Process Parameters Optimization of Aa2024 Alloy Friction Stir Welding using Taguchi's Technique

Ch. Radhika, N. Shyam kumar

ABSTRACT: *Within this research study, Taguchi system of style of experimental was utilized to assess the impact of some welding process parameters of sound state welding techniques like rotational speed(spinning velocity), travel speed in addition to pin profile on Tensile Strength (UTS), microhardness in addition to effect strength of Friction Stir Welded (FSW) 2024 light weight aluminum alloy joint. An orthogonal array of L9 design was actually employed for experimental trials and also Signal to noise proportion(S/N) values for each process specifications was computed. Based upon the S/N review the optimal level of process specifications was actually decided on as 1120 revoltions per minute, 25 mm/min and also Cylinder pin with Flutes(CWF) for best Tensile Strength and also micro Hardness. The ideal degree of process parameters for Impact toughness was actually pinpointed as 1120rpm,31.5 mm/min and also Tapered Cylindrical pin account(Drawback). Depending on to Analysis of variance (ANOVA), it was seen that the task of spinning, travel velocity and also pin geometry was 37.31, 64.84 and 1.13 per-cent effect on Ultimate tensile strength, 34.16, 51.28 and 0.58 per-cent impact on micro Hardness as well as 50.10, 43.7 and 6.2 percent influence on Influence Toughness of joint respectively. Eventually based upon FSW guidelines a model was actually created for tensile strength, Micro Hardness and Toughness values. The results were confirmed by further experiments, which yield the experimented values as 349.83 MPa for tensile strength, 114.26 Hardness and 7.8kJ Impact strength.*
Index Terms : 2024 aluminum alloys, Friction stir welding, Weld process parameters, ANOVA, Taguchi.

I. INTRODUCTION

The joining of light weight aluminum metals through welding process has constantly a higher difficulty for designers, makers, as well as technologists. Due to simple fact, a large number of difficulties are connected with this type of signing up with process, mainly pertaining to the high thermal buildings like higher thermal growth coefficient, high thermic conductivity, higher likeness to oxidization, concretion contractions visibility of a tenacious oxide coating and most importantly, higher solubility of hydrogen, and also other gasoline's, in molten state [1] TIG welding is among the traditional participating in modern technology for light weight aluminum and its own blends; having said that, it is linked with some difficulties, such as hotcracking in weld zone(dissolved region) because of separation of alloying factors during concretion, nullifies warmth procedure impact and creates an actors crude microstructure [2],

which results in bad mechanical residential properties of the joint. The welding framework may become limit light weight aluminum alloy applications in the aerospace market. Friction stir welding is a sound state welding process, it uses a non-consumable device of a more challenging product than the bottom material [3,4] FSW as connecting technology for metals joints it possesses numerous benefits of no costly weld preparation lowers the manufacturing prices due to the elimination of defects like porosity as well as insufficient blend, filler materials. Additionally, friction stir welds of Al and also its own blends exhibit better mechanical residential properties than standard fusion welds due to defect-free joints [2,5] The primary variety of study papers are released on the effect of FSW process specifications on microstructure accumulation [6,7], and also evaluations between FSW as well as regular blend processes likeTIG, MIG joined Al composites buildings have been actually extensively looked into [8,9] the top quality of the weld in friction stir welding process (FSW) typically depends on shared layout and also resource geometry of device considering that these specifications have major result on warmth circulation, product circulation design, warmth circulation as well as created microstructures, which in turn makes a decision the quality of bonded junctions [10] A really good amount of posted documents have been actually focused on the impact of FSW guidelines on mechanical as well as metallurgical as well as mechanical residential or commercial properties of comparable and diverse light weight aluminum alloys junctions [11,12] Yet, handful of researchers have performed focus on formalization and optimization of impacts of FSW process criteria on metallurgical and mechanical homes of similar and different Al junctions [13,14]Taguchi technique of concept of experiments is useful for the optimization of methods parameters. It additionally suggests the efficiency of included parameters on the primary objective of the process [15,16] For example, In FSW of A319 directed alloy among three welding criteria(trip velocity rotational speed and vertical center force) the upright pressure possesses additional importance on tensile strength of joint than that of other specifications [13] whereas, couple of papers presented that spinning speed possesses the highest possible impact as opposed to vertical pressure as well as travel speed in boosting tensile strength of fsw of RDE-40 aluminum alloy joints [17] Next to convenient, the optimization and formalization of welding specifications likewise are going to lessen the price of performed practices for similar and also dissimilar Al alloys joints. Within this paper, it has actually been made an effort to explore the effect of spinning speed, traveling rate as well as pin profile page criteria on buildings of AA2024 metals shared, in order that the efficiency of each parameter on flexible toughness,

solidity, impact stamina as well as superior disorder of abrasion mix assembly process for 2024 joints, could be identified.

II. EXPERIMENTAL PROCEDURE

The optimal combo of the process parameters may be at that point predicted. A 2024-T6 Al Alloy of 5mm thickness plates were made use of as a base material. The normal composition of 2024 light weight aluminum blends in wt.%: 1.2-1.8 Milligrams, 0.5 Si, 3.8-4.9 Cu, 0.1 Cr,0.5 Fe,0.30.9 Mn,0.15 w,0.15 Zn, as well as the equilibrium is actually Al. The 2024 Light weight aluminum plates were actually partitioned the size of 100 mm x 60 mm. The welding guidelines are actually tool rotational speed, in rpm (900, 1120, 1400), travel speed, in mm/min (25, 31.5, 40). A welding resource crafted from H13 steel with pin account of Cylinder pin along with flutes, Tapered Cylindrical pin and also Triangular pin specifically were made use of to assemble FSW (Square butt joint) joints.
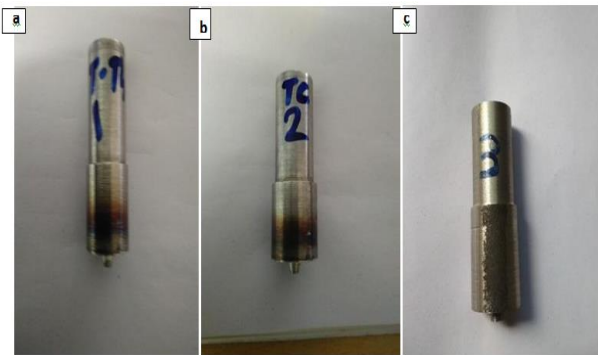

Figure 1. shows the tool pin profilegeometry a) Triangular pin profile b) Tapered Cylindrical pin profile c) Cylinder pin with Flutes

Table 1. FSW parameters and design levels.

S.No	Parameters Code	Unit	Level 1	Level 2	Level 3
1	Rotational speed (W)	r.p.m	900	1120	1400
2	Travel speed (V)	mm/min	25	31.5	40
3	Tool geometry	-	Cylinder pin with Flutes(CWF)	Tapered Cylindrical pin profile(Con)	Triangular pin profile (TRI)

Taguchi concept of practices of an L9 orthogonal array was worked with to improve the FSW parameters of 2024 aluminum metals. The FSW guidelines decided on for this study were Rotational speed (W), travel velocity (V) as well as Device pin geometry as received table.1. The tensile strength, Impact strength as well as hardness as output characteristics. The signal to noise proportion (S/N) for each and every quantity of procedure criteria was analyzed . Signal to noise evaluation was actually made use of to minimize changes in preferred characteristics. Consequently results of ultimate Tensile strength(UTS), impact strength, and Hardness worth's were actually even more appropriate and comparable. The objective of this particular research was to attain much better mechanical homes(tensile strength, Hardness & Impact strength) of joints for selected alloys. The

S/N proportion which shows the quality characteristics was computed utilizing the formula 1 [18]:

$$\frac{S}{N} = -10\,\text{Log}(1/n\sum_{i=1}^{R}\frac{1}{Y_i^2})\qquad\qquad 1$$

Where n is the lot of reproduces of each experiment at the very same conditions and also Yi is the intended value (ultimate tensile strength, microhardness, and also impact stamina) of each sample in test number i in each mechanical characteristics measurement. A Comprehensive Evaluation of difference construct for taking a look at the relevance of the weld standards which influence the Ultimate strength, Micro Hardness and Impact stamina of FSW AA2024 joints are also given. The superior combination of the weld specifications for each and every Mechanical characteristics (Ultimate tensile strength, Hardness, and Impact strength) may be at that point anticipated. The mean Ultimate tensile strength , Micro Hardness means of ways , Impact strength and also S/N ratio proportion are actually given in Tables 3,6 as well as 9 respectively. Besides, the F-test may additionally be utilized to figure out which process has a statistically considerable result on supreme tensile strength, Micro Hardness and also Impact strength of the FSW junction. Typically, the change of the process parameter has a notable result on the premium of the FSW joint, when F is actually sizable. The end results of ANOVA suggest that the taken into consideration welding specifications were actually extremely notable factors influencing the outcome characteristics of FSW Aluminum 2024 junctions in the purchase of traverse rate, rotational speed, Device pin geometry for Ultimate tensile strength, Micro Hardness as well as for the Impact strength the order was actually Resource pin geometry, rotational velocity, and also pass through velocity(Travel speed).

III. RESULTS AND DISCUSSION

3.1 Ultimate tensile strength:

UTS test samplings gotten are actually tabulated in table 2, this reveals that the highest possible UTS was actually 352.48 MPa for the example of practice 4 (1120rpm, 25.0 mm/min, CWF) as well as the most affordable UTS was actually 306.43 MPa for the example readied coming from experiment 9 weld ailment(1400rpm, 40mm/min, Triangular pin). All the test samples were actually fractured at weld zone.

Table 2. Experimental results of tensile test

S.No	Rotational Speed(W)	Travel speed (V)	Tool Geometry	Ultimate Tensile Strength(UTS) in Mpa
1	900	25.0	CWF	344.23
2	900	31.5	Con	313.62
3	900	40	TRI	327.51
4	1120	25.0	CWF	352.48
5	1120	31.5	Con	320.03
6	1120	40.0	TRI	335.27
7	1400	25.0	CWF	330.39
8	1400	31.5	Con	327.18
9	1400	40.0	TRI	306.43

3.2.*Analysis of the S/N ratio*

In this work, Ultimate tensile strength (UTS) had been investigated as one of the particular residential property based on which parameters of FSW is maximized.

The function of this particular study was to secure the much better utmost tensile strength FSW junction of the stated alloy. Highest UTS is intended so the "much higher is actually Much better" principle. The S/N ratio of matching to experiments carried out as per L9 orthogonal selection design2024 light weight aluminum alloy joints has been displayed in Dining table 3. All the tensile exam examples were fractured at the welding one.

Table 3. S/N ratio of 2024 aluminum alloys joints

S.No	Rotational Speed(W)	Travel speed (V)	Tool Geometry	ultimate tensile Strength(UTS) in Mpa	S/N ratio
1	900	25.0	CWF	344	50.7601
2	900	31.5	COn	313	49.9353
3	900	40	TRI	327	50.2376
4	1120	25.0	CWF	352	50.8775
5	1120	31.5	COn	320	50.1319
6	1120	40.0	TRI	335	50.5254
7	1400	25.0	CWF	330	50.3154
8	1400	31.5	COn	327	49.6611
9	1400	40.0	TRI	306	49.8841

How much the worth of the signal to noise proportion is actually better, are going to induce the best efficient effectiveness of the FSW procedure. Thus the optimum level of process specifications is in fact the confess the most ideal S/N truly worth. As a result, the best level of the process criteria is the rotational rate of 1120rpm, the Travel seed of 25mm/min and also the Resource pin geometry of CWF respectively. Fig .2 reveals the primary results story on S/N proportion.
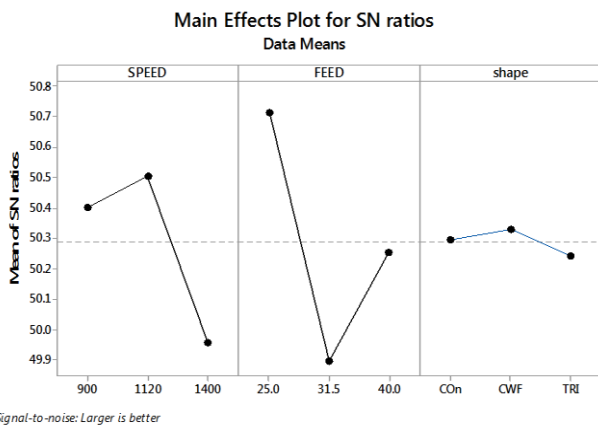
Figure 2. main effects plot on S/Nratio

From Fig. 2, it is crystal clear that the S/N proportion of spinning speed increases from 900rpm to 1120rpm and then decreases from 1120rpm to 1400rpm; as a result the optimum rotational rate is actually 1120rpm. In a similar way, the S/N proportion of welding travel speed decreases from 25.0 mm/min to 31.5 mm/min and after that raises because of 31.5 mm/min to 40mm/min, thus the optimal welding velocity is 40mm/min. The S/N ratio values determined based on the resource pin profile page signifies that cylinder pin with flues results in much better stamina for the FSW joint.

3.3.Analysis of Variance (ANOVA)

ANOVA is actually conducted to know the efficiency of individual process criteria on supreme tensile strength. Dining table 4 presents the amount payment of each controlled parameter which is actually signified by column F. F-test is accomplished to find the substantial each weld parameter having an effect on the UTS of joined 2024aluminum metals joint in friction stir welding.

Table 4. Analysis of variance for mean

Source	DF	Adj SS	AdjMS	F	P
Rotational speed	2	0.47944	0.239721	37.31	0.026
Travel speed	2	0.83318	0.416591	64.84	0.015
Tool Pin Profile	2	0.01454	0.007269	1.13	0.469
Error	2	0.01285	0.006424		
Total	8	1.34001			

In Table 4. F values presents the amount association of manageable process specifications to obtain optimal UTS, whereas the P market value suggests the probability of uncontrollability of process criteria. For a much better top quality of joint, it is actually desired to possess the highest possible market value of F, the minimum market value of P as well as the parameter which possesses listed below 5% possibility is looked at as a significant parameter. It is watched that the travel speed with 64.84% payment and rotational speed adds 37.31% complied with by the and 13% contribution due to the pin geometry. So it clearly presents that the travel speed has the highest possible contribution in achieving maximum UTS.

3.4.Hardness on weld zone:

The Micro Hardness of the AA2024 welded junctions was actually worked out utilizing Micro Vickers hardness tester as well as the results are actually tabulated in table 5. It shows that the highest possible Micro Hardness was actually 117for the sample of the 8th practice (1400rpm, 31.5 mm/min, Con).

Table 5. Experimental results of Vickers Hardness test

S.No	Rotational Speed(W)	Travel speed (V)	Tool Geometry	Vickers Hardness Number
1	900	25.0	CWF	116.340
2	900	31.5	Con	109.670
3	900	40	TRI	113.000
4	1120	25.0	CWF	117.000
5	1120	31.5	Con	116.340
6	1120	40.0	TRI	109.670
7	1400	25.0	CWF	113.000
8	1400	31.5	Con	117.000
9	1400	40.0	TRI	116.340

3.5. Analysis of S/N ratio:

In this particular study, Micro Hardness was actually looked at as being one of the preferable unique feature based upon which parameters of friction stir welding was optimized. Greatest Hardness was desired so the "Larger is actually Better" concept was actually embraced in the analysis making use of S/N proportion. In Table.6 S/N ratio of Micro Hardness of aluminum alloy 2024 junctions representing experiments done according to L9 orthogonal array design.

Table 6. S/N ratio of 2024 aluminum alloys joints

S.No	Rotational Speed(W)	Travel speed (V)	Tool Pin Geometry	Vickers Hardness Number	S/N ratio
1	900	25.0	CWF	116.340	41.3146
2	900	31.5	COn	109.670	40.8018
3	900	40	TRI	113.000	41.0616
4	1120	25.0	CWF	117.000	41.3637
5	1120	31.5	COn	108.333	40.6952
6	1120	40.0	TRI	112.667	41.0359
7	1400	25.0	CWF	110.667	40.8803
8	1400	31.5	COn	105.000	40.4238
9	1400	40.0	TRI	108.000	40.6685

For greater micro hardness value the optimal degree of process guidelines along with the best S/N value was actually the spinning rate of 1120rpm, trip speed 25.0 mm/min and device pin profile of cylinder pin with flutes (CWF)
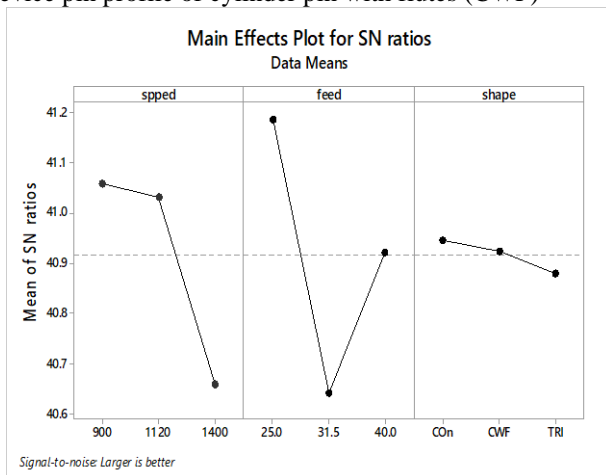

Figure 4. main effects plot on S/Nratio

Coming from Fig 4, it is clear that the S/N proportion of rotational speed minimizes coming from 900rpm to 1400rpm; for this reason the ideal rotational speed is 900rpm which possesses a the greatest value. Similarly, the S/N ratio of Travel velocity lowers from 20mm/min to 31.5 mm/min and after that reduces coming from 31. mm/min to 40mm/min so the optimum Travel speed is 31.5 mm/min. Then the S/N proportion of the Device pin profile page is the same for CWF to Drawback and after that reduced from CWT to TRI, hence the optimal Resource pin account is actually CWF.

3.6. Analysis of Variance :

It is in fact executed to understand the efficiency of specific process guidelines on microhardness. F-test is actually carried out to discover the significant each parameter impacting the microhardness of welded 2024 aluminum joint in friction stir welding. Table 7 shows the percentage impact of each manageable parameter which is actually been of consequence through pillar F.

Table 7.Analysis of variance for mean

Source	DF	Adj SS	AdjMS	F	P
Rotational speed	2	0.273261	0.136631	34.16	0.028
Travel speed	2	0.410241	0.205120	51.28	0.019
Tool Pin Profile	2	0.004611	0.002305	0.58	0.634
Error	2	0.007999	0.004000		
Total	8	0.696112			

Coming from Table.7. It is actually observed that the travel speed with 51.28% contribution as well as rotational speed adds 34.16 %. So it plainly presents that the travel speed has the highest payment in accomplishing max microhardness than other parameters of AA2024 alloy, the trael speed is actually the crucial parameter to control the residential property such as microhardness.

3.7. Impact Strength:

The impact strength of the AA2024 welded joints were worked out making use of the Charpy screening device and also the results are actually arranged in Table 8. It presented that the highest possible Impact Strength was actually 7J for the samples of experiment 3 (900rpm, 31.5 mm/min, TRI), experiment 5(1120rpm, 25mm/min, Con) and the minimum Impact Durability was actually 3.7 J for the example of practice 1 (900rpm, 25mm/min,CWF).

Table 8. Experimental results of Impact strength test

S.No	Rotational Speed(W)	Travel speed (V)	Tool Pin Geometry	Impact Strength in Joules
1	900	25.0	CWF	3.7
2	900	31.5	COn	5
3	900	40	TRI	7
4	1120	25.0	CWF	5
5	1120	31.5	COn	7
6	1120	40.0	TRI	4.8
7	1400	25.0	CWF	6.8
8	1400	31.5	COn	5
9	1400	40.0	TRI	5.6

3.8. Analysis of S/N ratio:

Within this research study, Influence Strength was actually considered as being one of the good symbolic building based on which guidelines of friction stir welding was optimized. Max Influence Toughness was preferred so the "Larger is actually A lot better" principle was adopted in the analysis making use of S/N proportion. Table 9 suggests S/N ratio of friction stir bonded 2024aluminum metals joints representing practices conducted as per L9 orthogonal array design.The superior amount of process criteria was the confess the highest S/N market value were actually 1120rpm, 31.5 mm/min as well as Downside specifically.

Table 9. S/N ratio of 2024 aluminum alloys joints

S.No	Rotational Speed(W)	Travel speed (V)	Tool Pin Geometry	Impact Strength in Joules	S/N Ratio
1	900	25.0	CWF	3.7	11.6591
2	900	31.5	COn	5	13.9329
3	900	40	TRI	7	16.6534
4	1120	25.0	CWF	5	13.7308
5	1120	31.5	COn	7	17.1970
6	1120	40.0	TRI	4.8	13.5783
7	1400	25.0	CWF	6.8	16.6037
8	1400	31.5	COn	5	13.7308
9	1400	40.0	TRI	5.6	15.2588

Advantageous functionality of FSW, the ideal level of process specifications with the best S/N worth was the spinning rate of 1120rpm, travel velocity 31.5 mm/min and tool pin profile page of conical cylinder pin(Con).
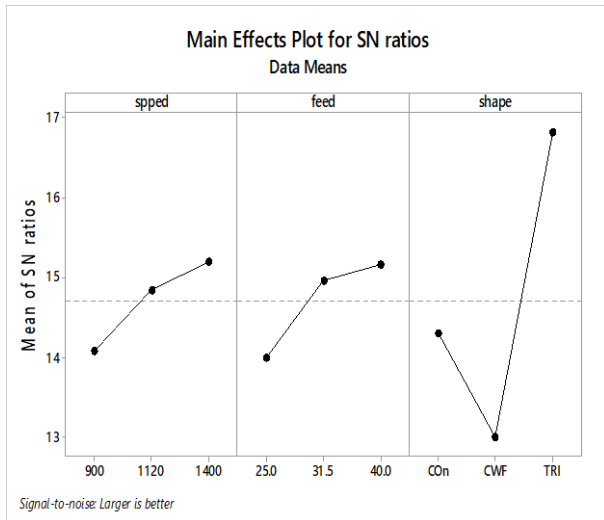
Figure 5. main effects plot on S/Nratio

From Fig 5, it is actually very clear that the S/N proportion of rotational velocity rises due to 900rpm to 1400rpm; as a result the optimal rotational rate is actually 1400rpm which possesses a the greatest market value. Similarly the S/N proportion of Traveling velocity boosts from 20mm/min to 40mm/min a therefore the optimum Trip velocity is 40mm/min. After that the S/N proportion of Tool pin account lowers from Downside to CWF resource and then improves due to CWF to TRI is the same for CWF to Drawback and afterwards lowered from CWTto TRI pin.

3.9. ANOVA:

It is actually executed to recognize the effectiveness of specific process criteria on durability property such as Impact strength. Table 10 series the percentage addition of each manageable parameter which is been of significance by column F. F-test is actually accomplished to find the significant each process parameter impacting the Influence stamina of bonded 2024 aluminum alloy joint in friction stir welding.

Table 10.Analysis of variance for mean

Source	DF	Adj SS	AdjMS	F	P
Rotational speed	2	1.9446	0.9723	4.29	0.189
Travel speed	2	2.3162	1.1581	5.11	0.164
Tool Pin Profile	2	22.6983	11.3492	50.10	0.020
Error	2	0.4531	0.2265		
Total	8	27.4123			

From Table.10, It is complied with that the tool pin geometry account along with 64.84% addition and also rotational speed contributes 4.29% observed by the and 5.11% payment by travel speed. So it precisely presents that the device pin profile page possesses the best addition in achieving maximum Impact strength.

IV. CONCLUSIONS

In this study, the effect of rotational speed(spinning rate), travel speed and Device pin geometry on best UTS, Micro Hardness as well as Impact strength of AA2024 alloy joint was checked out by utilizing the Taguchi design of practices procedure and also ANOVA evaluation. Process parameters(rotational speed, travel speed, and tool pin profile)were optimized usingL₉orthogonal array design.

S/N analysis results indicated that the optimal parameters for ultimate strength(UTS) and Micro Hardness were 1120rpm, 25.0mm/min, CWF; and Impact Strength of AA2024 alloy joint are achieved when values of rotational speed, travel speed, and tool pin profile were 1120rpm, 31.5mm/min, Con respectively. In such ailments, the UTS, Micro Firmness and also Toughness of the joint were actually 143.59 MPa,117.000 J respectively. Ultimately, ANOVA analysis revealed that the performance of individual weld criteria.

The ideal method parameters for achieving maximum UTS were rotational speed-1120rpm, travel speed-25.0mm/min and tool pin profile- cylinder pin with flutes(CWF).

The percentage contributions of each controllable parameter to achieve maximum UTS are rotational speed-37.31%,travelspeed-64.84% and tool pinprofile-1.13%.Therefore travel speed has the highest influence on UTS than various other parameters.

The optimal process parameters for the greatest microhardness are Rotational speed-1120rpm, travel speed-25.0mm/min and tool pin profile-cylinder pin with flutes(CWF).

The percentage of contributions of each controllable parameter to achieve maximum microhardnessis rotational speed-34.16%, travel speed- 51.28% and tool pin profile-0.58%.Therefore travel speed has the highest influence on microhardness than other parameters.

The optimum process parameters for highest Impact strength are Rotational speed-1120rpm, travel speed-31.5mm/min and tool pin profile-COn

The percentage of contributions of each controllable parameter to achieve maximum Impact strength are rotational speed-4.29%, travel speed- 5.11% and tool pin profile-50.10%.Therefore tool pin profile has the highest influence on impact strength than other parameters.

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