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A COMPARATIVE STUDY ON OPTIMIZATION OF MACHINING PARAMETERS BY TURNING NICKEL BASED SUPER ALLOYS ACCORDING TO TAGUCHI METHOD

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SAN FRANSİSCO -2015

CONTENT

- Intent
- Literature
- Taguchi Method
- Experimental Study
- Numerical Analysis
- Results and Discussion
- Conclusions
- References

TAGUCHI METHOD

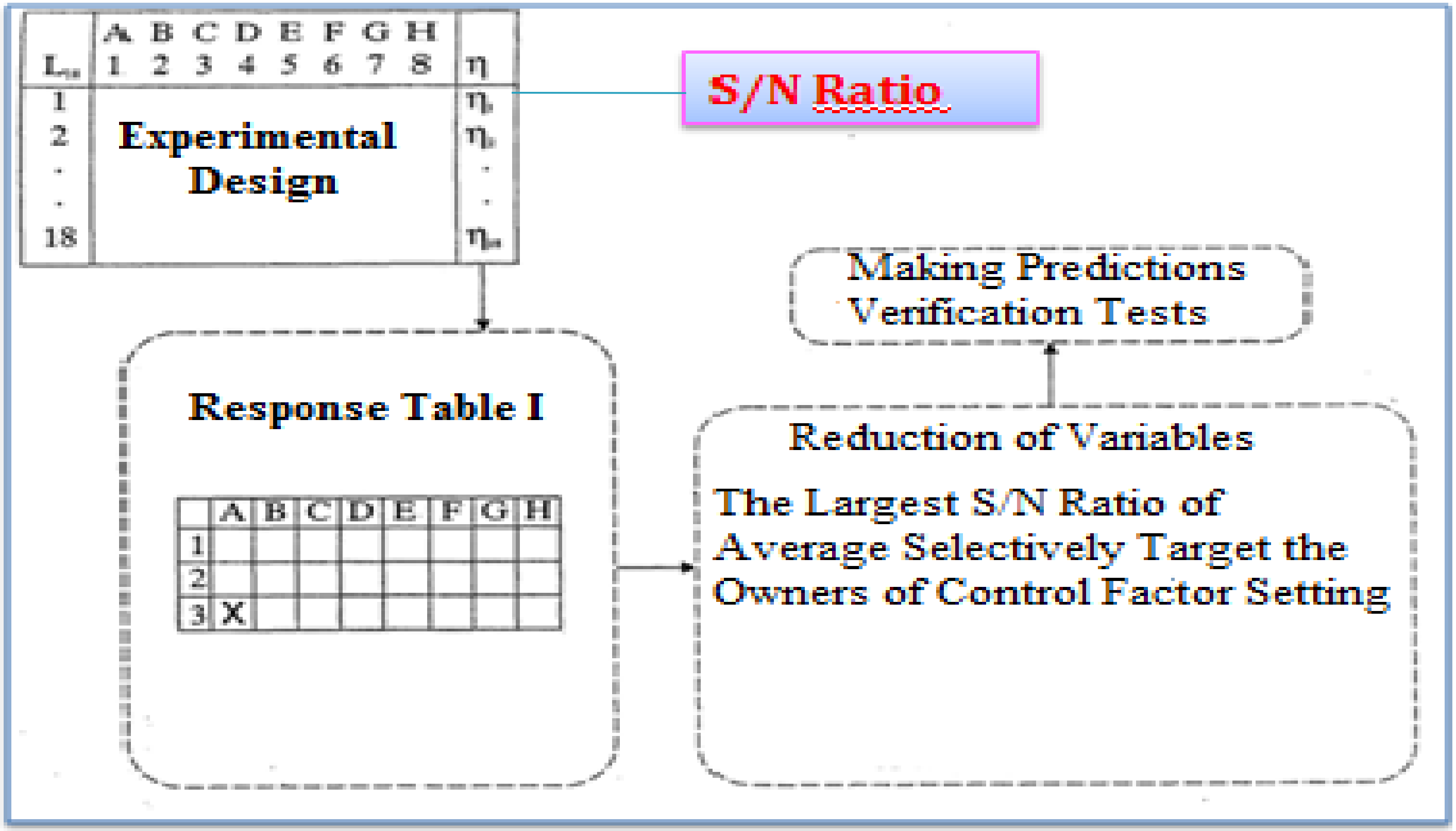
Taguchi, is reached as a result of combining three tools.

- To analyze and evaluate the numerical results
- Orthogonal experimental design
- The S/N (signal / noise) ratio and ANOVA (analysis of variance)

Stages of Taguchi Method

1. Determining Cutting Conditions
2. Selection of The Array Ortognal
3. Turning Tests
4. S/N Ratio
5. Anova Analysis
6. Determination of the most appropriate Cutting Conditions
7. Conclusions

TAGUCHI METHOD-I



TAGUCHI METHOD-II

Taguchi orthogonal experimental design (12)

	Control factors															
Test	A	B	C	D	E	F	G	H	I	J	K	Image factors			η	$\bar{y}$
No.	1	2	3	4	5	6	7	8	9	10	11	N_1	N_2	N_3		
1	1	1	1	1	1	1	1	1	1	1	1	oo	oo	oo	η_1	$\bar{y}_1$
2	1	1	1	1	1	2	2	2	2	2	2	oo	oo	oo		
3	1	1	2	2	2	1	1	1	2	2	2	.				
4	1	2	1	2	2	1	2	2	1	1	2	.				
5	1	2	2	1	2	2	1	2	1	2	1	.				
6	1	2	2	2	1	2	2	1	2	1	1	.				
7	2	1	2	2	1	1	2	2	1	2	1					
8	2	1	2	1	2	2	2	1	1	1	2					
9	2	1	1	2	2	2	1	2	2	1	1					
10	2	2	2	2	1	1	1	2	2	1	2					
11	2	2	1	1	1	2	1	1	1	2	2					
12	2	2	1	1	2	1	2	1	2	2	1	oo	oo	oo		

***S/N ratio** = $\eta = 10 \log \frac{\bar{y}^2}{\sigma^2}$, $\bar{y}$ = **mean** σ^2 = The average variance around

PERFORMANCE CHARACTERISTICS OF TAGUCHI

Taguchi method, the signal/noise (S/N) ratio depends on the performance characteristics of the three basic uses.

$$S/N_{SB} \quad \eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^2\right]$$

Smaller is better

$$S/N_{LB} \quad \eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} \frac{1}{y_i^2}\right]$$

Bigger is better

$$S/N_{NB} \quad \eta = 10\log\left(\frac{\bar{y}}{s^2 y}\right)$$

Nominal is better

An Experimental Study

- Method
- Material
- Orthogonal design
- Cutting conditions
- Cutting force and surface roughness measurement
- Taguchi Analysis

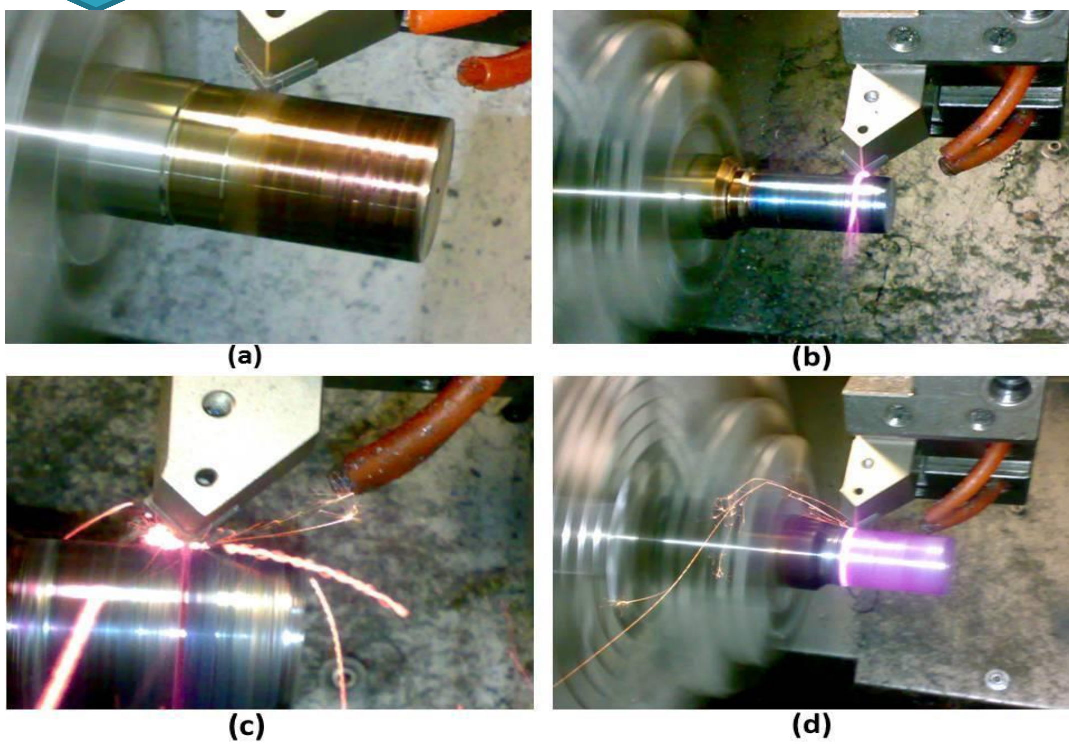
METHOD

- *Control factors*

V : Cutting speed

f: Feedrate

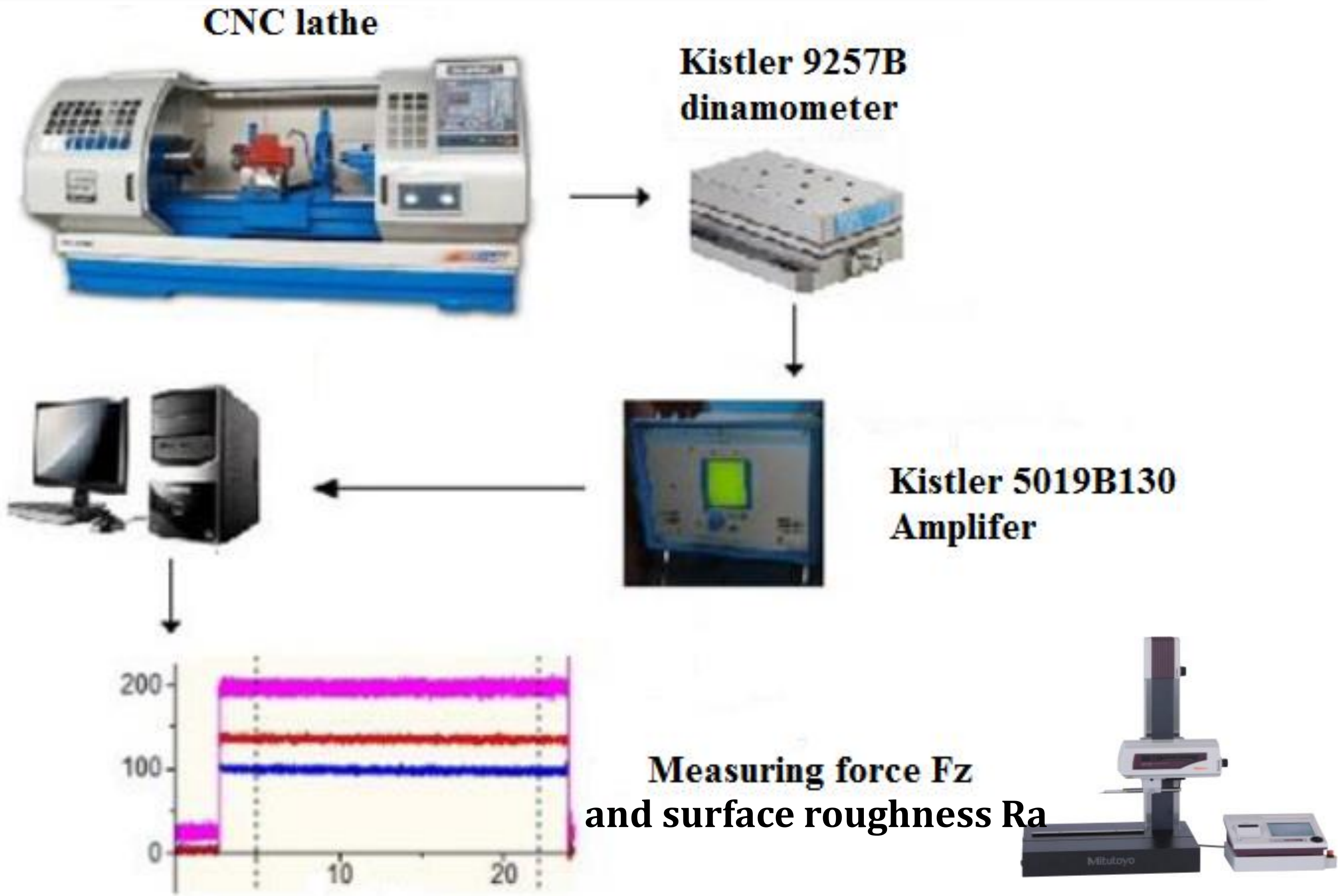
: Cutting tool



Out

(Cutting force-Surface finish)

The experimental setup



MATERIALS

- Inconel 625 is a nickel based super alloy with excellent mechanical properties, corrosion resistance and withstand high temperatures in the aviation industry which need to be used in the manufacture of airframe and engine parts. Non-magnetic and is very resistant to many corrosive environments.

- Hastelloy X is a nickel-chromium-iron-molybdenum alloy developed for high temperature applications. Hastelloy X is a face-centered cubic (FCC), nickel-based and corrosion-resistant superalloy. The Hastelloy is derived from the strengthening particles, Ni2 (Mo, Cr), which is formed after the two-step age-hardening heat treatment process.

Chemical composition

Elements	Inconel 625	Hastelloy X
Carbon (C)		1
Silicon (Si)	0.1	0.08
Chrome (Cr)	22	20.5-23
Nickel (Ni) + Cobalt (Co)	58,08	51
Molybdenum (Mo)	9,1	8-10
Manganese (Mn)	11	0.8
Phosphorus (P)	0.015	
Sulfur (S)		0.01
Iron (Fe)	4.73	17-20
Cooper (Cu)		
Niobyum (Ni) +Tantal (Ta)	5.325	
Aluminium		
Titanium (Ti)	0.33	

CUTTING CONDITIONS

Levels	*Parameters*		
	F (mm/rev) (A)	**V (m/min) (B)**	**Tool (C)**
1	0.1	65	K313
2	0.15	80	KT315
3		100	KC9240

The experimental setup

Orthogonal design $L_{18\ 2x\ (3)^3}$

Exp. Num.	*Feedrate mm/rev (A)*	*Cutting speed mm/min (B)*	*Tools (C)*
1	1	1	*1*
2	1	1	*2*
3	1	1	*3*
4	1	2	*1*
5	1	2	*2*
6	1	2	*3*
7	1	3	*1*
8	1	3	*2*
9	1	3	*3*
10	2	1	*1*
11	2	1	*2*
12	2	1	*3*
13	2	2	*1*
14	2	2	*2*
15	2	2	*3*
16	2	3	*1*
17	2	3	*2*
18	2	3	*3*

Types of cutting tools

Cutting Tools

- Covered tools
  - KT315
  - KC9240
- Uncovered
  - K313

S/N ratio analysis

S/N_{SB}

$$\eta = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^{2}\right]$$

Exp. Num.	Feedrate mm/rev	Cutting speed mm/min	Tools	Hastelloy X				Inconel 625			
				Ra (µm)	Ra (S/N)	Fz (N)	Fz (S/N)	Ra (µm)	Ra (S/N	Fz (N)	Fz (S/N)
1	0.10	65	K313	1.70	-4.6090	691	-56.7896	1.452	-3.2393	695	-56.8397
2	0.10	65	KT315	1.605	-4.1095	622	-55.8758	3.179	-10.0458	560	-54.9638
3	0.10	65	KC9240	1.455	-3.2573	715	-57.0861	0.725	-2.7932	505	-54.0658
4	0.10	80	K313	1.599	-4.0770	655	-56.3248	1.691	-4.5629	705	-56.9638
5	0.10	80	KT315	1.410	-2.9844	601	-55.5775	1.235	-1.8333	550	-54.8073
6	0.10	80	KC9240	1.368	-2.7217	694	-56.8272	0.576	4.7916	508	-54.1173
7	0.10	100	K313	1.717	-4.6954	658	-56.3645	1.001	-0.0087	695	-56.8397
8	0.10	100	KT315	1.667	-4.4387	598	-55.5340	1.027	-0.2314	568	-55.0870
9	0.10	100	KC9240	0.755	-2.4411	538	-54.6156	0.755	-2.4411	483	-53.6789
10	0.15	65	K313	3.649	-11.243	919	-59.2663	0.958	-0.3727	875	-58.8402
11	0,15	65	KT315	2.669	-8.5269	863	-58.7202	.785	-2.102	785	-57.8974
12	0.15	65	KC9240	1.492	-3.4754	966	-59.6995	1.580	-3.9731	691	-56.7896
13	0.15	80	K313	3.462	-10.786	901	-59.0945	1.307	-2.3255	876	-58.8501
14	0.15	80	KT315	1.880	-5.4832	855	-58.6393	1.533	-3.7108	707	-56.9884
15	0.15	80	KC9240	1.405	-2.9535	696	-56.8522	1.476	-3.3817	555	-54.8859
16	0.15	100	K313	3.137	-9.9303	854	-58.6292	0.812	-1.8088	887	-58.9585
17	0.15	100	KT315	3.132	-9.9164	830	-58.3816	0.950	-0.4455	724	-57.1948
18	0.15	100	KC9240	1.085	-0.7086	697	-56.8647	1.380	-2.7976	610	-56.5853

THE AVERAGE ANSWER SHEET (Ra)

Parameters	*Average of levels*					
	Inconel 625			**Hastelloy X**		
	I	**II**	**III**	**I**	**II**	**III**
A Feedrate (F)	**-10.58**	-5.046		-3.703	-7.002	
B Cutting speed (V)	-6.889	**-8.169**	-9.593	-5.870	-4.834	**-5.355**
C Tools	-7.284	-7.941	-8.227	-7.567	-5.909	-2.592

THE AVERAGE ANSWER SHEET (Fx)

Kesme Şartları	*Average of levels*					
	Inconel 625			Hastelloy X		
	I	II	III	I	II	III
A Feedrate (F)	-54.097	-55.889		-56.110	-58.460	
B Cutting speed (V)	-55.637	-55.004	-54.338	-57.058	-57.219	-56.731
C Tools	-56.176	-53.945	-56.591	-57.744	-57.121	-56.990

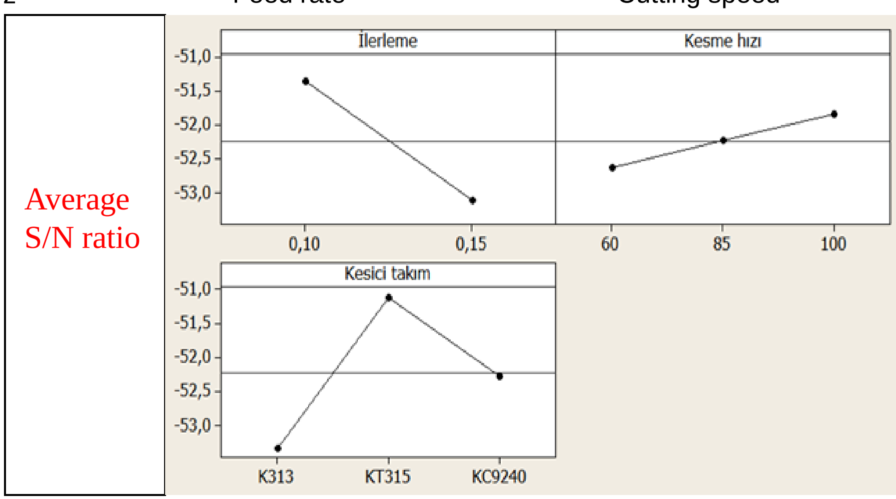
ANOVA ANALYSIS of INCONEL 625(Fz)

Taguchi Optimization	Predict			Correction experiment		
Level	A1B3C2			A1B3C2		
Cutting conditions	0,10	100	KT315	0,10	100	KT315
Surfage roughness (Ra)	780,389			765		
S/N ratio	-57.717			-57,673		

According to Fz

Feed rate

Cutting speed



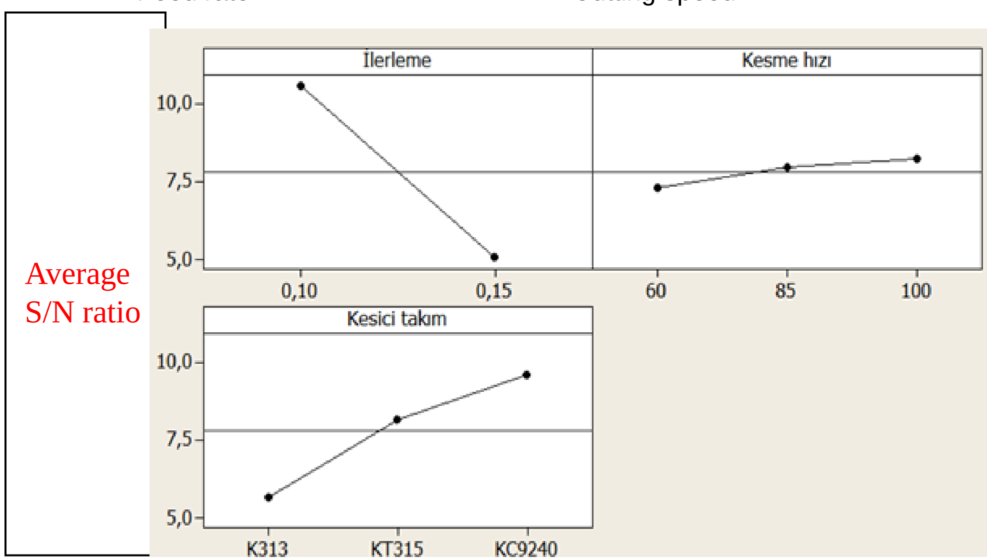
S/N Smaller is better

Cutting tool

ANOVA ANALYSIS of INCONEL 625(Ra)

Taguchi Optimization	**Predict**			**Correction experiment**		
Level	**A1B3C3**			**A1B3C3**		
Cutting conditions	**0,10**	**100**	**KC940**	**0,10**	**100**	**KC9240**
Surfage roughness (Ra)	**0.280**			**0.179**		
S/N ratio	**-11.350**			**-14.942**		

According to Ra' Feed rate Cutting speed



Cutting tool

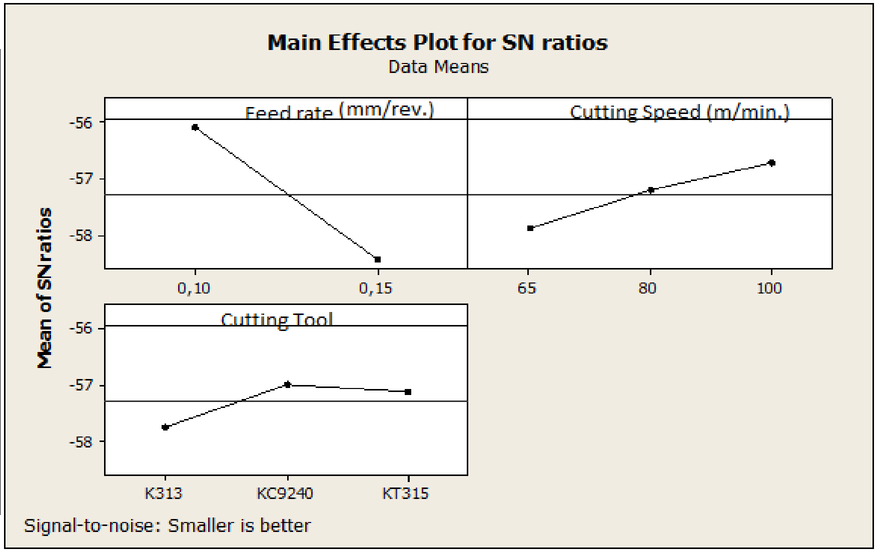
S/N Smaller is better

ANOVA ANALYSIS Hastelloy X (Fx)

Taguchi Optimization	Predict			Correction experiment			
Level	A1B3C2			A1B3C2			
Cutting conditions	0.10	100	KC9240	0.10	100	KC9240	
Cutting force	562			598			
S/N ratio	-54.99			-55.53			

According to Fz

Average
S/N ratio



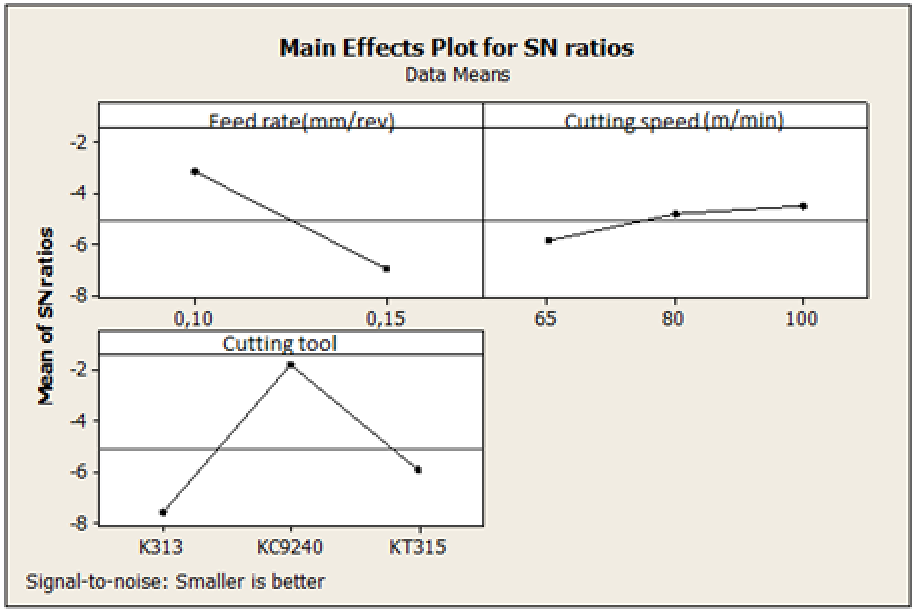
S/N Smaller is better

ANOVA ANALYSIS Hastelloy X (Ra)

Taguchi Optimization	Predict			Correction experiment			
Level	A1B3C2			A1B3C2			
Cutting conditions	0.10	100	KC9240	0.10	100	KC9240	
Surface roughness	1.050			1.667			
S/N ratio	-0.423			-4.43			

According to Ra

Average S/N ratio



S/N Smaller is better

Table 6. ANOVA results for the main cutting force (Fz) S/N ratio in Inconel 600

Hastelloy X (Ra)

Parameters	Degree of freedom (Dof)	Sum of squares	Means of squares	F	P ($p<0.05$)	Effect of parameter (%)
Feed rate	1	4.1424	4.1424	56.56	0.002	***33.15***
Cutting speed	2	0.18817	0.09408	1.28	0.371	***1.51***
Cutting tool	2	5.04646	2.52323	34.45	0.003	***40.38***
Error	12	0.29294	0.07323			***2.34***
Total	17	12.4974				***100***

Hastelloy X (Fz)

Parameters	Degree of freedom (Dof)	Sum of squares	Means of squares	F	P ($p<0.05$)	Effect of parameter (%)
Feed rate	1	181805	181805	57.75	0.002	***65.99***
Cutting speed	2	30700	15350	4.88	0.085	***11.14***
Cutting tool	2	13213	6607	2.1	0.238	***4.80***
Error	12	12592	3148			***4.57***
Total	17	275517				***100***

INCONEL 625 (Fz)

Parameters	Degree of freedom (Dof)	Sum of squares	Means of squares	F	P (p<0.05)
Feed rate	1	14.457	14.4571	24.44	34.02
Cutting speed	2	5.066	2.533	4.28	11.92
Cutting tool	2	15.872	7.9361	13.42	37.35
Error	12	7.098	0.5915		16.70
Total	17	42.294			100.00

INCONEL 625(Ra)

Parameters	Degree of freedom (Dof)	Sum of squares	Means of squares	F	P (p<0.05)
Feed rate	1	138,24289	138,2429	28,4011	56,13
Cutting speed	2	46,80772	23,4039	4,8082	19,00
Cutting tool	2	2,80624	1,4031	0,2883	01,13
Error	12	58,41029	4,8675		23,71
Total	17	246,26714			100,00

CONCLUSIONS

- It was observed that while cutting tool (37.35 %) and feed rate (34.02%) has higher effect on cutting force in Inconel 625, the feed rate (65,99%) and cutting speed (11,14) has higher effect on cutting force in Hastelloy X.

- While feed rate (56.13%) and cutting speed (19.00%) has higher effect on average surface roughness ın Inconel 625, cutting tool (40,38 %), and feedrate (33,15%) has higher effect on average surface roughness in Hastelloy X.

- Array of parameters by the Taguchi method, the optimization of cutting parameters has been shown an efficient methodology.

- In turning operations average surface roughness and cutting forces can be controlled by three factors (cutting tool, cutting speed and feed rate).

- Using results of analysis of variance (ANOVA) and signal-to–noise (S/N) ratio, effects of parameters on both average surface roughness and cutting forces were statistically investigated according to the "the smaller is better" approach.

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Thanks

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