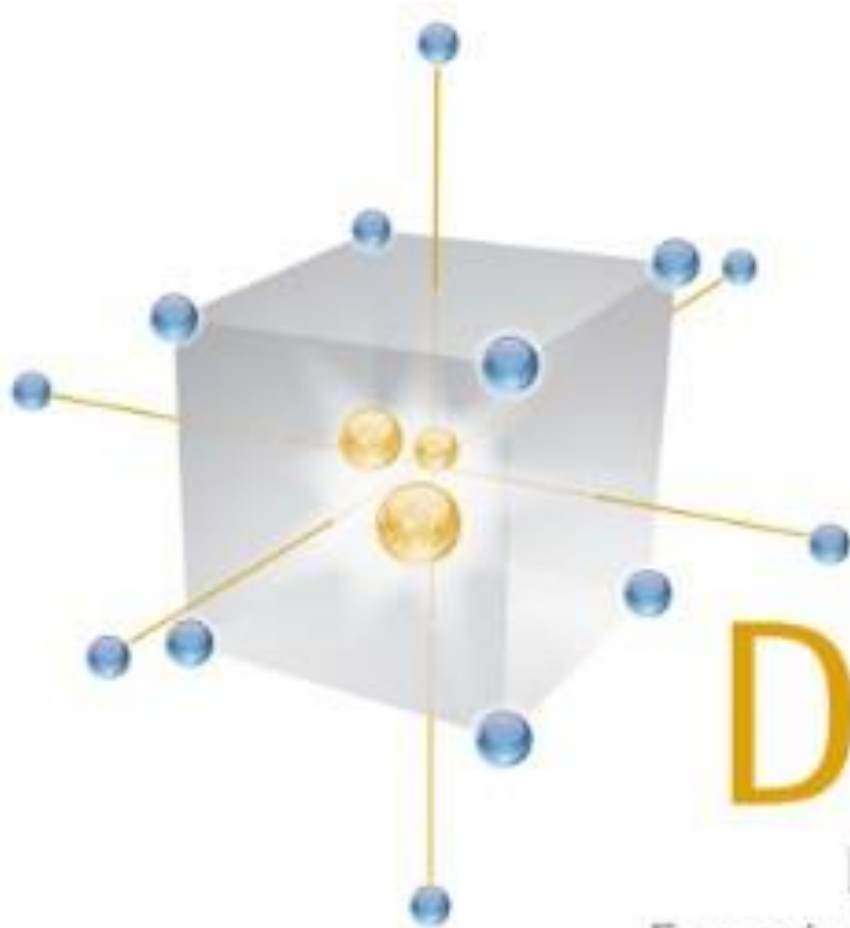


A BRIEF INTRODUCTION TO DESIGN OF EXPERIMENTS

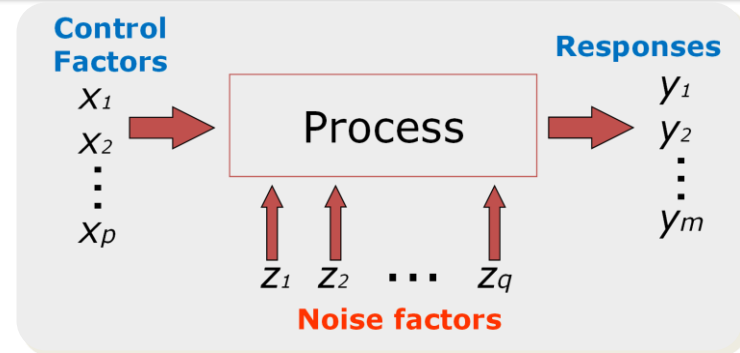


DoE
Design of
Experiments



Why should we use DOE?

DOE is a statistical tool that allow us:



- Identify vital “Xs” for a particular process;
- Quantify causal relationships between “Xs” and “Ys”;
- Build an empirical model, $Y=f(x)$, to represent a physical process;
- Optimize the process in order to obtain Y on target, or minimum, or maximum, depending on the optimization objective.



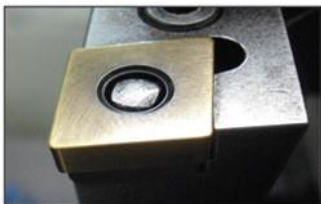
APLICAÇÕES

Torneamento do aço endurecido ABNT 52100

INPUTS



AISI 52100 hardened steel bars



Wiper-mixed ceramic inserts



Control factors

Cutting speed
 x_1
(m/min)

Feed rate
 x_2
(mm/rev)

Depth of cut
 x_3
(mm)

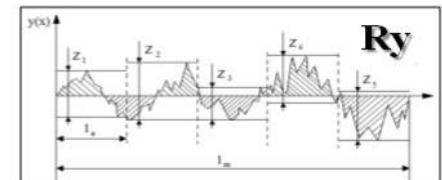
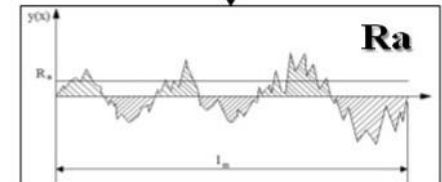
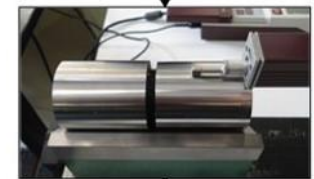


Hardness
 \tilde{x}_1
(HRC)

Noise factor



OUTPUTS



APLICAÇÕES



Fresamento de topo do
aço ABNT 1045

Velocidade de corte v_c
Avanço por dente f_z
Penetração de trabalho a_e
Profundidade de usinagem a_p



Rugosidades
 R_a e R_t



Ruído
Concentração de fluido (C)
Vazão de fluido (Q)
Desgaste da fresa (v_b)



(1) ferramenta; (2) corpo de prova;
(3) dispositivo de fixação do corpo
de prova; (4) mesa fresadora.

Variáveis de controle

Velocidade de alimentação do arame (V_a)

Tensão (T)

Velocidade de soldagem (V_s)

Distância bico de contato peça (N)

PROCESSO

Soldagem de revestimento do aço ABNT 1020 com o aço inoxidável ABNT 316L



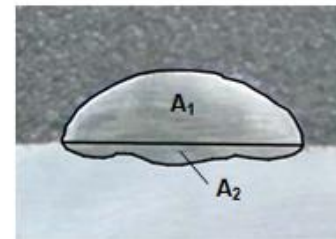
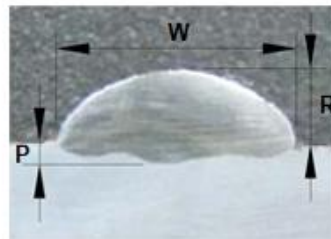
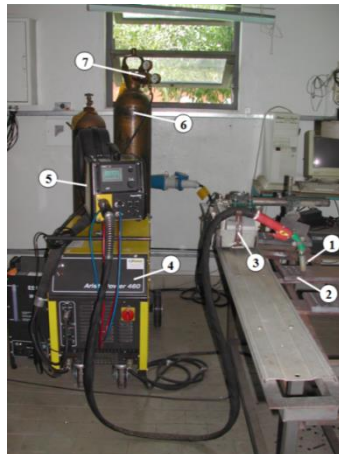
Respostas

Largura do cordão (W)

Penetração (P)

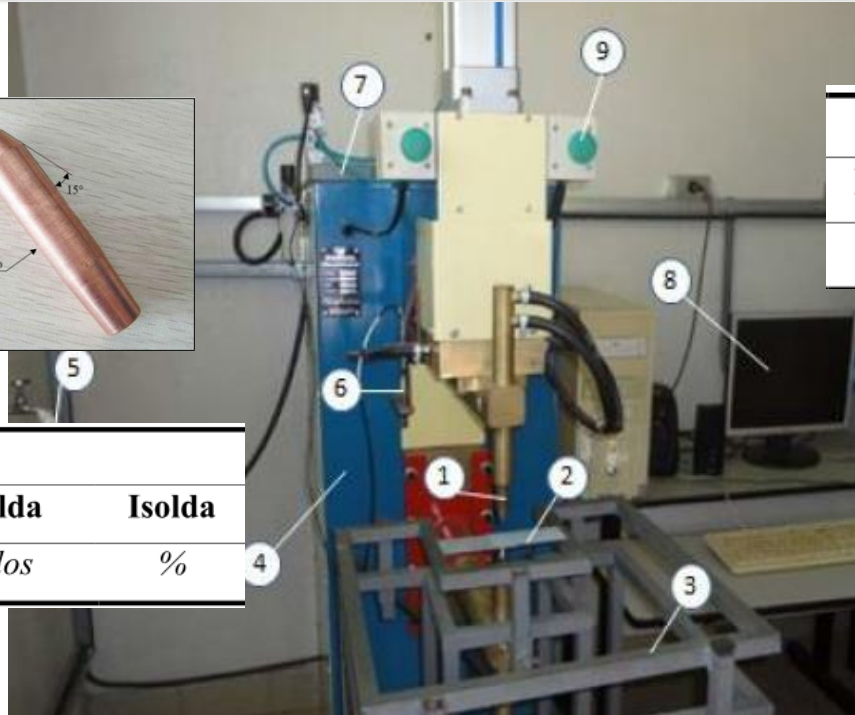
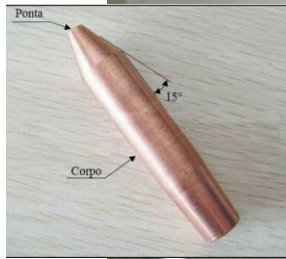
Reforço (R)

Diluição (D)



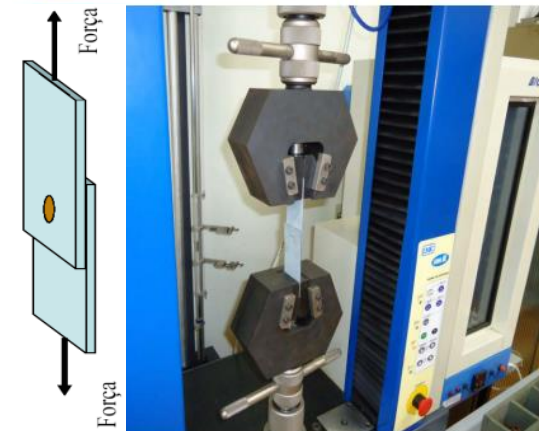
• Aplicações

- Indústrias petrolíferas, químicas, alimentícias, agrícolas, nucleares, navais, ferroviária, construção civil



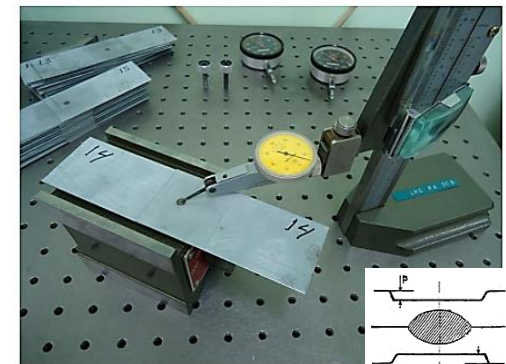
Respostas			
RC	DFmáx.	IS	IM
<i>N</i>	<i>mm</i>	<i>mm</i>	<i>mm</i>

Parâmetros			
Tpreaq	Ipreaq	Tsolda	Isolda
<i>ciclos</i>	<i>%</i>	<i>ciclos</i>	<i>%</i>



Soldagem a ponto por resistência elétrica de chapas de aço AISI 1006 galvanizado

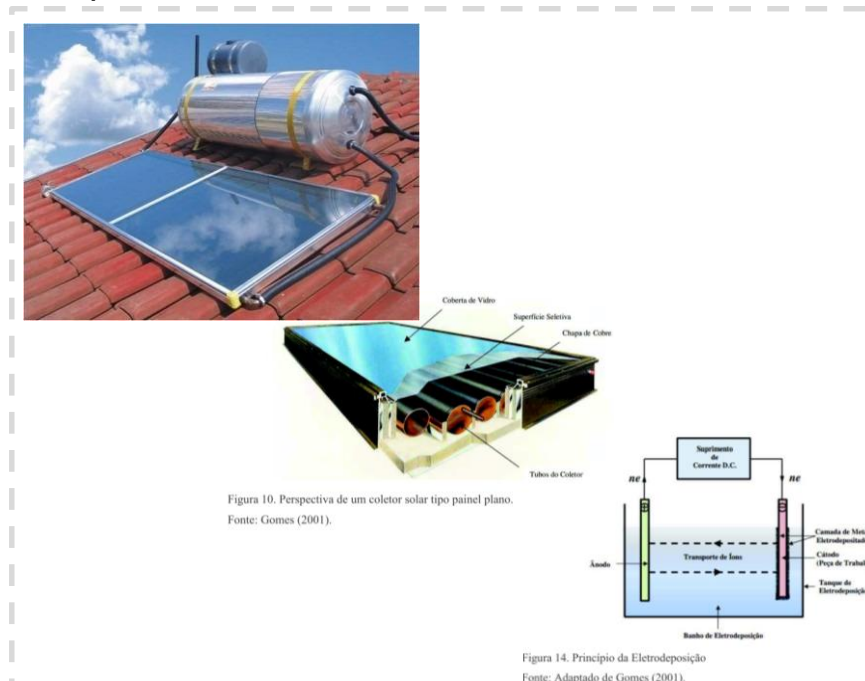
1. Eletrodo; 2. Corpo de prova; 3. Dispositivo para fixar o corpo de prova; 4. Estacionária Presol TWPRV50 6kA; 5. Água de refrigeração; 6. Sensor LVDT Metrolog; 7. Condicionador digital Metrolog SD 20; 8. Interface; 9. Botão de acionamento pneumático



Sistemas solares térmicos usam placas coletoras (ou tubos) para captar o calor do sol e transferir o calor para um líquido. A capacidade de absorção da luz solar nestas placas é um requisito essencial.

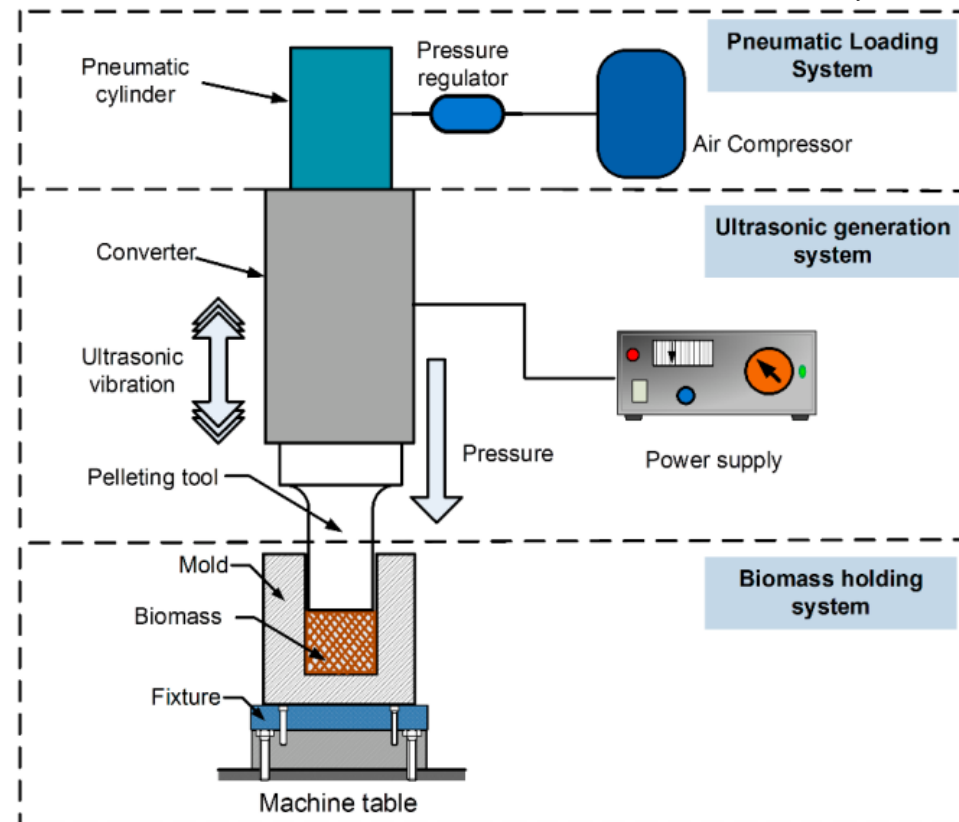
Experimento: eletrodeposição de superfície de cromo negro revestido com camada antirreflexo (AR) à base de resíduo de bagaço de cana-de-açúcar usando cobre como substrato (Medeiros, 2016).

x1-voltagem ->
x2-distância ->
x3-tempo ->
x4-camada antirreflexo ->



-> y1-nível de absorção
-> y2-rugosidade da superfície

Matéria prima, tal como biomassa celulósica, tem sido usada como fonte renovável de combustível para produzir energia. Neste processo, os custos de manuseio, transporte e armazenagem devem sempre ser levados em consideração. Comprimir a biomassa em pellets, aumenta significativamente a densidade e durabilidade da biomassa, reduzindo estes custos (Zhang et al., 2018).

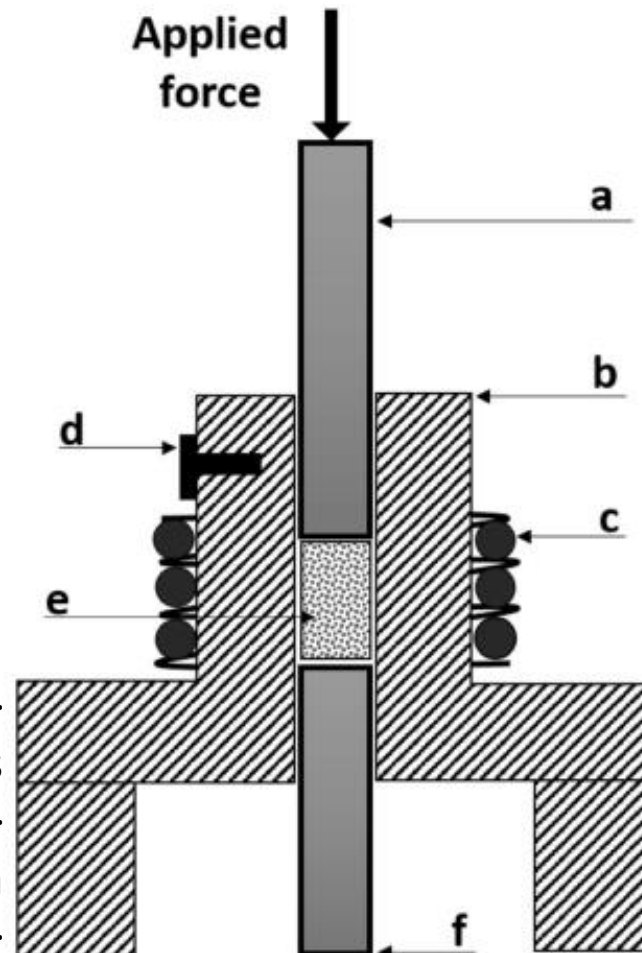


x1-Pelleting time (s) ->
x2-Pressure (psi) ->
x3-Ultrasonic power(%)->

-> y1-Density(kg/m³)
(max)
-> y2-Durability (%)
(max)

Figure 1. The illustration of the experimental set-up for ultrasonic vibration-assisted (UV-A) pelleting.

Biomassa é considerada uma fonte renovável de energia para substituir combustíveis fósseis. Pellets de biomassa são produzidos por compressão de resíduos florestais que são queimados para gerar calor. Neste estudo foram usados resíduos de árvores de pistache. Variáveis de processo podem afetar significativamente a qualidade final da produção de calor destes pellets (Ramezanzade & Moghaddam, 2018).



x1-Mistura (%) ->
x2-Tamanho das
partículas(mm)->
x3-Temperatura
(°C) ->

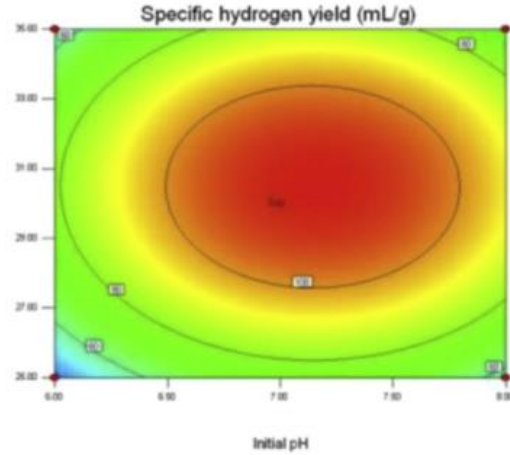
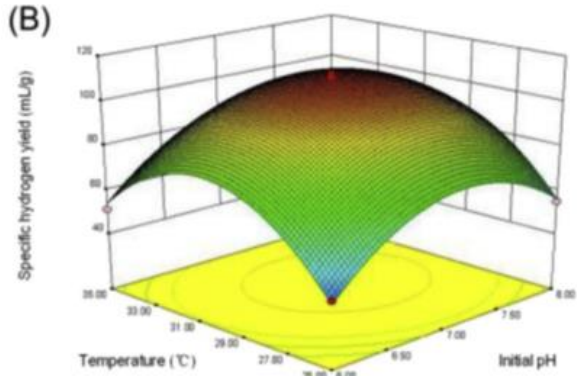
-> y1(max)-Fator de Compressão (N/mm)
-> y2(max)-Density (kg/m³)
-> y3(max)-Durability (%)
-> y4(min)-Fator de Fricção (N/mm)

Fig. 1 Schematic diagram of the pelletizer, **a** piston, **b** cylindrical die, **c** heating element, **d** thermocouple, **e** raw materials, **f** stopper bottom of the mold

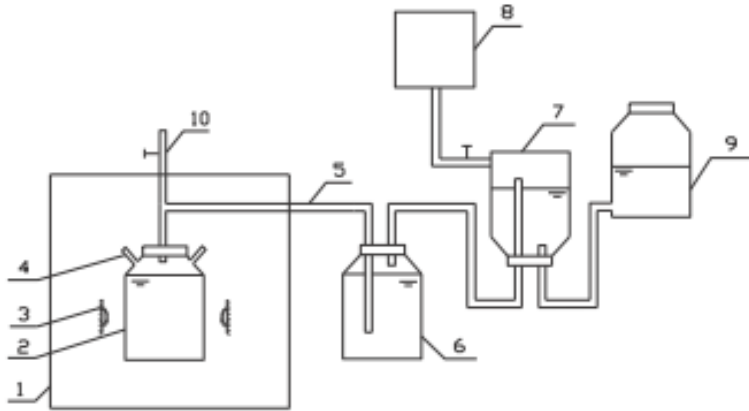
APLICAÇÕES



Resíduo de maçã é uma estratégia promissora para obter bio-hidrogênio (biomassa) como energia renovável. O hidrogênio pode ser obtido por esta biomassa através de processos biológicos ou termoquímicos, sendo o primeiro menos nocivo ao ambiente (Lu et al., 2016).



- x1-pH inicial (-) ->
- x2-Intensidade de luz(lx)->
- x3-Temperatura (°C) ->
- x4-Razão material-líquido (%) ->



-> y1(max)-Specific hydrogen yield-SHY (ml/g TS)

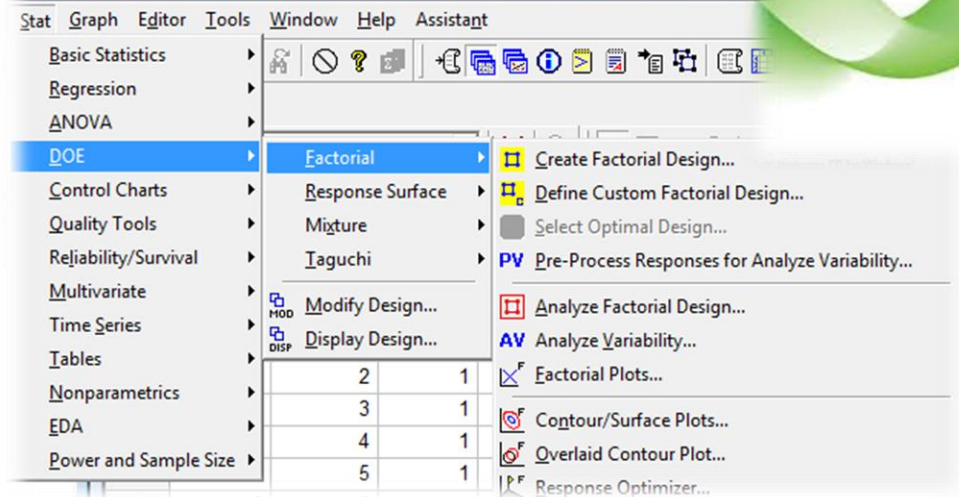
- 1. Incubator 2. Hydrogen production reactor 3. Incandescent lamp 4. Testing port 5. Airway 6. Gas purifier
- 7. Gas collecting bottle 8. Gas chromatograph 9. Water block 10. Argon gas valve

Fig. 1 – The experimental device of photosynthetic hydrogen production with apple waste.

Let's cook popcorn...



Minitab® 16



Reducing waste

- Make sure that the amount of popcorn kernels is minimized

Ensuring high level of quality

- Based on the cooking process, define which conditions provide the best taste



Variables

- (\downarrow) Y_1 Amount of popcorn kernels
- (\uparrow) Y_2 Taste

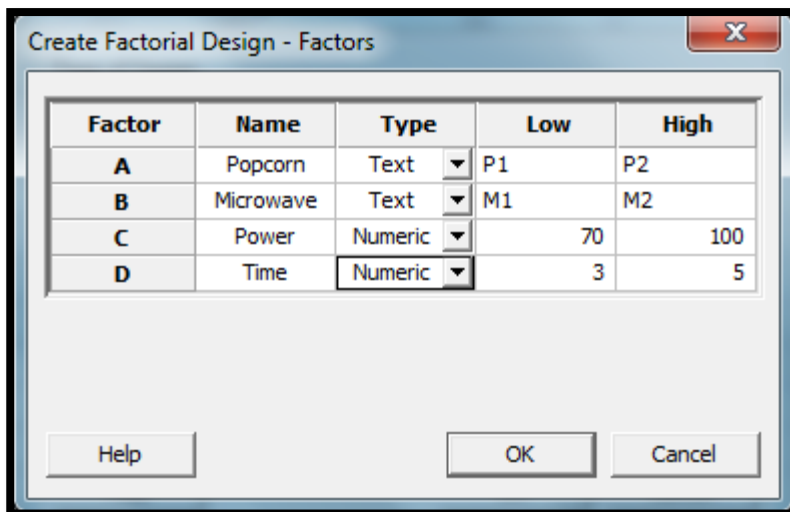
- X_1 Popcorn brand (P1 e P2)
- X_2 Microwave brand (M1 e M2)
- X_3 Microwave power (70 e 100)
- X_4 Cooking time (3 e 5)



Selecting the experimental design:

<Stat> <DOE> <Factorial> <Create Factorial Design>

Factors



Factor	Name	Type	Low	High
A	Popcorn	Text	P1	P2
B	Microwave	Text	M1	M2
C	Power	Numeric	70	100
D	Time	Numeric	3	5

Responses

StdOrder	Taste	Kernels	StdOrder	Taste	Kernels
1	9	61	17	9	61
2	6	61	18	5	60
3	7	63	19	9	65
4	6	65	20	4	63
5	9	60	21	9	60
6	5	61	22	3	59
7	9	56	23	8	55
8	3	55	24	5	57
9	0	45	25	0	45
10	6	46	26	7	47
11	0	49	27	0	49
12	7	51	28	5	49
13	1	33	29	2	34
14	5	34	30	5	34
15	1	29	31	2	30
16	4	29	32	4	29

Flight optimization of paper helicopters



Box, G. E. P. (1992). Teaching engineers experimental design with a paper helicopter. **Quality Engineering**, 4(3): 453–459.

Teaching Engineers Experimental Design With A Paper Helicopter

George Box

How a paper "helicopter" made in a minute or so from a 8 1/2" × 11" sheet of paper can be used to teach principles of experimental design including— conditions for validity of experimentation, randomization, blocking, the use of factorial and fractional factorial designs, and the management of experimentation.

When Søren Bisgaard, Conrad Fung and I teach engineers about designed experiments, we find it very valuable to use a paper helicopter for illustration. We were introduced to this idea some years ago by Kip Rogers of Digital Equipment. Using the generic design shown in Figure 1 a "helicopter" can be made from an 8 1/2 × 11 sheet of paper in a minute or so.

Dick times its fall with a stopwatch. We explain to the class that we would like to find an improved helicopter design which has a longer flight time. The helicopter can then be used to illustrate a number of important ideas.

VARIATION

1. Recognition of and statement of the problem;
2. Selection of the response variables;
3. Choice of factors, levels, and ranges;
4. Choice of experimental design;
5. Performing the experiment;
6. Statistical analysis of the data;
7. Conclusions and recommendations.