Relationship between Cycle Time and Setup Value in Single type Preventive Maintenance Scheduling

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Contents

(1) Introduction

- **<u>What is the PM?</u>**

- PM is abbreviation of Preventive Maintenance.

- Maintaining equipment and facilities in satisfactory operating condition by providing for systematic inspection, detection.

- Primary goal is to avoid or mitigate the consequences of failure of equipment.

- In brief, periodic unproductive examination of equipment before use it.

(1) Introduction

- **<u>What is the PM?</u>**

Automobile

- Oil changes are part of a car's preventive maintenance.

➔ Preventing a car from being stopped unexpectedly.

Train

- Preventive maintenance on railroad tracks.

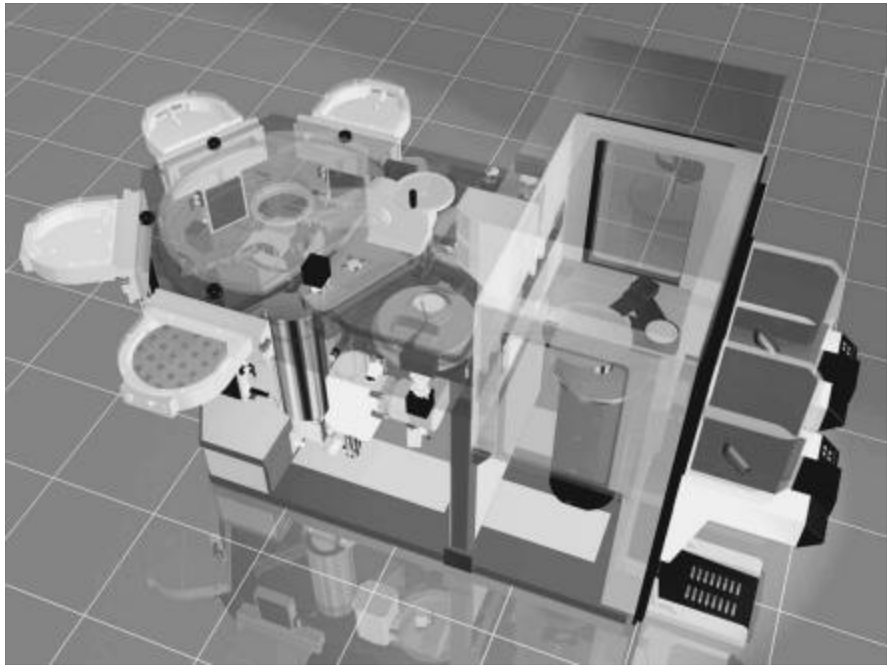
➔ Preventing a train derailment resulting in damage of human life.

(1) Introduction

- **<u>PM in semiconductor manufacturing equipment</u>**

  - PM activities are more complex and essential than any other manufacturing system.

  - Thus, PM tasks have to be scheduled carefully.



(1) Introduction

- **<u>Why we need a good PM plan?</u>**

- A good PM plan can increase equipment availability.

➔ Occurring planned downtime due to PM.

➔ But preventing a risk of costly unplanned downtime due to equipment failure.

Existing trade-off

➔ Overall equipment availability ⬆

- Equipment reliability ⬆

(1) Introduction

- **What we have to do**

- Consider queueing system in the production process,

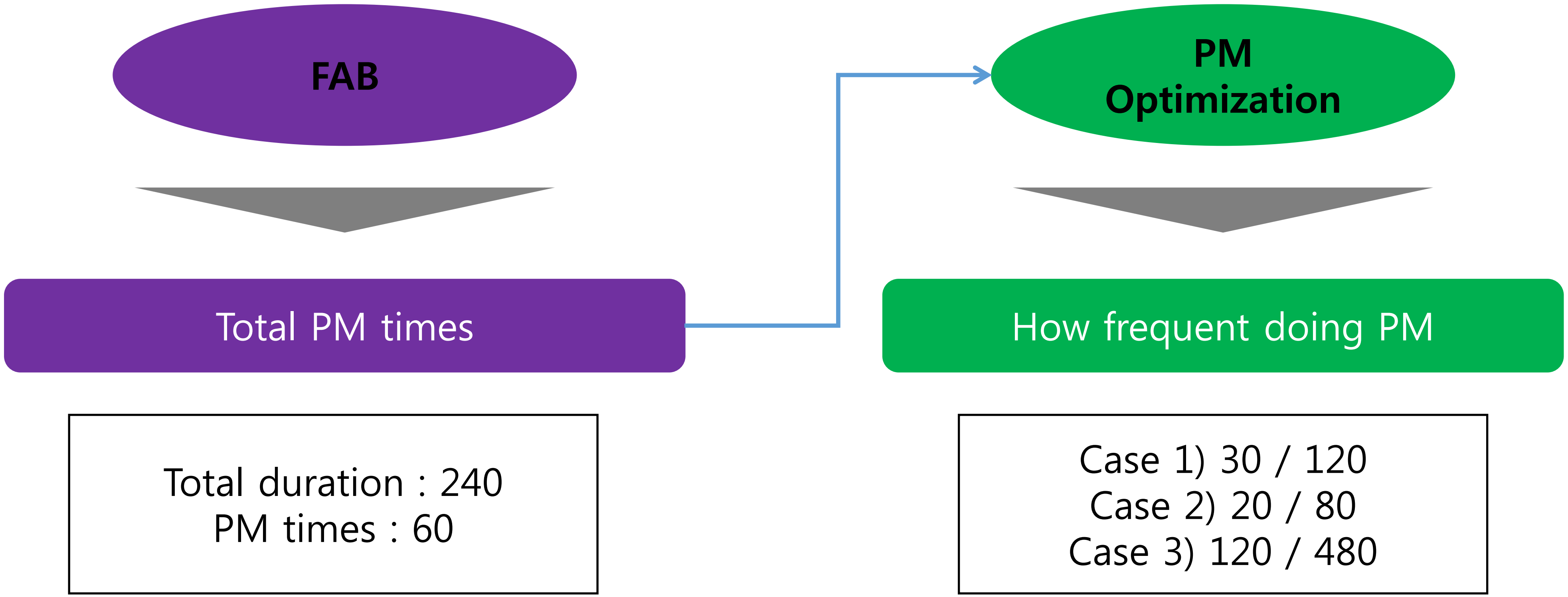
  ➔ We want to minimize cycle time in queueing system

- When the original PM plan is given from fab, we can change the PM cycle in accordance with the PM type.

- PM times of total cycle is determined by fab, we just determine when or how frequent we do PM.

(1) Introduction

- **What we have to do**



(2) System description

① New trade-off

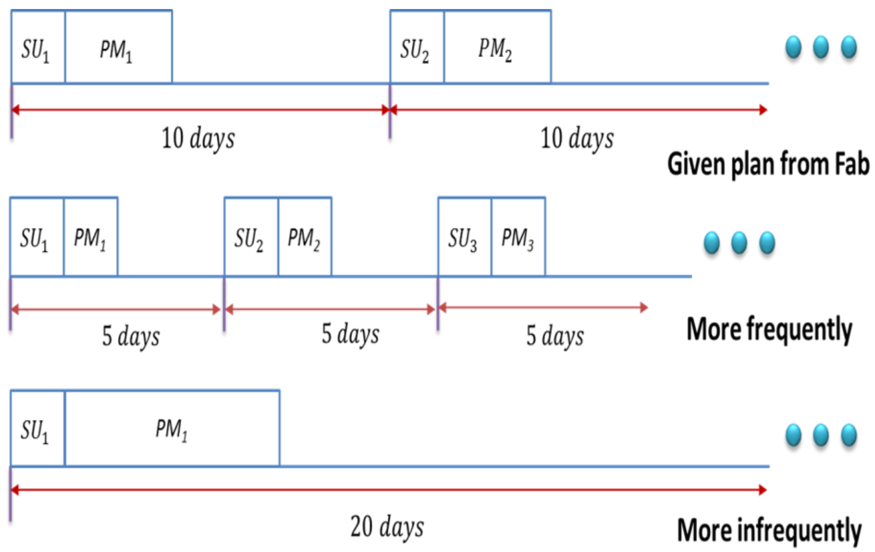
- Even though the PM cycle is change, the setup time is fixed.

1) More frequent PM : Total incurred setup times ↑

➔ Availability ↓ , mean time to repair ↓

2) More infrequent PM : Total incurred setup times ↓

➔ Availability ↑ , mean time to repair ↑



(2) System description

① New trade-off

$$E(CT) = \frac{1}{\mu A} + \frac{1}{\mu A}\left(\frac{\rho}{1-\rho}\right)\left(\frac{1}{2}\right)\left(1 + C_S^2 + \frac{(1+C_R^2)A(1-A)m_R\mu}{\rho}\right)$$

Factory Physics Mean Cycle Time formula

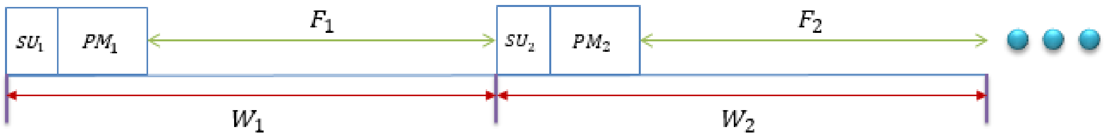
- Frequent case : Availability (A) ↓
- Frequent case : mean time to repair (m_R) ↓

- Infrequent case : Availability (A) ↑
- Infrequent case : mean time to repair (m_R) ↑

Existing trade-off

(2) System description

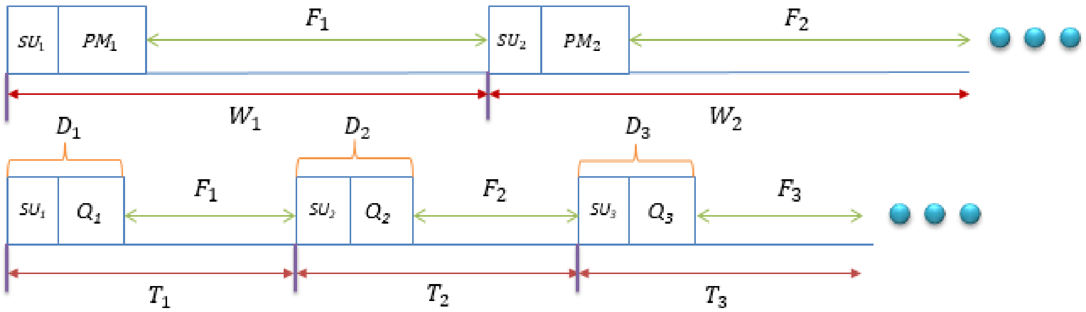
② Queueing networks of single type of PM



- Four random variables
  - $\{F_j\}_{j=1}^{\infty}$ denote IID random variables of the j^{th} duration of uptimes.
  - $\{PM_j\}_{j=1}^{\infty}$ denote IID random variables of the j^{th} preventive maintenance.
  - $\{SU_j\}_{j=1}^{\infty}$ denote IID random variables of the j^{th} setup times. where $SU_j = \frac{PM_j}{k_j}$
  - $\{W_j\}_{j=1}^{\infty}$ denote IID random variables of the j^{th} total duration ($W_j = F_j + PM_j + SU_j$).

(2) System description

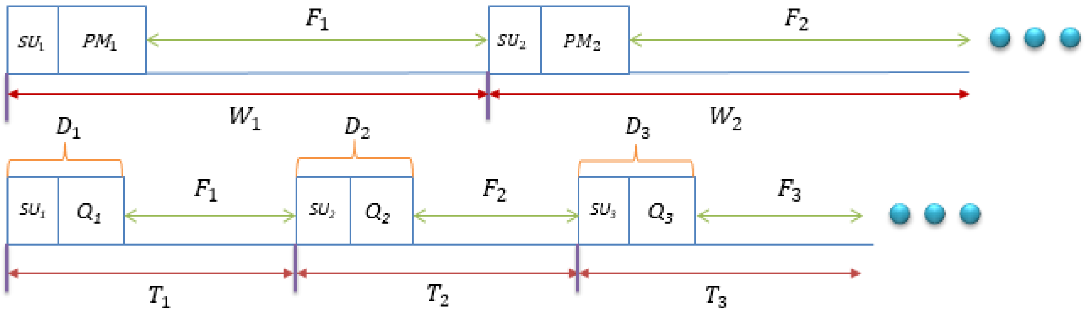
② Queueing networks of single type of PM



- Original plan and Changed PM plan
  - m_W: The mean time of total duration of Original plan
  - m_T: The mean time of the changed PM cycle.
  - m_T is decision variable. $L \leq m_T \leq U$

(2) System description

② Queueing networks of single type of PM



- $m_R(m_T) = \left(\frac{1}{k_j} + \frac{m_T}{m_w}\right) E[PM] = E[SU] + E[Q], \quad {C_R}^2 = {C_{PM}}^2$
- $m_F(m_T) = m_T - m_R, \; F_i \sim Exp\left(\frac{1}{m_F(m_T)}\right)$ IID
- $\mathrm{A}(m_T) = \frac{m_F}{m_F + m_R}$ $(Availability), \; \rho(m_T) = \frac{\lambda}{\mu A(m_T)}$ $(System\ loading)$.

(2) System description

② Queueing networks of single type of PM

- Nonlinear programming problem
- M/G/1-queue case

$$\textbf{Min } CT(m_T)$$

Subject to

$$m_T > \frac{m_{SU} m_W}{(m_{W^*}(1 - {}^{\lambda}/_{\mu}) - m_{PM})}$$ (system loading constraint)

$$L \le m_T \le U$$

$$E(CT) = \frac{1}{\mu A} + \frac{1}{\mu A}\left(\frac{\rho}{1-\rho}\right)\left(\frac{1}{2}\right)\left(1 + C^2{}_S + \frac{(1 + C^2{}_R)A(1-A)m_R\mu}{\rho}\right)$$

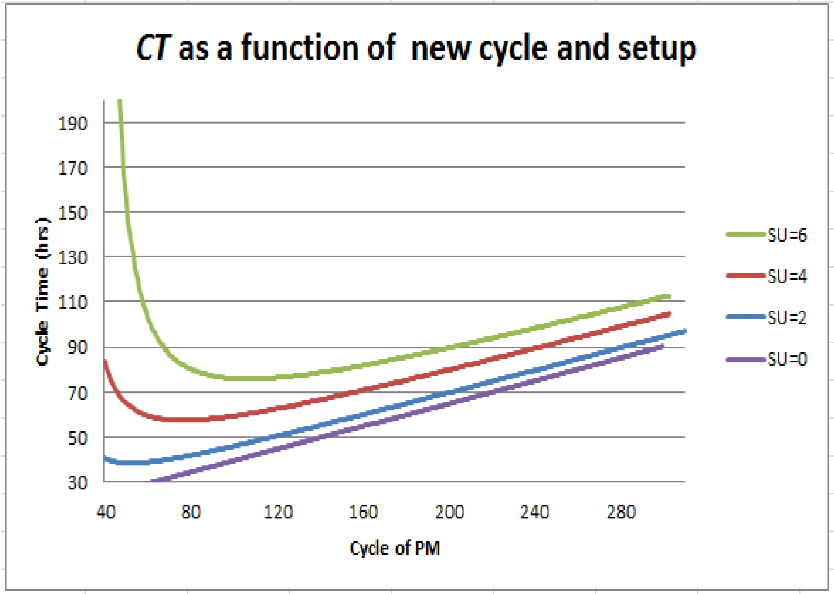
(3) Relation between Cycle Time and Setup Value

- **<u>In Hungil's thesis</u>**

- Setup time is given parameter.
- Decision variable : Cycle of PM (m_T)
- Objective : Cycle time ($E(CT)$)

➔ Function of cycle time according to cycle of PM is strictly convex.

➔ So we can calculate optimal cycle time easily.



(3) Relation between Cycle Time and Setup Value

- **Research goal**

- Setup value is a given parameter.

- We observe change of the optimal cycle time according to changing setup value.

- If the relation between optimal cycle time and setup value is linear, optimal cycle time is easier to calculate. $E(CT) = \alpha * m_T + \beta$

(3) Relation between Cycle Time and Setup Value

- **<u>How to prove</u>**

- Optimal cycle time : Using Excel solver

- Observe regression line of cycle time and setup time.

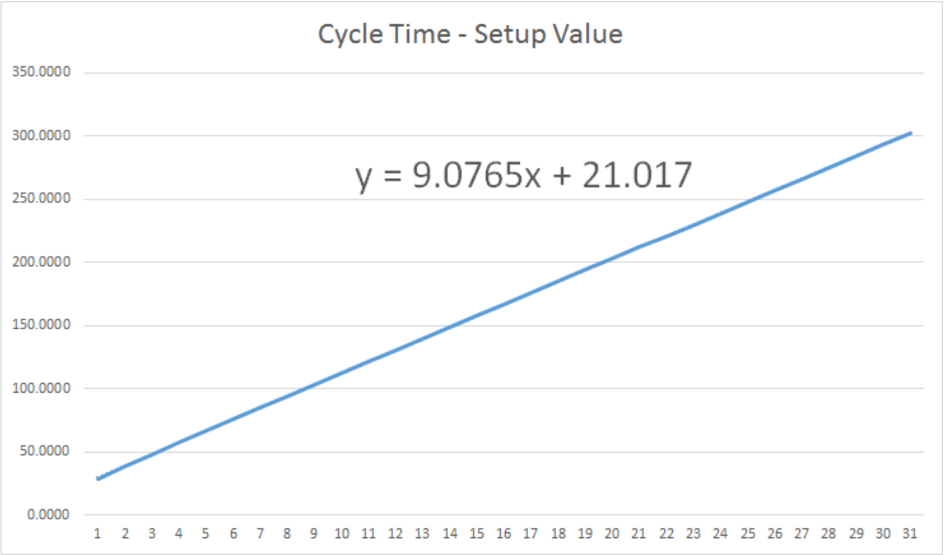
- First case : Change setup value from 1 to 30 (∵ Cycle of PM have bounds)
- Second case : Change setup value from 0.1 to 2

(3) Relation between Cycle Time and Setup Value

- **First case (From 1 to 30)**

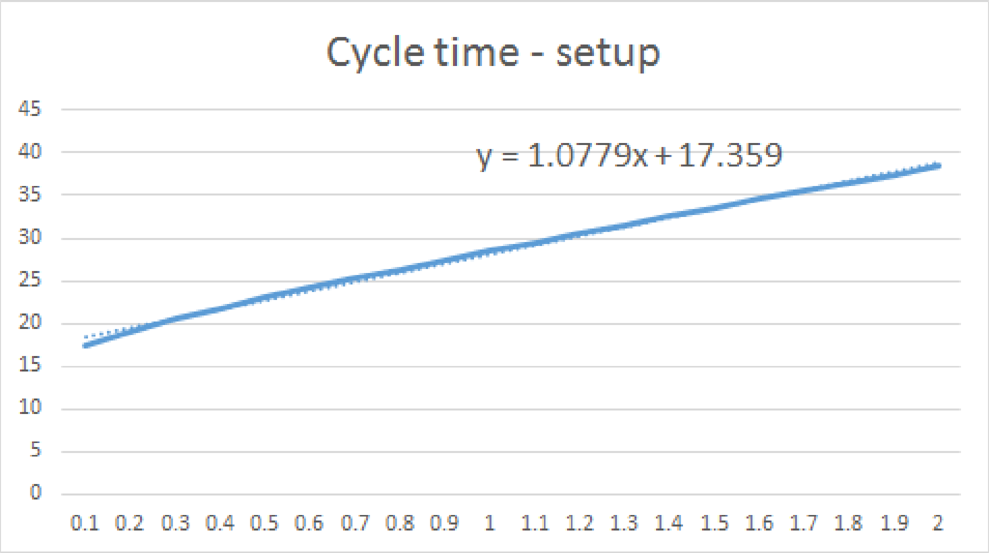
  - Observe the error between optimal value and value of the regression line.

  - The error at lower setup values(1~2) between optimal value by using Excel solver and value of regression line are a little bigger than higher setup values.



(3) Relation between Cycle Time and Setup Value

- **<u>Second case (From 0.1 to 2)</u>**
  - To observe more accurate, change the range of setup value from 0.1 to 2.
  - More clear that the relation is not linear.
  - Similar to linear, not perfect linear



(4) Relation between the cycle of PM(m_T) and Setup Value

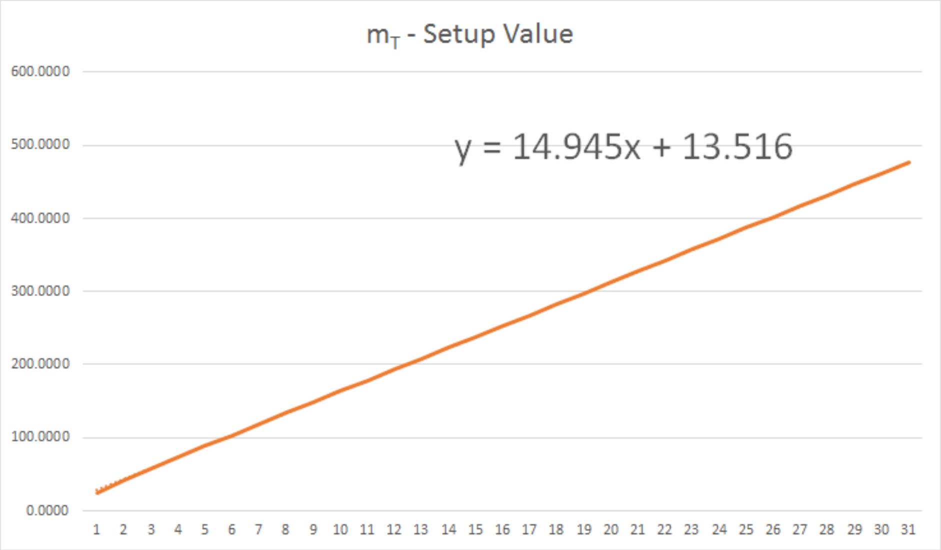
- **<u>How to prove</u>**

- Similar to previous case.

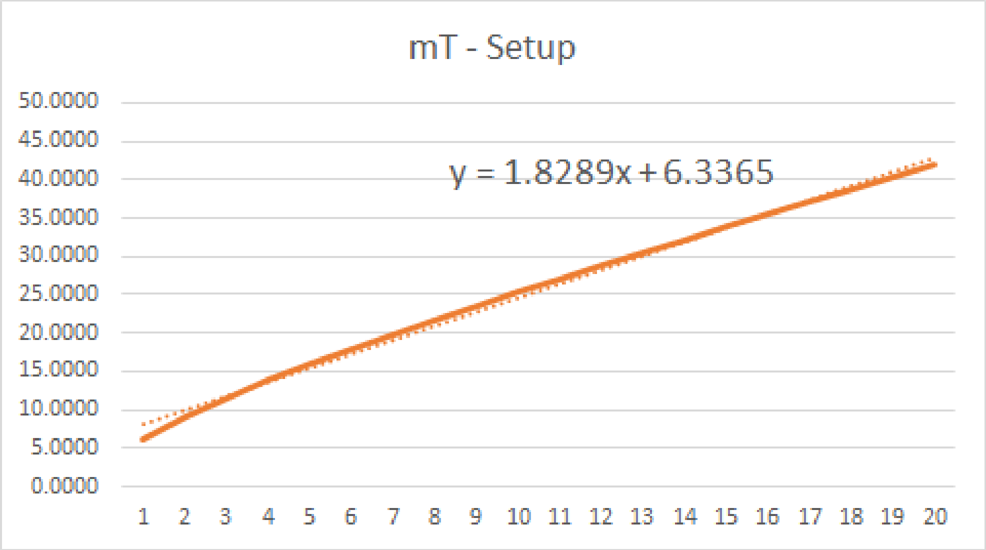
- First case : Change setup value from 1 to 30 (∵ Cycle of PM have bounds)
- Second case : Change setup value from 0.1 to 2

(4) Relation between the cycle of PM(m_T) and Setup Value

- **First case (From 1 to 30)**



- **Second case (From 0.1 to 2)**



➔ Same results with previous case.

(5) Conclusion and future task

- **<u>Conclusion & Future task</u>**

- Relation between cycle time(or PM cycle) and setup value is not perfect linear.
- If we know the exact relation between cycle time and setup value and if we can express the relation using the simple formula, calculating cycle time with incurred setup value becomes easier.

(5) Conclusion and future task

- **Dominance property**

- If there are two types of PM.
- One is more influential to cycle time.
- And we have to choose type of PM which is rescheduled preferentially.
- Thus we need the rule of thumb.