Improvement of medical wire manufacturing

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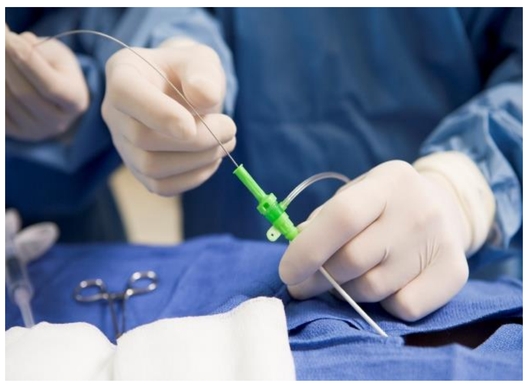
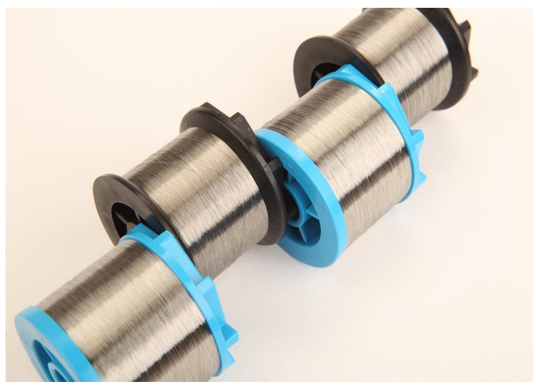




Medical wire is a very inconspicuous device but plays a big role during the surgery. The strength of the Medical wire is critical.

Problem:

- Design an experiment with four main factors to test the effects of factors or interactions to the Yield Strength of the medical wire.

Variables	Meaning
Spool ID	Identify spools used in the experiment. 1~48
Block	Doctors who handle the machines. 1=Doctor 1, 2=Doctor 2, 3=Doctor3.
Machine	Drawing Machine. X1=0:Type 1, X1=1:Type 2.
Angle	Die Reduction Angle. X2=0: 8.5-10.1, X2=1: 11.1-12.1.
Length	Die Bearing Length. X3=0: Short 16%-26% X3=1: 28%-36%.
Diameter	Supply Diameter. X4=0: Short 0.0049in, X4=1: Long 0.0051in.
YS/UTS	Yield Strength/Ultimate Tensile Strength (%) in Medical Wire.

- Find the combination that will yield the best quality of medical wire.

Implications:

- This experiment will help manufacturers to select a more suitable method to improve efficiency and quality on their operation.

Fractional factorial design

- **Design of experiment:**

  2^{4-1} fractional factorial with 4 factors, 3 blocks and 5 replications.

  We used 24 different spools at this level of experiment.

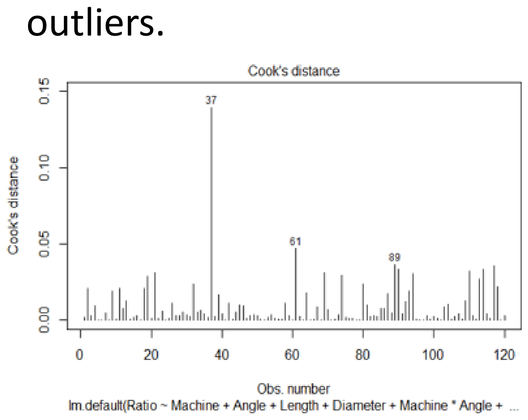
Spool ID	Block	Machine	Angle	Length	Diameter	Order	YS/UTS
2	1	0	0	0	0	1	93.3
26	1	1	0	0	1	2	92.5
9	1	0	1	0	1	3	92.9
35	1	1	1	0	0	4	93.5
11	1	0	0	1	1	5	93.2
36	1	1	0	1	0	6	92.4
5	1	0	1	1	0	7	93.7
29	1	1	1	1	1	8	92.9

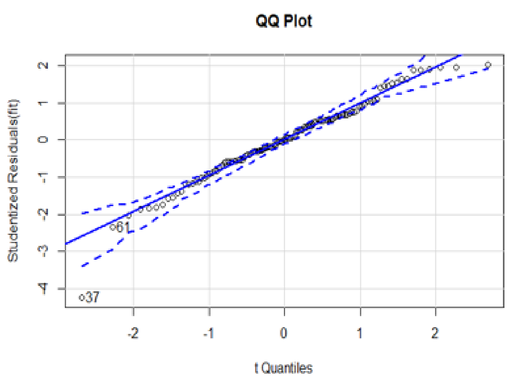
- **Outliers:**

  Conducted a regression analysis using the design table directly.

  R-Square adj=28%

  So it is necessary to explore the data and try to exclude outliers.





  From figures above, we replaced the outliers by the average value in their spool then:

  R-square adj=44%

- **Improvement:**

New response variable
Avg(YS/UTS)
1/Avg(YS/UTS)
Log(YS/UTS)

Summary of Fit	
RSquare	0.718619
RSquare Adj	0.568549
Root Mean Square Error	0.383572
Mean of Response	93.21167
Observations (or Sum Wgts)	24

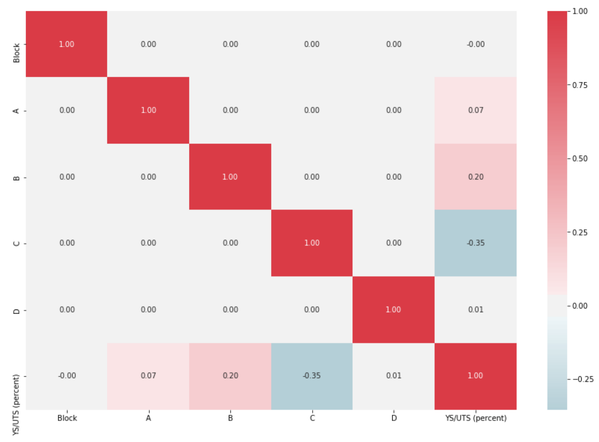
Significant Factors:

X2(Angle); X3(Length); X1(Machine)&X2(Angle); X1(Machine)&X3(Length)With DV: Avg(YS/UTS)

R-square adj=56%

- **Correlation coefficient**

  After exploring the model's correlation, we decide to use X1, X2 and X3 to design a full factorial experiment in the next step.



Full factorial design

- **Design of experiment:**

  2^3 Full FD with 3 factors and 3 replications. We used new set of spools at this level to avoid bias.

Spool ID	Machine	Angle	Length	Diameter	Mean
20	0	0	0	3	93.43
47	0	0	1	7	93.34
46	0	1	0	20	93.36
23	0	1	1	6	93.3
13	1	0	0	12	93.42
18	1	0	1	15	92.23
14	1	1	0	19	94.26
41	1	1	1	4	94.04

Significant Factors:

B(Angle); A(Machine)&B(Angle); B(Angle)& C(Length)

R-square adj=87%

Summary of Fit	
RSquare	0.90701
RSquare Adj	0.866327
Root Mean Square Error	0.237136
Mean of Response	93.39792
Observations (or Sum Wgts)	24

Scaled Estimates

Continuous factors centered by mean, scaled by range/2

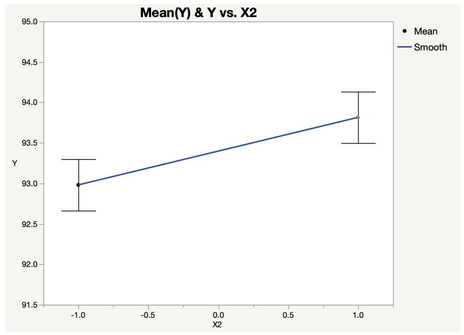
Term	Scaled Estimate	Std Error	t Ratio	Prob>|t|
Intercept	93.397917	0.055288	1689.31	<.0001*
X1	0.0979167	0.055288	1.77	0.0956
X2	0.4170833	0.055288	7.54	<.0001*
X3	-0.115417	0.055288	-2.09	0.0532
X1*X2	0.3454167	0.055288	6.25	<.0001*
X1*X3	-0.077083	0.055288	-1.39	0.1823
X2*X3	0.15875	0.055288	2.87	0.0111*
Block	-0.101875	0.067713	-1.50	0.1519

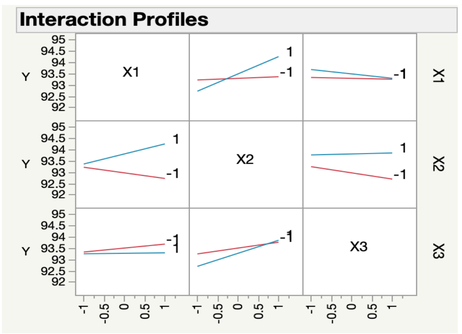
- **Regression equation**

$$Y = 0.41 * B + 0.35 * AB + 0.16 * BC + 93.4$$

- **Effect graph:**

  From the main effect and interaction plots we can make a conclusion that optimization of the process may be a consequence of the combination of multifactor.





Conclusion

- We find the manufacturing of medical wires is a multi-factor interactive process. Experiments of changing one factor at a time may not maximize the Yield Strength

- For a medical wire manufacturer, we recommend using a **short bearing length** and **wide reduction angle** with **type 2 machine** (even machine is not a significant factor).