 1mm +/- 0.1mm so that when the customer vacuum-formed the vinyl sheet to panels, the thickness was > 0.5mm.

However: Despite meeting the specification, there was significant variation in sheet vinyl thickness which negatively impacted the vacuum-forming process.

Example - How SPC Can Improve Resource Efficiency (2)

Solution: Statistical analysis revealed sources of variation.

- Polymer company reduced thickness variation significantly
- Reduced target specification thickness from 1mm to 0.75mm while improving performance of the vacuum-formed product

Reducing product variation resulted in:

- 25% saving in the amount of raw material
- Increase in profits since product still met customer specifications and sold for same price
- Improved product processing performance (longer lifetime of vacuum-formed product due)
- Customer satisfaction

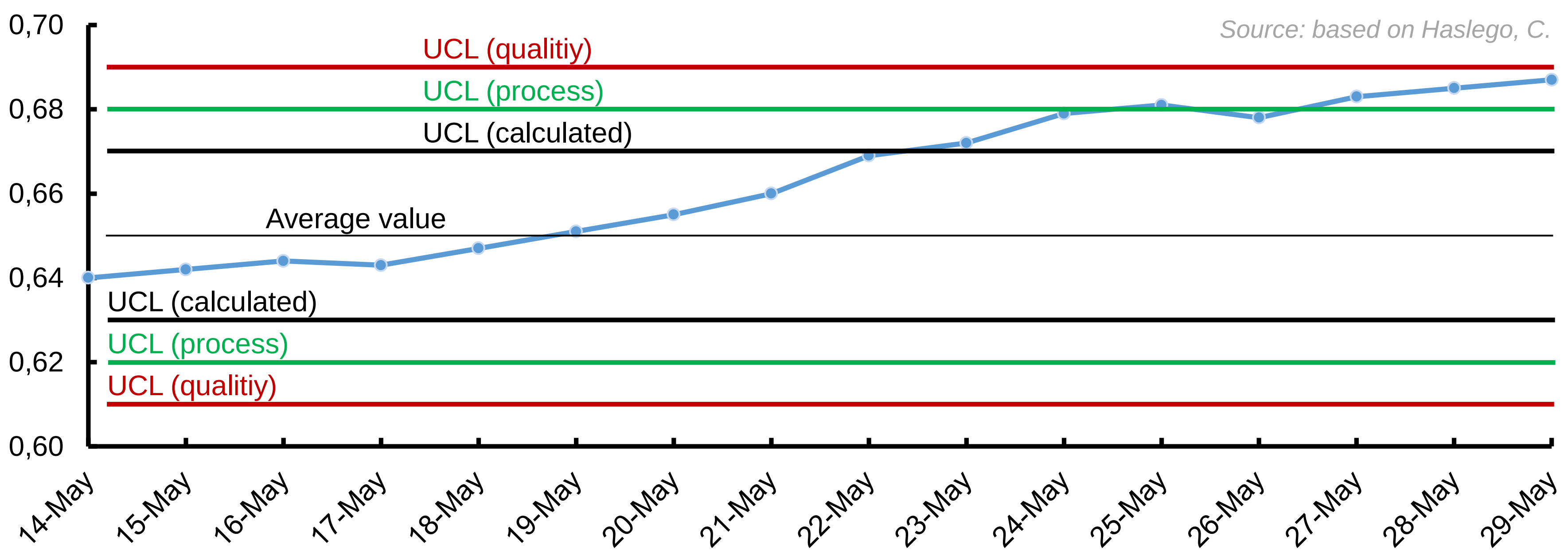
n-Hexane Example-2: Using Control Charts (1)

Process engineer arrives in the morning to see the following diagram.

Not out of specification but something is seriously wrong!

Continued operation will result in significant off-spec material (waste) and perhaps damaged equipment

Where would you look for the problem?



n-Hexane Example-2: Using Control Charts (2)

Questions to ask:

- Is there an intentional process change (e.g. switching from n-hexane to glycol?)
- What process equipment directly affects the control signal (in this case specific gravity)?
- How does it compare to when the process was operating normally? For example, are there any specific outliers?

In this case: the reason was a decrease in separation equipment efficiency.

Design of Experiments

- SMED (Single-Minute Exchange of Dies) techniques
- Mistake proofing
- Statistical process control
- Design of experiments

Design of Experiments (DOE)

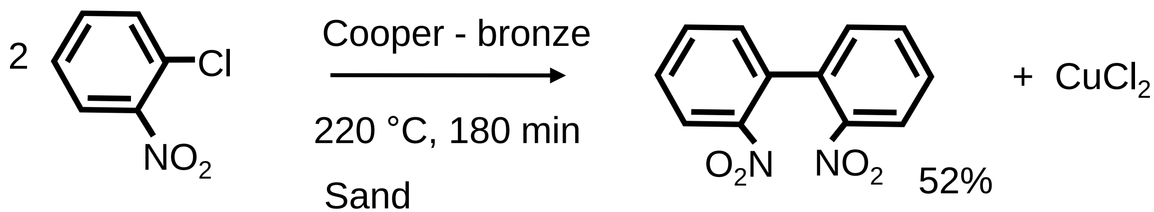
Design of experiments:

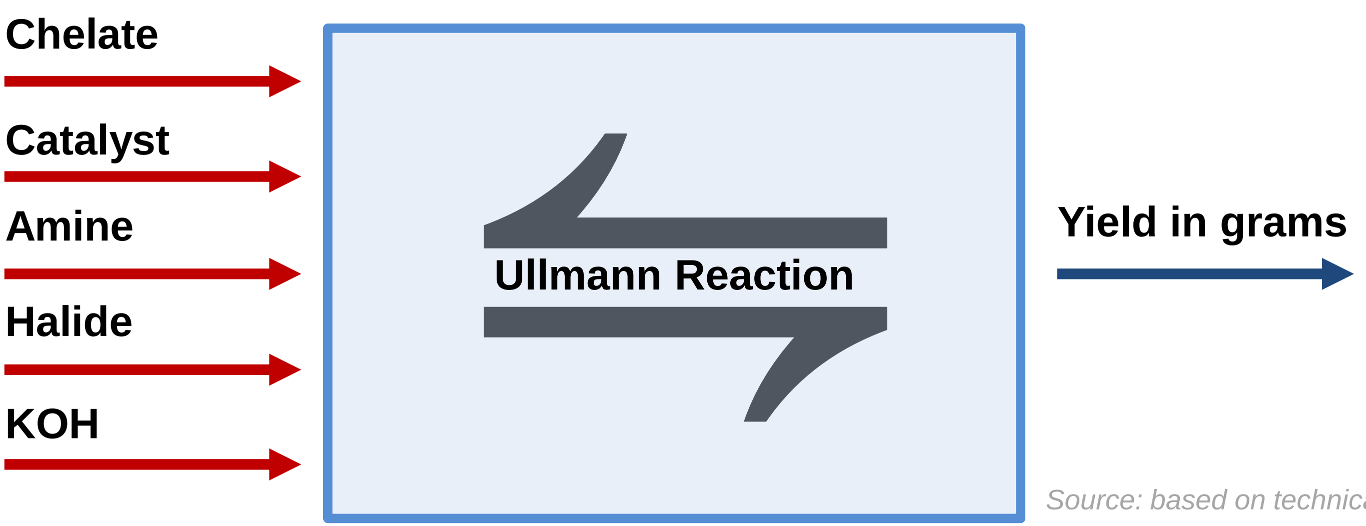
- Used to optimize existing processes and chemistries
  ⇨ maximize resource efficiency
- Can be used to build a statistical representation for process control (including interactions)
- Facilitates effective use of resources:
  - maximum amount of statistical accuracy with minimum amount of experiments (process experiments can be costly)

DOE Example: Ullmann Reaction (1)

Ullmann reaction, e.g. 2,2'-dinitrobiphenyl production.

Contains many process parameters as well as ingredients





Source: based on technically.com

DOE Example: Ullmann Reaction (2)

An eight experiment, two level array can be devised.

Two levels are typically +/-X%. For example, if control temperature is 80°C, level 1 = 75°C; level 2 = 85°C.

Example experimental matrix and result (yield)

Exp. #	Chelate level	Catalyst level	Amine	Halide level	KOH level	Yield (grams)
1	1	1	1	1	1	12.0
2	2	1	1	2	1	11.1
3	1	2	1	2	2	12.9
4	2	2	1	1	2	13.3
5	1	1	2	2	2	13.4
6	2	1	2	1	2	12.3
7	1	2	2	1	1	14.0
8	2	2	2	2	1	14.2

DOE Example: Ullmann Reaction (3)

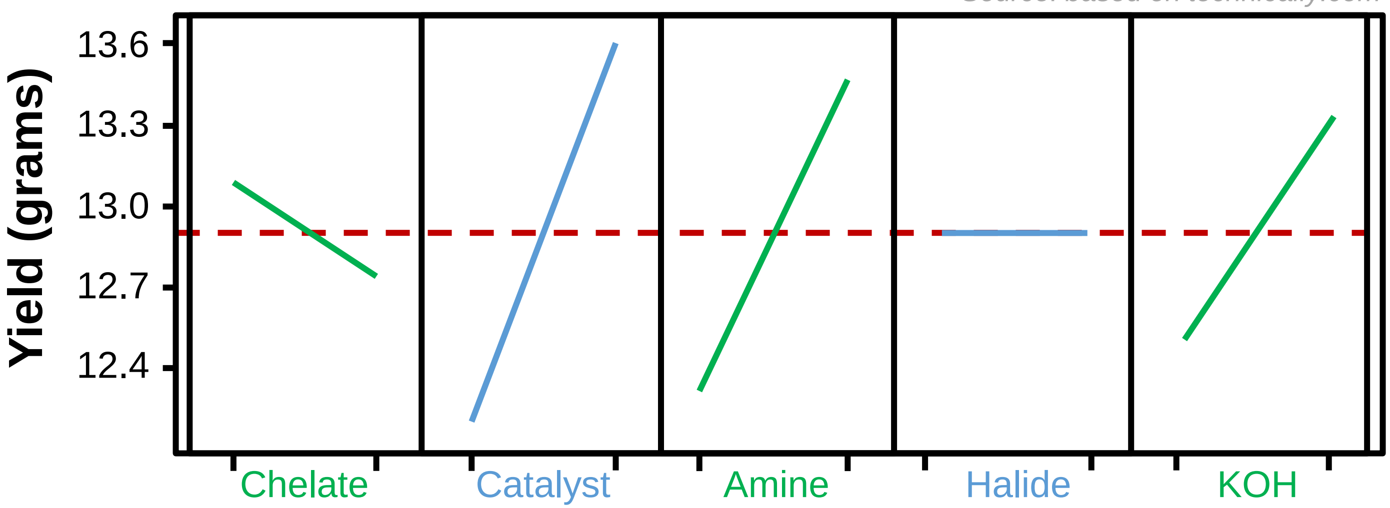
What are the main parameters on yield? What are insignificant parameters?

- Catalyst and amine have strong positive effects on yield. KOH to a lesser extent
- Chelate has a negative effect on yield; halide none.

⇨ Results: increase in yield over 6% (significant improvement in resource efficiency and reduction of waste)

Main effects plot (95% confidence interval)

Source: based on technically.com



Key Messages

Key Messages (1)

Operational Excellence is an integrated programme or management system for continuous improvement and creating long-term value in a safe and responsible way. It is a way in which an organization can achieve its objectives more effectively.

Operational Excellence in the chemical industry can include the following approaches:

- SMED is a tool for reducing waste (time (labor, equipment), materials) in a manufacturing process and is a rapid and efficient way to change a manufacturing process from producing one product to another.
- Mistake proofing is a simple but powerful tool for continuous improvement when formalized for frontline personnel (operators).

Key Messages (2)

Additional Operational Excellence approaches include:

Statistical process control:

- Many chemical plants have process and product variability that can lead to:
  - Off-spec product (waste material, time, equipment)
  - Damage of process equipment
- Statistical process control improves the control of processes and quality of products which is:
  - a key business operation
  - a pillar for continuous improvement to improve resource efficiency and decrease waste

Design of experiments:

- Is used to optimize existing processes and chemistries maximizing resource efficiency
- Can be used to build a statistical representation for process control (including interactions)
- Facilitates effective use of resources:
  - maximum amount of statistical accuracy with minimum amount of experiments (process experiments can be costly)

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