Robust Design by using Taguchi Method

- Optimization of ACF(Auto Cash Feeder) at ATM-

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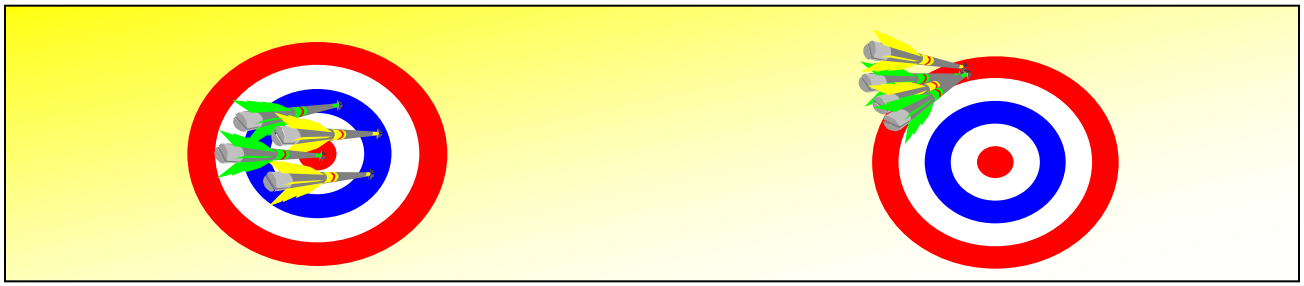
Presented by Yong-Gyun Shin
QC professional engineer

Han Quality Management Research Lab

Optimization Problem

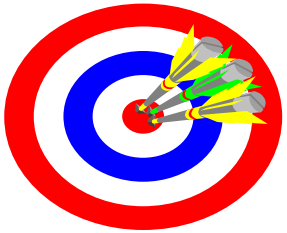
Which is the priority for Optimization?



Accuracy-good
Precision-no good

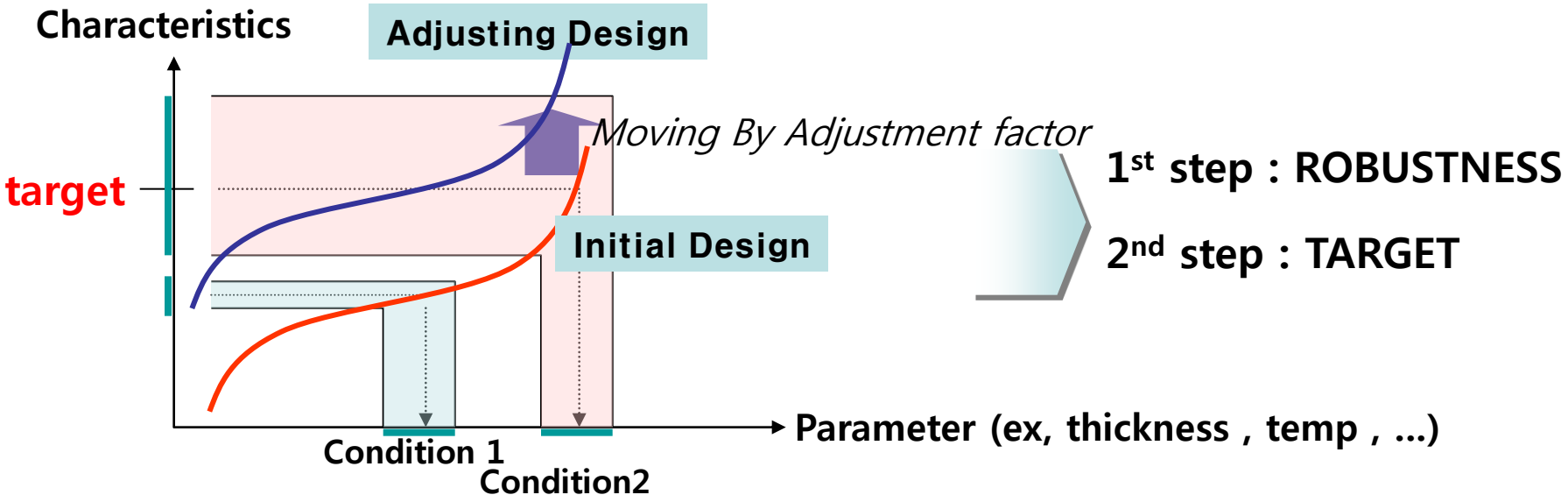
Accuracy-no good
Precision-good

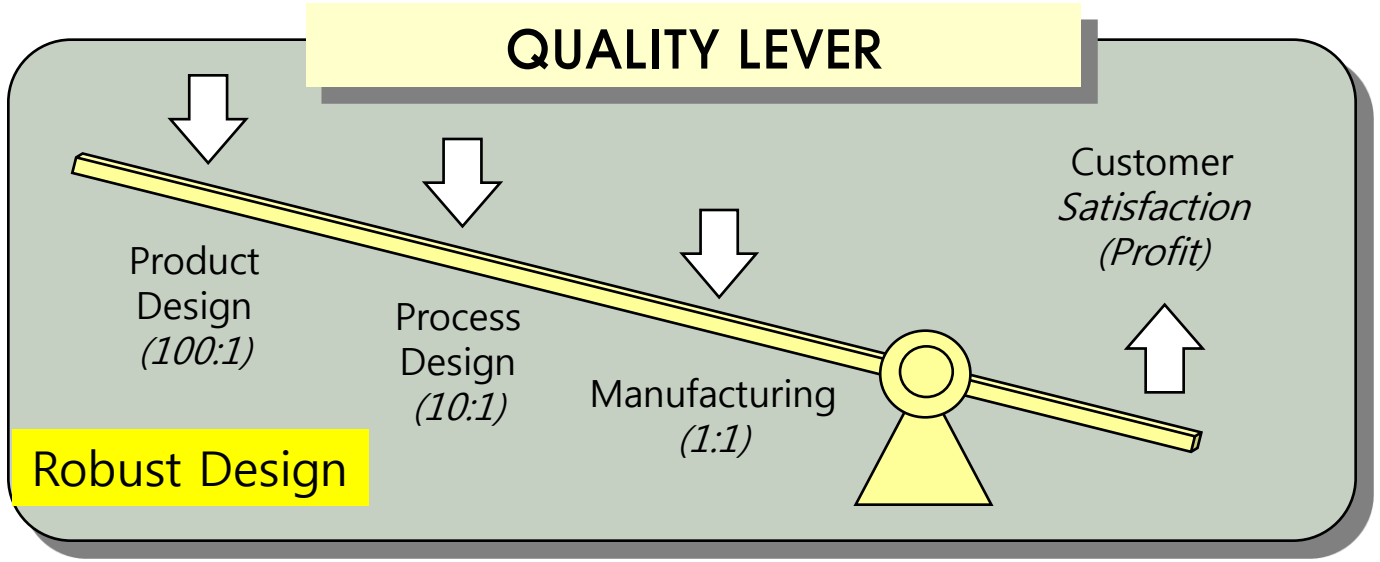
Minimizing deviation &
Adjusting to target



Accuracy-good
Precision-good

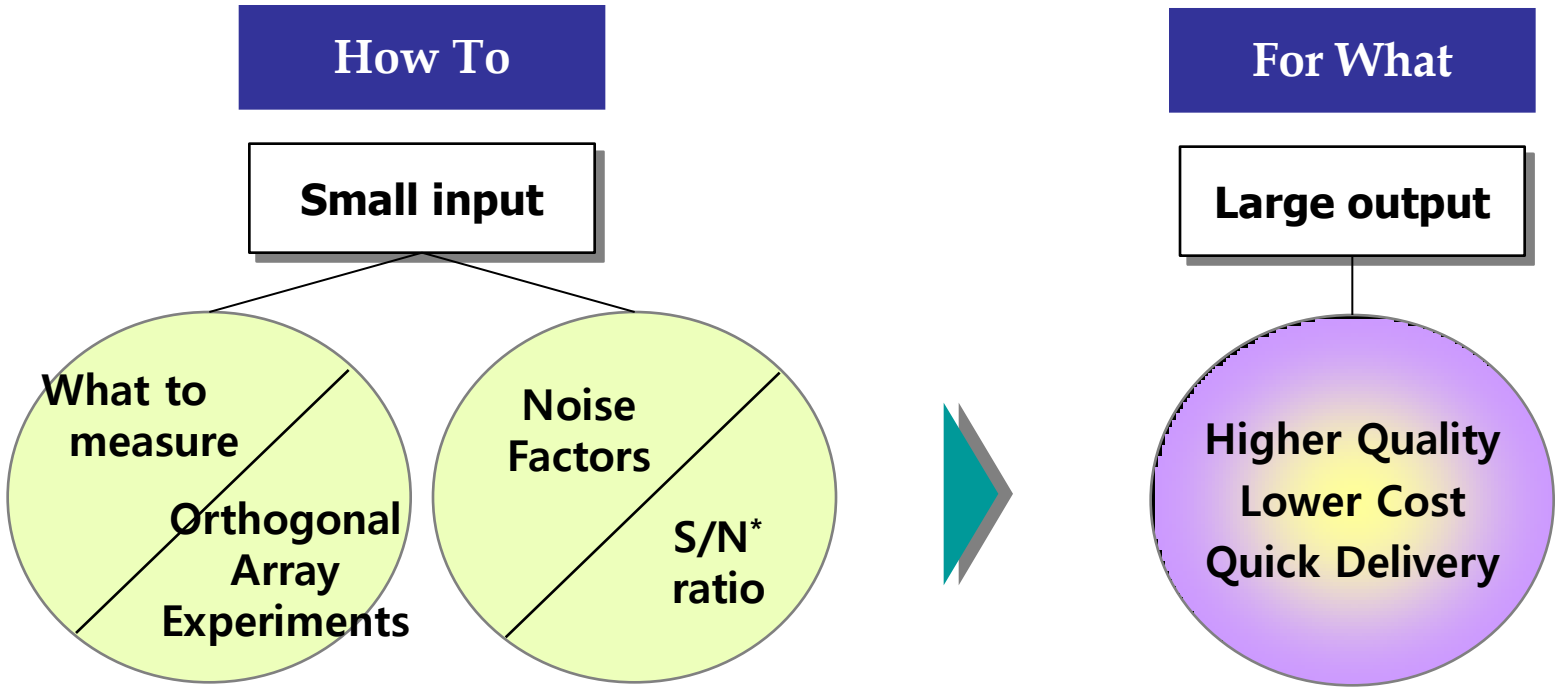
Robust Design





Taguchi Method

Taguchi method = Robust design method = Quality Engineering



*S/N = Signal to Noise

Project background

Project : Optimization for ACF(Auto Cash Feeder)

- More accuracy for Money Feeding at ATM
  : miss-feeding
  : multi-feeding

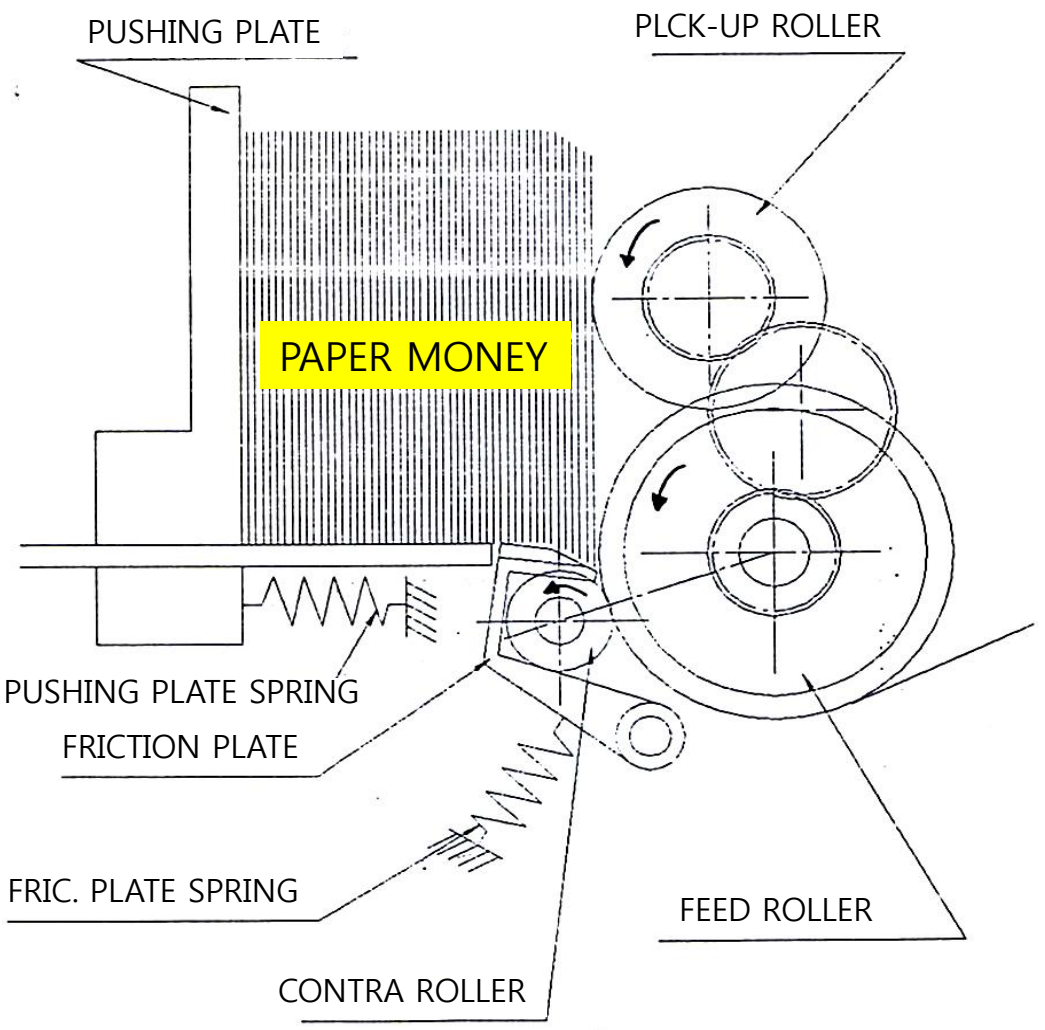
- Under Paper Money condition (old , new , combination of these)
  & various inputs for 50 , 100 , 700k wons

- If malfunctions of ACF under using ATM , customer satisfaction?

ACF Structure

ACF(Auto Cash Feeder) Function

- Separating of paper
- Feeding of paper



Factors related to ACF Function

1) Control Factors : The contacting area to paper

- The gap between Feed Roller and Contra Roller
- The hardness of Feed Roller
- The hardness of Contra Roller
- The pressure to Plate
- The strength of Fric. Plate Spring
- The hardness of Pick-up Roller

} Engineer's Area

2) Noise Factors : The condition of Paper

- New paper money
- Old paper money

} Environment's Area

3) Signal Factors : User's input to ATM

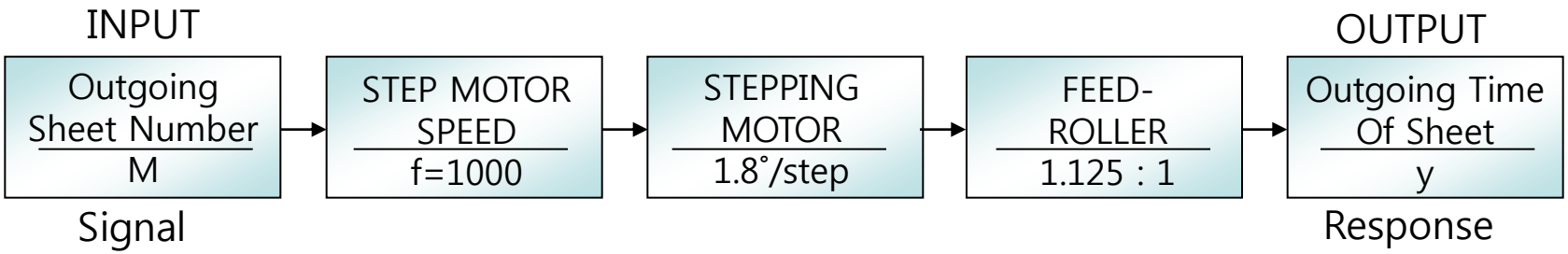
- 5 , 10 , 30 , 50 papers

} User's Area

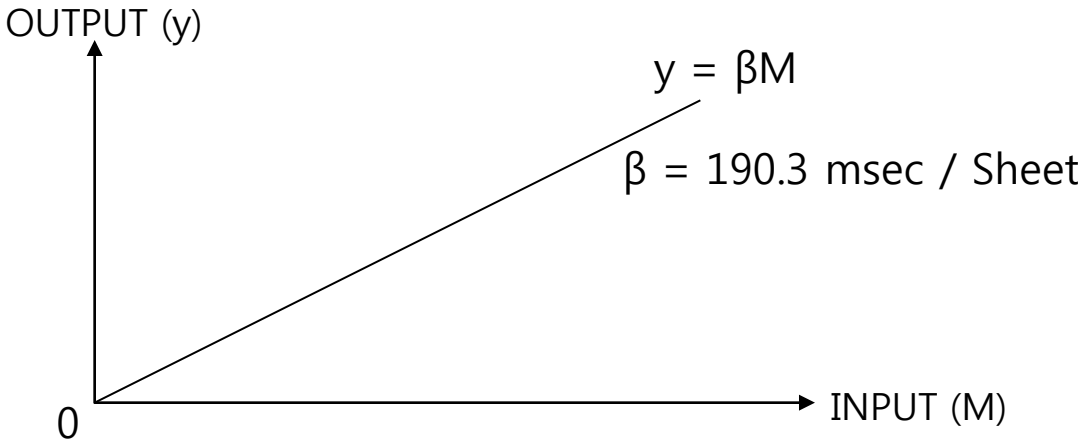
What to measure

- **What to measure : outgoing time of sheet**

1) Block diagram of ACF



2) Linearity of Input & Output



Factors & Levels

Type	Factor name	Level 1	Level 2	Level 3	Level4
Control	A. Gap btwn Feed-R & Contra-R	-1 step	STD	+1 step	-
	B. Hardness of Feed-R	20˚	STD	30˚	-
	C. Hardness of Contra-R	60˚	STD	80˚	-
	D. Pressure of Plate (Dia. of Spring)	Φ 4.5	STD	Φ 5.5	-
	E. Strength of Friction Plate Spring (Dia. of S)	Φ 0.4	STD	Φ 0.5	-
	F. Hardness of Pick-up R	30˚	STD	45˚	-
Uncontrol	N. Paper Money condition	New Paper	Old Paper	-	-
Signal	M. Paper Sheet Q'ty	5	10	30	50

Matrix Experiments using Orthogonal Array

- $L_{18}2^1*3^7$ *If using full factorial design, experiments will be 3^6=729.*

									$M_1(5)$		$M_2(10)$		$M_3(30)$		$M_4(50)$	
NO	err	err	A	B	C	D	E	F	N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2
1	1	1	1	1	1	1	1	1								
2	1	1	2	2	2	2	2	2								
3	1	1	3	3	3	3	3	3								
4	1	2	1	1	2	2	3	3								
5	1	2	2	2	3	3	1	1								
6	1	2	3	3	1	1	2	2								
7	1	3	1	2	1	3	2	3								
8	1	3	2	3	2	1	3	1								
9	1	3	3	1	3	2	1	2								
10	2	1	1	3	3	2	2	1								
11	2	1	2	1	1	3	3	2								
12	2	1	3	2	2	1	1	3								
13	2	2	1	2	3	1	3	2								
14	2	2	2	3	1	2	1	3								
15	2	2	3	1	2	3	2	1								
16	2	3	1	3	2	3	1	2								
17	2	3	2	1	3	1	2	3								
18	2	3	3	2	1	2	3	1								

Data & SN ratio for each experiments

NO	M_1(5sheets)								M_2(10sheets)					M_3(30sheets)					M_4(50sheets)			S/N	SLOPE
	NEW				OLD				NEW		OLD			NEW			OLD		NEW		OLD		
	1	2	3	4	1	2	3	4	1	...	1	...	4	1	2	3	1	...	1	...	...		
1	925	795	951	951	961	933	951	956	1907		1804		1908	4900	4863	4936	6750		9520			-9.53	195.29
2	754	767	785	927	1063	990	874	954	1364		2208		1919	5070	5046	4998	5829		7764			-8.60	186.29
3	943	945	776	950	939	952	932	948	1703		1701		1897	5517	5722	5715	5722		8586			-5.94	180.91
4	778	749	752	833	939	760	929	761	1321		1916		1910	5345	4980	5143	6097		7823			-9.76	181.66
5	909	672	911	896	903	905	907	913	1617		1898		1904	4373	4679	4490	5705		8304			-11.73	168.23
6	948	945	958	954	954	954	956	951	1903		1906		1894	5714	5714	5708	5713		9521			32.11	190.37
7	951	898	570	562	956	942	952	965	1559		3074		1888	5131	4962	4778	5711		4792			-13.81	173.35
:																						:	:
14	944	801	947	958	947	956	955	953	1899		1901		1900	5712	5693	5886	5695		9518			3.12	193.04
15	952	935	947	774	936	950	942	956	1907		1910		1911	5369	5701	5521	5702		9505			-11.91	181.50
16	767	611	334	945	756	955	786	941	1324		1997		2108	3849	3353	3613	5984		5491			-15.24	156.95
17	947	929	633	932	945	948	946	944	1923		1887		1907	5711	5705	5710	5710		8745			-10.98	177.68
18	949	955	953	938	957	943	946	959	1762		1908		1936	5664	5571	5711	5703		9522			9.30	189.85

$$S/N = 10LOG(\frac{\beta^2}{V_{err}}) \quad dB$$

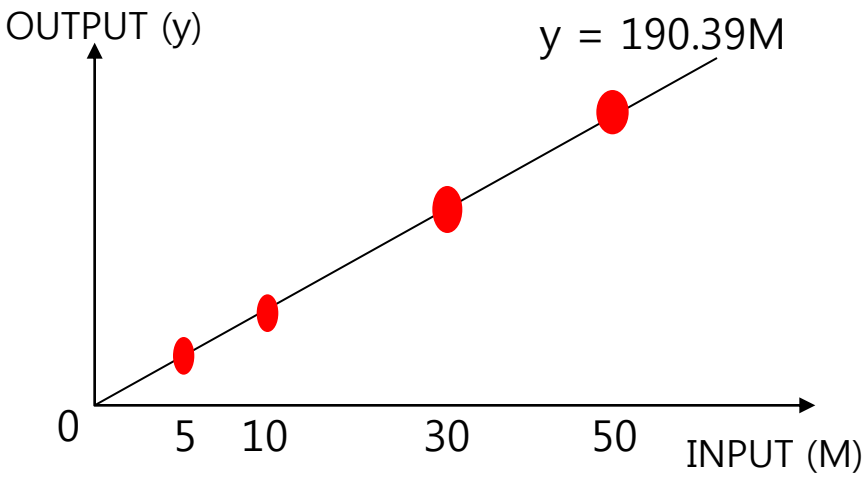
$$\beta(Slope) = \sqrt{\frac{SS_\beta}{r_o * r}} \qquad SS_\beta = \frac{(L_1 + L_2)^2}{r_0 * r} \qquad r_o = 8$$

$$r = 5^2 + 10^2 + 30^2 + 50^2$$

$$V_{err} = \frac{SS_{err}}{n-1} \qquad SS_{err} = SS_{total} - SS_\beta$$

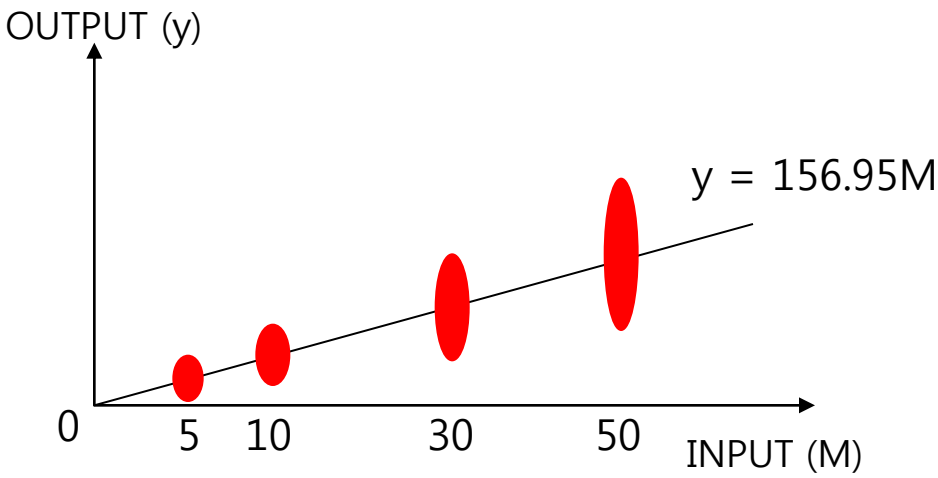
Understanding of SN ratio & Slope

Exp #6



S/N=32.11 Slope=190.39

Exp #16



S/N=-15.24 Slope=156.95

More robust under noise on overall signal

Data Analysis

For Variation control factors *For Adjustment factors*

-Analysis of S/N-

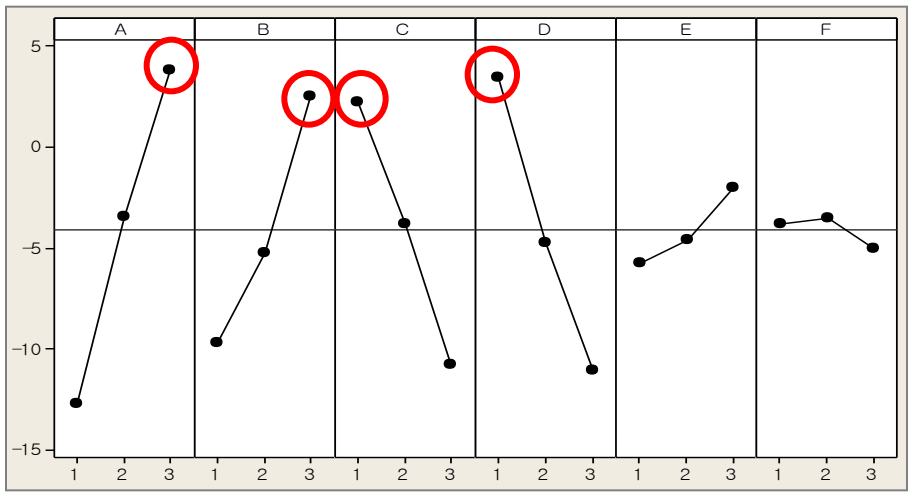
Avg Each Level

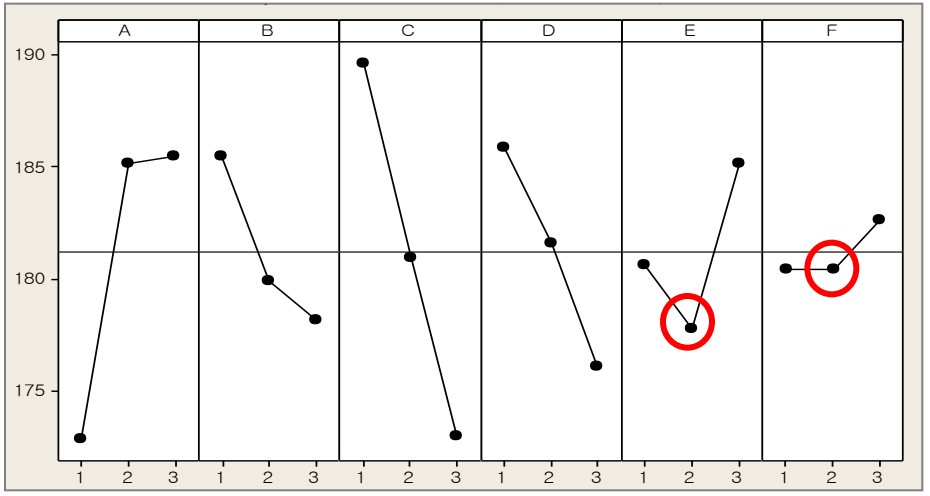
Level	A	B	C	D	E	F
1	-12.7	-9.64	2.25	3.438	-5.7	-3.8
2	-3.41	-5.2	-3.83	-4.71	-4.58	-3.49
3	3.786	2.521	-10.7	-11.1	-2.04	-5.04
Delta	16.48	12.16	13	14.49	3.667	1.55
Delta %	26.9%	19.8%	21.2%	23.6%	6.0%	2.5%

-Analysis of Slope-

Level	A	B	C	D	E	F
1	172.9	185.5	189.6	185.9	180.6	180.4
2	185.2	179.9	181	181.6	177.8	180.5
3	185.5	178.2	173	176.1	185.1	182.7
Delta	12.5	7.3	16.6	9.8	7.3	2.2
Delta %	22.4%	13.1%	29.8%	17.6%	13.1%	3.9%

Main Effects plot





Optimum : A_3 B_3 C_1 D_1 for maximizing S/N or minimizing variation.
E_2 F_2 for adjusting Slope target (target = 190.5 msec)

Gain & Verification for optimum condition

- Estimate & conduct the verification for the optimum condition

1) Optimum condition

$A_3\ B_3\ C_1\ D_1\ E_2\ F_2$ (target = 190.5 msec)

2) Gain & Verification results

	CONDITION	Predicted		Confirmed	
		S/N	Slope	S/N	Slope
OPTIMUM	$A_3\ B_3\ C_1\ D_1\ E_2\ F_2$	24.46	191.47	29.55	190.85
CURRENT	$A_2\ B_2\ C_2\ D_2\ E_2\ F_2$	-4.68	179.98	-7.72	185.33
Gain		29.14		37.25	

Conclusion

1) By engineer

- effective & efficient method in R&D job.
- Output of higher reliability for ATM.
- using with other methods for fixing R&D process.

2) By consultant

- What to measure
  : should avoid the percentage of products for Quality Characteristics.
  : suggest to use Static characteristics than Dynamic one.

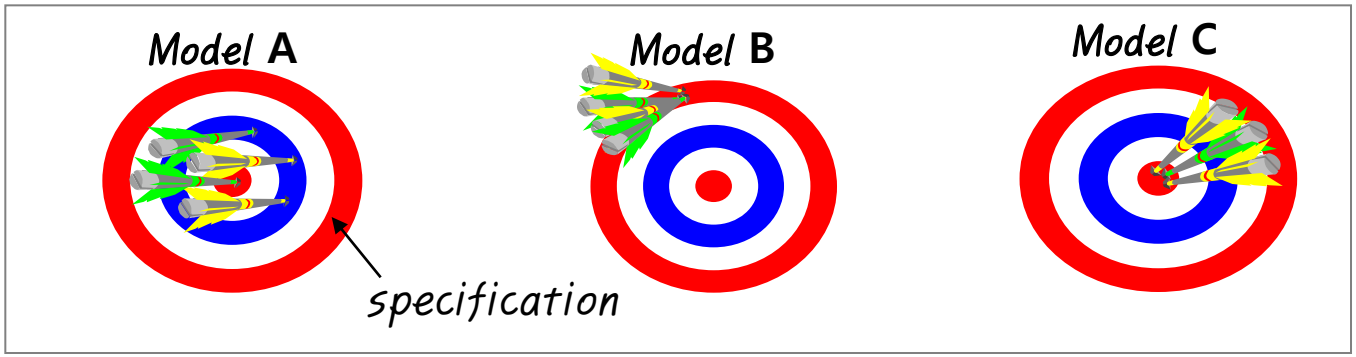
- Control Factors
  : The various parameters (4~10factors) for Experiments.
  : Not full factorial design, but orthogonal array - L8 , L9.

- TRIZ & Taguchi method
  : TRIZ for idea generation & Taguchi method for parameter optimization.

Conclusion

3) For more understanding of percentage characteristics.

If using the percentage of products ,
Best model will be Model A & C due to no defectives.
However in view of Taguchi method,
The priority will be Model C > B > A.



4) For more understanding of orthogonal array for optimum condition

After experiments, the optimum condition will be selected by data analysis.
However I'd like to suggest to select two types of the optimum conditions- one is the optimum by data analysis, and the other is the best overall condition within the orthogonal array experiments.
Because that is to minimize the error of the selection of the optimum by the interaction effects.

Han Quality Management Research Lab.
CEO Yong-Gyun Shin (QC professional eng'r)
Call 02-6203-7959
C.P 011-736-6260
www.HANQM.co.kr
syg6260@hanmail.net