The Process of Optimization of Spot-Welding Conditions and Analyze of the Effect on the Nugget Diameter by Using Taguchi Methodology

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1. Introduction

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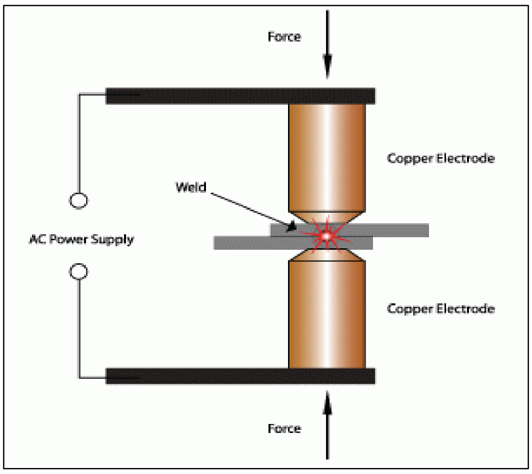
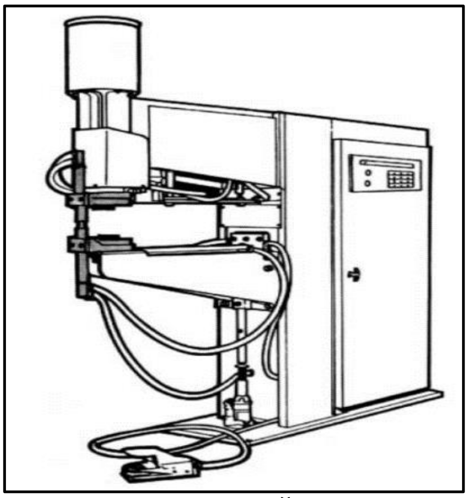
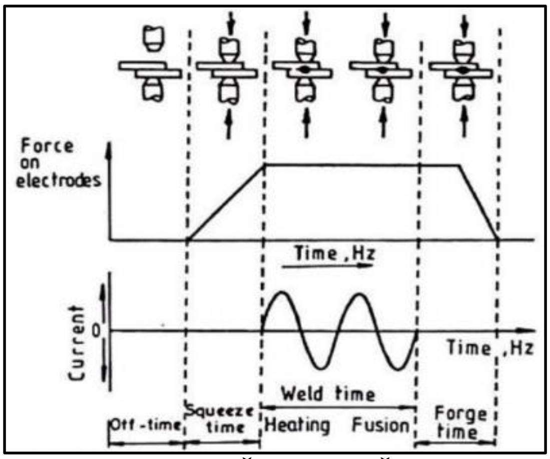

Force
Copper Electrode
Weld
AC Power Supply
Copper Electrode
Force

(1)





[illegible]

2. Previous Investigation

[illegible]

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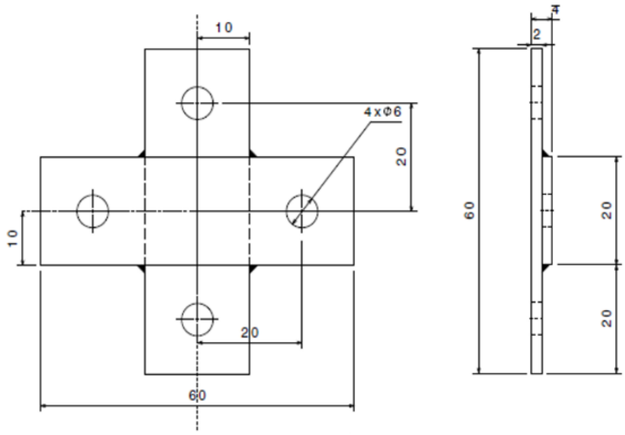
3. Approach Used

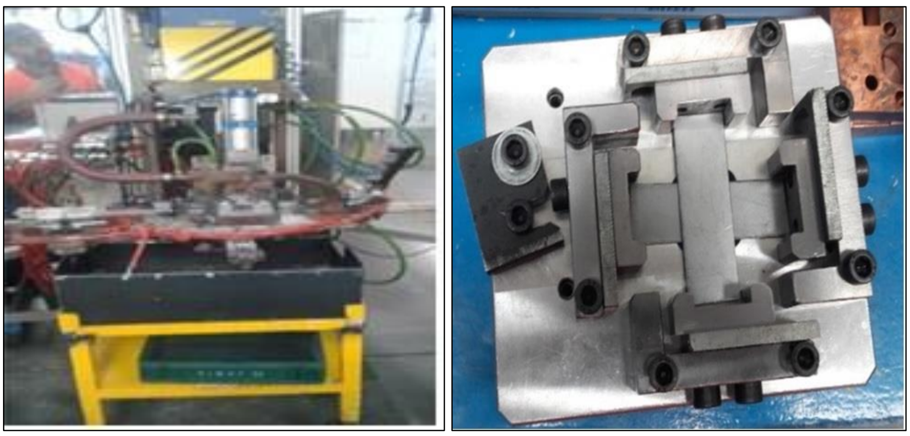
3.1. Experience Details



Chemical composition %		C	Mn	Si	P	S
	-	0.08	0.4	-	0.03	0.03
Mechanicalproperty	$R_{p0.2}$ min (MPa)		Rm min (MPa)	Rm max (MPa)		
	210		270	350		

3.2. Materials and Methods

(2)



3.3. Machine and Tool to Weld

Š‡•ƒ…Š‹•‡ —•‡†‹•–Š‹•–Š‡ •''– ™ƒŽ†‹•‰ •ƒ…Š‹•‡ ™‹–Š t ˆ• '䙇Š‡ –''Ž —•‡† ˆ'
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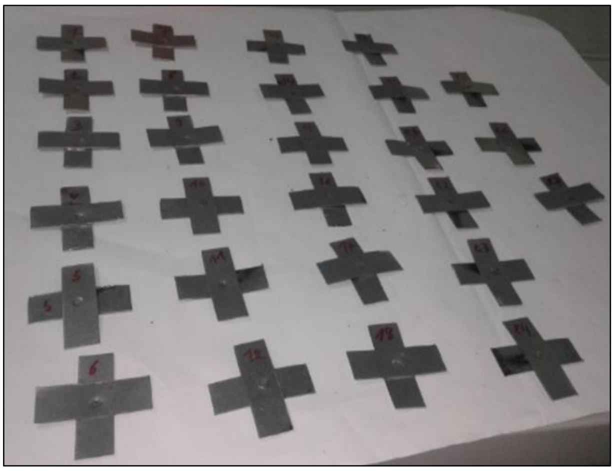
Š‡ –‡•'Žƒ–‡ Šƒ• „‡‡• ‹•ƒ–Š.ƒ— ™ƒ› –Šƒ– •‡–Š'† ‹• ƒ•'–Š‡” ™‹
'"''‡"Ž› †'…•‡†ä ˆ–‡" 'Žƒ…‹•‰ –Š‡ ‡Ž‡…–"'†‡ ™‹–Š –Š‡ …'
‡•–ƒ„Ž‹•Š‡† ‹•–' ƒ"‡ ‹• '™•ä xä



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4. Optimal Process Parameters Results and Discussion

4.1. Taguchi Methods

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–Š"‡‡ Ž‡˜‡Ž• ™‡Ž†‹•‰ ˆ'"…‡á …—""‡•–á ™‡Ž†‹•‰ –‹•‡á Š'Ž†‹•‰ –‹•‡ ƒ
–Š‹…•‡•• 'ƒ"ƒ•‡–‡"• ƒ•† Ž‡˜‡Ž•ã

ƒ„Ž‡ tä "'…‡•• ƒ"ƒ•‡–‡"• ƒ•† –Š‡‹" –Š‡‹" Ž‡˜‡Ž•

‡Ž†‹•‰ 'ƒ"ƒ•‡–‡"•	›•„'Ž	•‹–	‡˜‡Ž s	‡˜‡Ž t	‡˜‡Ž u
Ž‡…–"'†‡		†ƒ	tzw	urr	usw
‡Ž†‹•‰ –‹•‡		•	yäzz	zäu	zäys
‡Ž†‹•‰ ‡	™	›…Ž‡	yäx	z	zäv
'Ž†‹•‰ ‡	Š	›…Ž‡	wy	xr	xu
'"‰‹•‰ ‡	ˆ	›…Ž‡	svätw	sw	swäyw

ƒ„Ž‡ uä Š‡ ‡•‹‰• ƒ–"‹š ˆ'" ƒ‰—…Š‹ ty

No. experience	I (kA)	E (kN)	Tw	T	Th
1	1	1	1	1	1
2	1	1	1	1	2
3	1	1	1	1	3
4	1	2	2	2	1
5	1	2	2	2	2
6	1	2	2	2	3
7	1	3	3	3	1
8	1	3	3	3	2
9	1	3	3	3	3
10	2	1	2	3	1
11	2	1	2	3	2
12	2	1	2	3	3

13	2	2	3	1	1
14	2	2	3	1	2
15	2	2	3	1	3
16	2	3	1	2	1
17	2	3	1	2	2
18	2	3	1	2	3
19	3	1	3	2	1
20	3	1	3	2	2
21	3	1	3	2	3
22	3	2	1	3	1
23	3	2	1	3	2
24	3	2	1	3	3
25	3	3	2	1	1
26	3	3	2	1	2
27	3	3	2	1	3

Š ‡ † ‹ ƒ • ‡ ‡ Š ‡ ‡ Ž ‡ … – ” ‘ † ‡ Š ƒ • ƒ „ ‡ ‘ ” ƒ ” ƒ • ‡ – ‡ ” ä Š ‡ … ‘ ” ” ‡ … – ƒ ‰ — „ › – Š ‡ … ƒ Ž ƒ Ž — ‡ • — • ‡ ” • ƒ • ‡ Š ‡ – ƒ „ Ž ‡ … ‘ • – ƒ ‹ • • – ™ ‡ • – › æ • ‡ • — • „ ‡ ” ‘ ™ (3⁵ ƒ „ Ž ‡ u ä

Š ‡ ˜ ƒ Ž — ‡ • Š ‡ ƒ ‰ — … Š ‹ – ƒ „ Ž ‡ ‘ ‡ ƒ ” ƒ • ‡ – ‡ ” • ‘ ˆ ‡ ƒ … Š Ž ‡ ˜ ‡ Ž ƒ ” ‡ ˜ ƒ „ Ž ‡ v ä Š ‡ • ‡ Š ‡ † › ‹ • ‰ Ž — ‡ • Ž ‡ ‘ ” • ‘ † — … – „ ‡ ‰ ‹ • • ™ ‹ – Š † ‡ – ‡ ” • ‹ • ‹ • ‰ – … ‘ • „ ‹ • ƒ – ‹ ‘ • á ‹ † ‡ • – ‹ ˆ › ‹ • ‰ ˆ ‘ ” ‡ ƒ … Š ‡ š ‡ ” ‹ • ‡ • – ä

ƒ „ Ž ‡ v ä ‘ ƒ Ž ‰ ‘ ” ‹ – Š • ƒ „ Ž ‡

No. experience	Intensity (kA)	Electrode force (kN)	Welding time (period)	Forging time (period)	Holding time (period)
1	7.88	285	7.6	14.25	57
2	7.88	285	7.6	14.25	60
3	7.88	285	7.6	14.25	63
4	7.88	300	8	15	57
5	7.88	300	8	15	60
6	7.88	300	8	15	63
7	7.88	315	8.4	15.75	57
8	7.88	315	8.4	15.75	60
9	7.88	315	8.4	15.75	63
10	8.3	285	8	15.75	57
11	8.3	285	8	15.75	60
12	8.3	285	8	15.75	63
13	8.3	300	8.4	14.25	57
14	8.3	300	8.4	14.25	60
15	8.3	300	8.4	14.25	63
16	8.3	315	7.6	15	57
17	8.3	315	7.6	15	60
18	8.3	315	7.6	15	63
19	8.71	285	8.4	15	57
20	8.71	285	8.4	15	60
21	8.71	285	8.4	15	63
22	8.71	300	7.6	15.75	57
23	8.71	300	7.6	15.75	60
24	8.71	300	7.6	15.75	63
25	8.71	315	8	14.25	57
26	8.71	315	8	14.25	60
27	8.71	315	8	14.25	63

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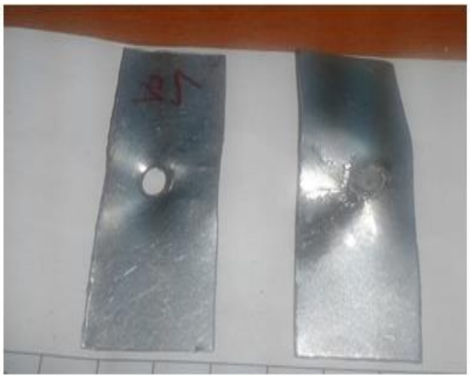
No. experience	Average of nugget diameter (mm)
1	5.190
2	5.360
3	5.290
4	5.710
5	5.640
6	5.430
7	6.130
8	5.710
9	6.090
10	5.480
11	4.570
12	5.460
13	5.330
14	5.440
15	5.150
16	5.590
17	5.770
18	5.200
19	4,675
20	5.940
21	4.540
22	4.890
23	4.790
24	5.170
25	5.460
26	5.340
27	5.160

No. experience	S/N dB ratio
1	14.3033472
2	14.5832958
3	14.4691134
4	15.1327222
5	15.0255821
6	14.6959966
7	15.7492095
8	15.1327222
9	15.6923459
10	14.7756112
11	13.198324
12	14.7438529
13	14.5345442
14	14.7119780
15	14.2361446
16	14.9482362
17	15.2235163
18	14.3200669
19	13.3956323
20	15.4757289
21	13.1411171
22	13.7861772
23	13.6067103
24	14.2698109
25	14.7438529
26	14.5508251
27	14.2529940



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4.2. Calculation of Quality Loss Function and Signal Noise (S/N) Rate

ƒš‹‹œ‡ –Š‡ ”‡•’‘•‡ ‘ˆ –Š‡ —‰‰‡– †‹ƒ‡–‡” ƒˆ–‡” –Š‡ ‡ˆˆ‡…–‹˜‡ ˆƒ…–‘”• ‘ˆ –Š‡ ”‡•’‘•‡ ˜ƒ”‹ƒ„Ž‡ ‹ ‡ƒ…Š ‡š’‡”‹‡–Ǥ „‹‰‰‡” ‹• „‡––‡” ˆ‘” –Š‡ ‘’‡”ƒ–‹‘ ‘ˆ –Š‡ “—ƒŽ‹–› Ž‘•• ˆ—…–‹‘Ǥ

$$L_i = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2} \tag{3}$$

Š‡ •‹‰ƒŽ –‘ •‘‹•‡ ”ƒ–‹‘ ‹• “—ƒ–‹‘ ͶǤ

5 0ÜL Fs r. K CÜ (4)

Š‡ •—„•‡“—‡– •–‡’ ‹• –‘ …ƒŽ…—Žƒ–‡ –Š‡ •‹‰ƒŽ –‘ •‘‹•‡ ”ƒ–‹‘ ˆ‘” ‡ƒ…Š ‡š’‡”‹‡– ˆ”‘ –Š‡ ”‡•’‘•‡ †‡•–”—…–‹˜‡ –‡•–Ǥ ‘ •ƒš‹‹œ‡ –Š‡ ”‡•’‘•‡ˆ ”‡•—Ž–• †‹ƒ‡–‡” ‘ˆ –Š‡ ™‡Ž†‹‰ ’ƒ”ƒ‡–‡”•á –Š‡ ƒ’’”‘ƒ…Š ‘ˆ ƒŠ‹ˆ –Š‡ •‹‰ƒŽ ‹• ˆ‹”•– ‘”†‡” ‘ˆ ‡ƒ…Š …‘„‹ƒ–‹‘ ™‹–Š –Š‡ ”‡•—Ž–• ‘ˆ ‡š’‡”‹‡–• ’”‘ˆ‹Ž‡• ƒ”‡ ’”‡•‡–‡† ‹ ƒ„Ž‡ ͶǤ

… … ‘ ” † ‹ • ‰ Š ‡ – ƒ á Ž ‡ Š ‡ ‘ ’ – ‹ • — • † ‹ ƒ ‘ • ‡ æ ‡ ™ ‡ Ž † ‹ • ‰ • — ‰ ‰ ‡ – Š ‡ ‘ Ž ƒ ‡ ‰ ‘ ‡ – ˜ ƒ Ž – ‘ ˆ – Š ‡ ” ƒ – ‹ ‘ á ƒ • † – Š ‡ ‘ – ƒ Ž ‡ ” ‡ • — Ž – • ƒ ” ‡ ã

$$(I_1 . E_3 . T_{w3} . T_{f2} . T_{h2})$$

Š ‡ ƒ „ Ž ‡ y • Š ‘ ™ • – Š ‡ – Š ‡ ” ƒ ˜ ‡ ” ƒ ‰ ‡ ˜ ƒ Ž — ‡ „ › – Š ‡ † ‹ ˆ ˆ ‡ ” ‡ • – … ‘ ˆ ‹ ‰ — ” ƒ – ‹ ‘ • • ™ ‡ Ž † ‹ • ‰ ’ ƒ ” ƒ • ‡ – ‡ ” • ä

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Parameter	Symbol	S/N Ratio			Total average	Extended
		Level 1	Level 2	Level 3		
Welding intensity	I	14.98	14.52	14.14	14.545	0.84
Electrode force	E	14.23	14.44	14.96		0.73
Welding time	Tw	14.39	14.57	14.67		0.28
Holding time	Th	14.49	14.6	14.55		0.11
Forging time	Tf	14.6	14.61	14.42		0.19

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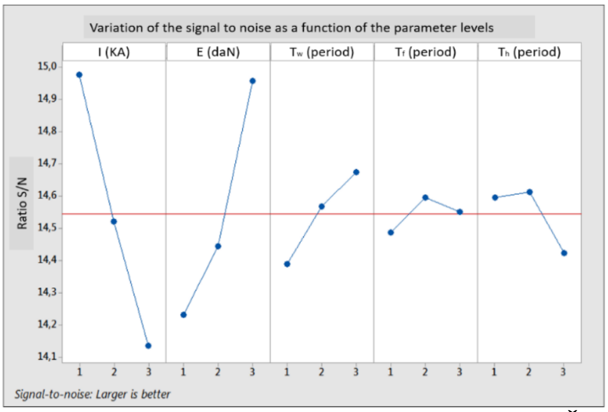

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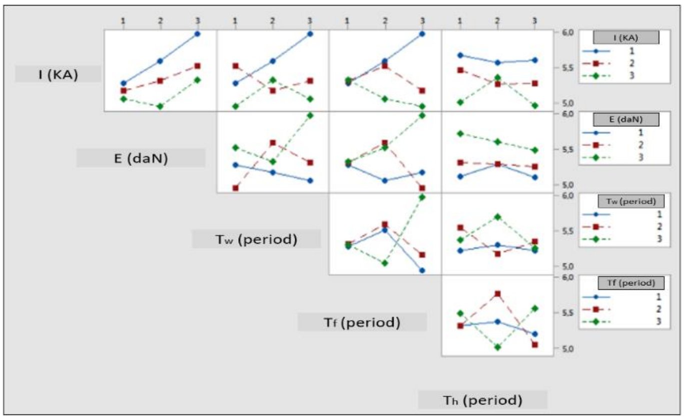

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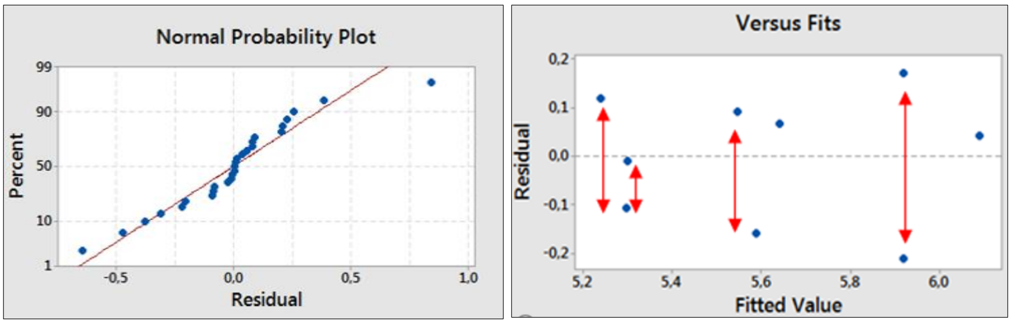
• – Š ‹ • ’ ƒ ” – ‹ … — Ž ƒ ” … ƒ • ‡ – Š ƒ – ‹ Š ƒ • ‹ • – ‡ ” ƒ … – ‹ ‘ • • ƒ ” ‡ • ‘ – ’ ƒ ” ƒ Ž Ž ‡ Ž á ™ Š ‹ … Š ƒ • ‹ – ‡ ” ƒ … – ‹ ‘ • „ ‡ – ™ ‡ ‡ • – Š ‡ • ‡ ’ ƒ ” ƒ • ‡ – ‡ ” • ‹ • † ‡ ’ ‡ • † ‡ • – ‘ ˆ – Š ‡ ’ ƒ ” ƒ • ‡ – ‡ ” • ‹ • – ‡ ” ƒ … – ‹ ‘ • „ ‡ – ™ ‡ ‡ • – Š ‡ ’ ƒ ” ƒ • ‡ – ‡ ” • Ž † ‡ ” „ — – – ‘ • ä

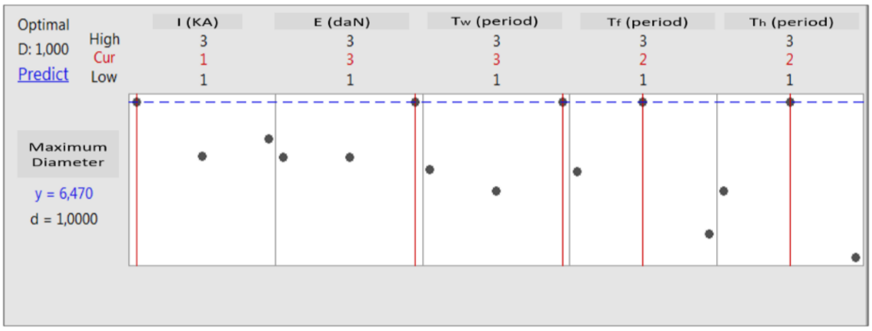
4.3. ANOVA Analysis



Settings and interaction	Percentage of contribution %
I (current)	9.25
E (Electrode force)	11,67
Tw (welding time)	1.2
Tf (cooling time)	1.24
Th (Holding time)	1.14
Interaction	3.65

4.4. Confirmation of Tests

$I_f.E_3.T_{w3}.T_{f2}.T_{h2}$



Factors controlled	Optimum level	optimum value
I (kA)	1	7.88
E (daN)	3	315
Tw (period)	3	8.4
Tf (period)	2	15
Th (period)	2	57

4.5. Conclusion

Conflict of Interest

Author Contributions

References

[1] [illegible]

[2] [illegible] *International Journal of Interdisciplinary Research* [illegible] 3(1) [illegible]

[3] [illegible] *International Journal of Mechanical and Production Engineering Research and Development* [illegible] 3(2) [illegible]

[4] [illegible] *International Journal of Mechanical Engineering and Robotics Research* [illegible] 3(4) [illegible]

[5] [illegible] *The Arabian Journal for Science and Engineering* [illegible] 34(2B) [illegible]

[6] [illegible] *International Journal of Science and Research (IJSR)* [illegible] 6(1) [illegible]

[7] [illegible] *International Journal of Research in Mechanical Engineering & Technology* [illegible] 7(2) [illegible]

[8] [illegible] *Journal of scientific and Industrial Research* [illegible] 69 [illegible]

[9] [illegible]

[10] [illegible]

[11] [illegible]

[12] [illegible] *Proceedings of the Annual Conference of the International Society of Parametric Analysts* [illegible]

[13] [illegible] *et al.* [illegible] *International Journal of Mechanical and Production, Engineering Research and Development* [illegible] 3(2) [illegible]

[14] [illegible]

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