Oliver Song - 2.008 Exam 2

Basic Factory Dynamics

Process-oriented: all machines of same kind laid out together
Product-oriented: factory designed around a specific part
Arrival rate (r_a): Rate that parts arrive at a machine
Bottleneck rate (r_b): Effective rate of bottleneck machine
Effective capacity (r_e): $1/t_e = Ar_0$
Effective process time (t_e): time it takes to process a single part at a particular workstation (long term average w. error)
Lead Time: theoretical 'perfect/goal' cycle time
Utilization (u): ratio of arrival rate into machine to capacity
Service level: probability that parts have CT < lead time
WIP: how many parts are in the current machine cycle
CT: Cycle time of a part
CV: Coefficient of variation, st dev over range. $c = \sigma/t$
m_f : Mean Time to Failure
c_f : CV for the time to failure
c_r : CV for the time to repair
c_a : CV of interarrival time
Availability: Fraction of time the machine is up $A = \frac{m_f}{m_f + m_r}$
SCV: Literally just the Squared CV

Little's law: **WIP = TH*C**

Best case performance:

$$TH_{best} = \begin{cases} w/T_0, & \text{if } w \le W_0 \\ r_b, & \text{otherwise.} \end{cases} \qquad CT_{best} = \begin{cases} T_0, & \text{if } w \le W_0 \\ w/r_b, & \text{otherwise.} \end{cases}$$

Worst case: $CT_{worst} = wT_0$
$TH_{worst} = 1/T_0$

Practical Worst case:

$$CT_{PWC} = T_0 + \frac{w-1}{r_b} \qquad TH_{PWC} = \frac{w}{W_0 + w - 1} r_b$$

Insight #1: Given two machines with the same availabilities (percentage uptimes), which would you prefer? One with long m_f's and long m_r's, or one with short m_r's and short m_f's? The short ones, because they result in smaller net c_e.

Insight #2: Given two machines with the same effective process times, would you prefer a fast machine with long setup stoppages or a slow machine with short setup stoppages? the latter, because it is more "smooth" as you can see from the formula: it results in lower c_e.

Kingman Equation:

$$CT = \underbrace{\left(\frac{c_a^2 + c_e^2}{2}\right)}_{\text{V for Variation}} \underbrace{\left(\frac{u}{1-u}\right)}_{\text{U for Utilization}} \underbrace{(t_e)}_{\text{T for Time}} + t_e$$

Possible sources of variation: operator pace, material fluctuations, product type/quality, breakdowns, downtime

Lean Manufacturing

Rules:
1. Eliminate waste
2. Minimize inventory
3. Maximize flow
4. Pull production from customer demand
5. Meet customer requirements
6. Do it right the first time
7. Empower workers
8. Design for rapid changeover
9. Partner with suppliers
10. Create a culture of continuous improvement

JIT- Just in time: produce only what is needed, when is needed in just the amount needed, AKA Pull
Push: Keep producing whenever possible

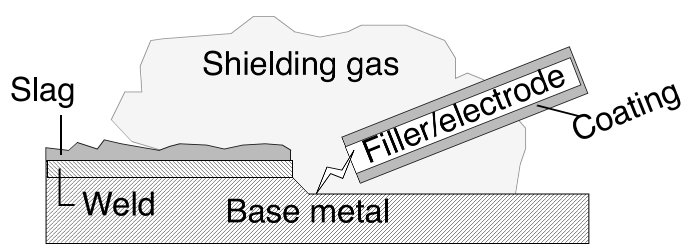
1. Zero Defects: **To avoid delays due to defects. (Quality at the source)**
2. Zero (Excess) Lot Size: **To avoid "waiting inventory" delays. (Usually stated as a *lot size of one*.)**
3. Zero Setups: **To minimize setup delay and facilitate small lot sizes.**
4. Zero Breakdowns: **Avoid stop tightly coupled line**
5. Zero (Excess) Handling: **To promote flow of parts.**
6. Zero Lead Time: **To ensure rapid replenishment of parts (core of the zero inventories objective).**
7. Zero Surging (sudden changes): **Necessary in system without WIP buffers.**

Welding

Jacob number: ----------------------> $Ja = c_p \frac{(T_{melt} - T_{initial})}{h_{fs}}$

Thermal diffusivity: $\alpha = \frac{k}{\rho C_p}$

Melt front moves as: $s = \sqrt{2\alpha Ja t}$
The time at a spot, t_{max}, is given by -----------> $\frac{s_{max}^2}{2\alpha Ja}$
You must feed at rate exceeding d/t_{max} (d: size of weld pool)
Energy input of welding current input = i^2Rt
Energy needed ideally: $E_{ideal} = \rho V C_p$



Also, I was wrong. The base metal is the cathode and the eletrode is the anode. Positive current flows from the anode to the cathode for some reason, I dunno.

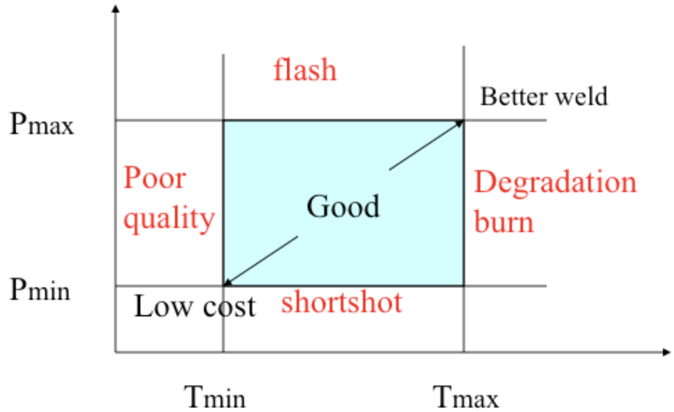
DFA

-Simplicity is best; minimize part numbers, operations; simplify assembly sequence and set-ups
-Standardize components, use suppliable common parts
-Minimize assembly directions
-Modular design
-Symmetry!
-Minimize sharp, delicate, flexible, slippery parts
-Relax tolerances on non-critical locations
-Line of sight

Variation

Causes of variation: random and assignable
Types of variation: physical var and temporal var

3 things that matter in Quality:
1. Size of target
2. Precision
3. Accuracy



Make the window as big as possible; this is robust design

Making injection molding robust:
-Formulation of plastic:
  -low viscosity
  -high burn temperature
  -medium melting point
-Passive locks to help hold molds together
-Better mold design

Looking things up in the z table: $z = \frac{x - \bar{x}}{s}$

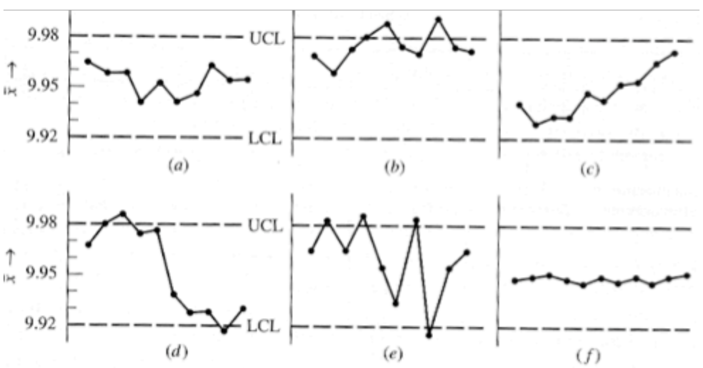


Figure 21–10 Statistical process control gives valuable clues: (a) process is in statistical control, (b) improperly set tooling, (c) rapid tool wear, (d) mixed material lot of two hardnesses, (e) process out of control, and (f) something is going very well and is worth investigating.

Computing charts
1. For each sample, calculate average

$$\bar{X}_i = \frac{\sum_{j=1}^{n} X_{ij}}{n}$$ where X_{ij} is the j-th measurement in the i-th sample.

2. Calculate the range within the sample: $R_i = X_{largest} - X_{smallest}$
3. Calculate grand average:

$$\bar{\bar{X}} = \frac{\sum_{i=1}^{N} \bar{X}_i}{N},$$ where N is the number of subgroups.

4. Calculate average of sample RANGES: ---> $\bar{R} = \frac{\sum^{N} R_i}{N}$
5. Control limits for Range chart:
$$LCL = D_3\bar{R}, \quad UCL = D_4\bar{R}$$

6. Control limits for X-bar (mean) chart
$$UCL = \bar{\bar{X}} + A_2\bar{R}$$
$$LCL = \bar{\bar{X}} - A_2\bar{R}$$

A_2, D_3, and D_4 are functions of sample size.

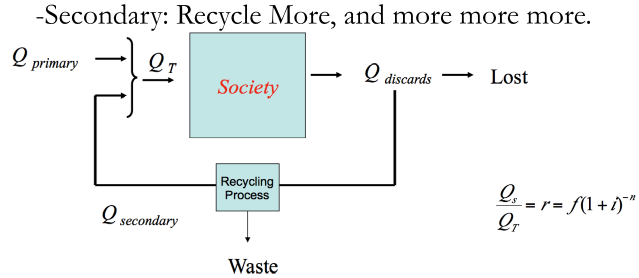
Capability index
$C_p = USL - LSL / 6\sigma_x$ (should be greater than 1.33)

$$C_{pk} = \frac{USL - \mu_x}{3\sigma_x} \text{ or } \frac{\mu_x - LSL}{3\sigma_x}$$ whichever is smaller.

Coatings
Improve resistance to wear/erosion/indentation, Control friction, Reduce adhesion, Improve resistance to corrosion and oxidation, Rebuild surfaces on worn components, Modify surface texture, Decoration, New material properties

Peening: Bombard part surface with tons of tiny balls, which makes the entire surface extremely hard. Good for gears, shafts, springs, jet engine parts
Burnishing: Highly polished rollers are pushed onto the surface, which improves surface finish and res. corrosion. Good for hydraulics, seals, valves
Cladding: Metals are coated with corrosion resistant material using rolls or explosives or lasers
Plating: Roll around some parts in a barrel filled with coating materials. Used for hardened steel parts in automobile manufacturing. Also Candy.
Case hardening: part is heated in the presence of various helper materials. Improves resistance to surface indentation, fatigue, wear. Gear teeth, cams, shafts, bearings, clutch plates
Hard Facing: thick layer of wear resistant metal deposited on surface used welding. Oil well drilling tools, dies. Worn parts can be built back up
Thermal Spraying- metals, alloys, carbides, ceramics can all be applied using spray gun. Aircraft engine components, storage tanks, rocket motor nozzles
Electroplating: workpiece (cathode) can be plated with the anode material. Metal ions from anode discharged due to voltage, then deposit onto cathode.
Electroforming: do electoroplating on a wax thing, then melt the wax; the plating is the product.
Painting: Cost effective and environmentally friendly
Powder Coating: Electrostatically applied, baked afterwards

Environmental Impact
-China is a monster and it's destroying the world
-Strategies for 2050 50% CO_2 output reduction goal
  -Need 75% reduction of energy intensity
  -Primary: Average to BAT
  -Primary: Cutting Edge
  -Secondary: Recycle More, and more more more.



$Q_{secondary} = f\ Q_{discards}$; $Q_{discards}(1+i)^n = Q_T$