OPTIMIZATION OF PROCESS PARAMETERS OF THE ACTIVATED TUNGSTEN INERT GAS WELDING FOR NOTCH TEST OF UNS S32205 DUPLEX STAINLESS STEEL WELDS

A.T.MAHENSRA SANKAR[1]
PG student (Engineering Design)
PSNA College of engineering and technology
Email:mahendrasankar9490@gmail.com

Dr.G.MAGUDEESWARAN[2]
Professor
Mechanical Department
PSNA college of engineering and technology

ABSTRACT

Notch tensile testing has ended up being a reasonable technique for testing the ductile or tensile properties of welded joints. The major affecting ATIG welding parameters, for example, electrode gap, travel speed, current and voltage that guide in controlling the tensile strength of DSS joints, must be improved to acquire attractive rigidity for DSS joints. Thus in this review, the above parameters of ATIG welding for tensile strength of ASTM/UNS S32205 DSS welds are optimized by utilizing Taguchi orthogonal Array (OA) experimental plan and other statistical apparatuses, for example, Analysis of Variance (ANOVA) and Pooled ANOVA methods. The optimum process parameters are observed to be 1 mm electrode gap, 140 mm/min travel speed,140 A current and 14 V voltage.

1. INTRODUCTION

The first generation Duplex stainless steels were produced over 70 years prior in Sweden for use in the sulfite paper industry. Duplex combinations were initially made to battle corrosion issues brought on by chloride-bearing cooling waters and other aggressive chemical process liquids. These first generation duplex stainless steels gave great execution qualities yet had confinements in as-welded condition [1]. In the 70's, the introduction of continuous casting in stainless steel production has contributed to lower production costs and higher quality.It is vital that the blend of ferritic and austenitic stage is approximately 50/50, (i.e., rise to extent of blend) a too high substance of any structure can prompt decreased erosion resistance and mechanical properties. Strength of DSS is higher than the single-stage austenitic stainless steel. Duplex stainless steel offers greater mechanical strength and higher corrosion resistance to chloride-induced stress corrosion cracking than most types of stainless steel[3,5]. Duplex stainless steel is a common structural material in the oil and gas industries, and has special applications in chemical, wastewater, and marine engineering fields as well.

Welding process, filler metal augmentations, protecting gas and warmth info are imperative variables that add to build up the equivalent extent of austenite-ferrite stage proportion (1:1) in the weld metal locale. Be that as it may, practically it is unrealistic to set up 1:1 austenite-to-Ferrite proportion in every one of the zones of the welded joints. Welding procedures should be designed to produce this same structure in the weld metal and heat-affected zones. Most of the conventional welding processes, such as submerged arc welding (SAW), shielded metal arc welding (SMAW) and tungsten inert gas (TIG) welding, can be used for welding DSS[4,6].The air ship industry built up the GTAW procedure for welding magnesium during the late 1930's and the mid 1940's. During that time, helium was the essential protecting gas utilized, alongside DCEP welding current. These brought about numerous issues that restrict use of GTAW welding process. Be that as it may, enhance the process effectiveness and diminished its cost. Prior to the improvement of the GTAW procedure, welding aluminum and magnesium was troublesome. TIG welding procedure is a standout amongst the most prominent innovations for welding thin materials in manufacturing industries since it delivers brilliant welds. However, compared with the metal inert gas welding process, the TIG welding has poor joint penetration when thick materials are welded in a single pass. For the most part, the single pass TIG welding with argon as protecting gas is restricted to a 3 mm depth for the butt-joint of stainless steelsA standout amongst the most remarkable systems is to utilize initiating flux with TIG welding. To make an activating flux, powder ingredients such as oxides, chlorides, and 22 to produce a paint-like constituent. Before welding, a thin layer of the flux was brushed on to the surface of the joint to be welded [7,8]. The Paton Welding Institute of Kiev (Ukraine) was the first to develop this process called the activated TIG welding (ATIG) process. Activated TIG enhances customary GTAW, by expanding the single pass joining thickness from 6 to 10 mm for stainless steel.

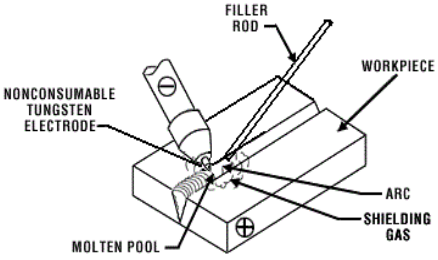

Fig1 A-Tig welding process

Taguchi strategy was created as a optimization process system by Genichi Taguchi. This approach provides the design engineers with a systematic and efficient method for determining nearoptimum design parameters for performance and cost. Additionally, the optimum working conditions determined from the laboratory work can be reproduced in the real production environment [9,10]. Various steps of Taguchi method are shown in Fig 3.

Thus, in this review, an attempt has been made to improve the above parameters of ATIG welding for notch tensile test of ASTM/UNS S32205 DSS welds utilizing Taguchi orthogonal array (OA) experimental design and other factual instruments, for example, Analysis of Variance (ANOVA) and Pooled ANOVA strategies [10].This investigation assumes significance, as no orderly review has been accounted for up until now, to break down the impact of process parameters of ATIG welding to acquire deisrable tensile strength of DSS joints.

2. EXPERIMENTAL WORK

2.1. Base metal

The base metal utilized as a part of this review is a duplex stainless steel (ASTM/UNS: S32205), which chemical composition is exhibited in Table 1. The microstructural feature of the base metal exhibits a duplex structure with embedded grains of austenite (white) and ferrite (brown), as shown in Fig 2.

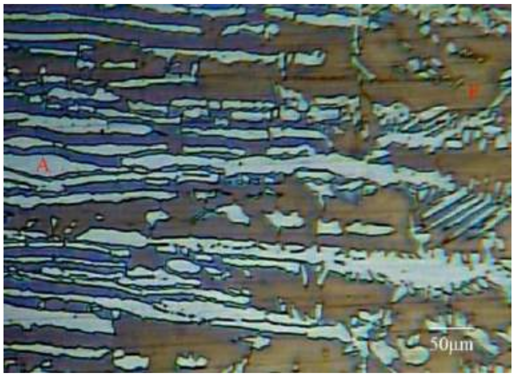

Fig. 2. Microstructure of base metal (A: Austenite; F: Ferrite)

2.2. Process parameters and their levels

The independently controllable predominant process parameters of ATIG welding that control toughness of DSS joints are identified as electrode gap, travel speed, current and voltage. The ranges of the parameters are chosen in view of the few test trials and are recorded in Table 2.

2.3. Taguchi design of experiments (DOE)

Taguchi strategy is a deliberate use of plan and examination of tests with the end goal of outlining and improving product quality. The Taguchi strategy utilizes a unique OA to study all the outlined variables with at least trials. Orthogonality means that each factor is independently evaluated and the effect of one factor does not interfere with the estimation of the influence of another factor [11]. Table 2 demonstrates the key four ATIG welding process parameters examined at the three test levels. In the following stride, a framework was composed with the suitable OAs for the chose parameters and their levels.

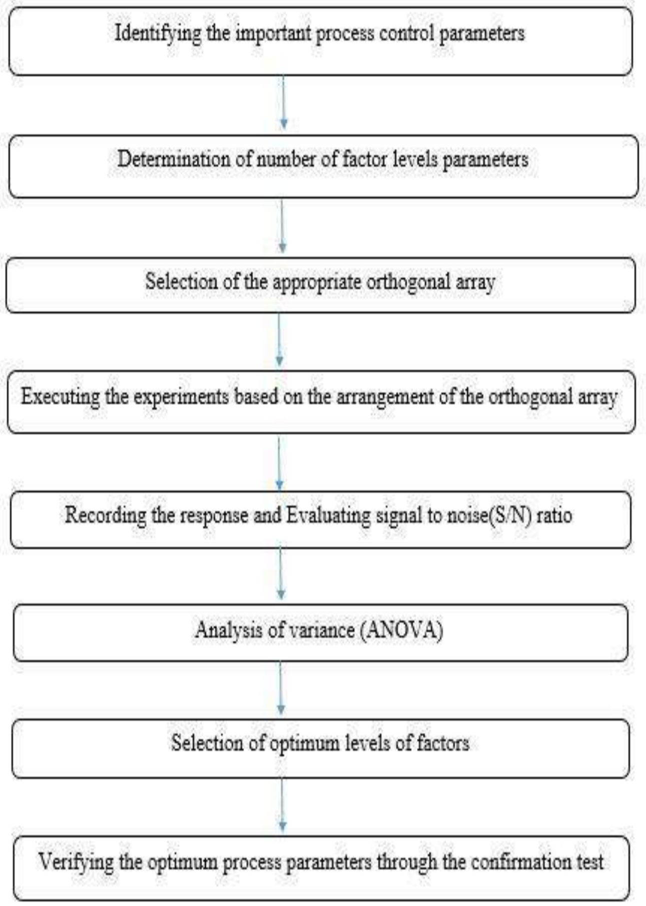

Fig 3. Various steps in Taguchi method

Table 1 Chemical composition (wt. %) of base metal

Material	C	Mn	P	S	Si	Cr	Ni	Ti	Mo	Cu	N	Fe
Duplex stainless steel (ASTM/ UNS: S32205)	0.014	1.36	0.018	0.001	0.4	22.3	5.68	0.006	3.1	0.14	0.18	Bal

The OA experimental design strategy was resolved a test arrange, L_9 (3^4) (Table 3), since it is the most reasonable for the conditions being examined; for the four parameters, each has three qualities. The L9 (34), which demonstrates 9 experimental trials, is one of the standard orthogonal trial arrangements of Taguchi. The request of the examinations was gotten by embedding the parameters into the sections of OA, L_9 (3^4), chosen as the experimental plan listed in Table 3, but the order of experiments was made randomly to avoid the noise sources which had not been considered initially and took place during an experiment and affected the results in a negative way.

Taguchi strategy prescribes the signal-to-noise (S/N) ratio, which is a performance characteristic, rather than the normal value. Ideal conditions were resolved utilizing the S/N ratio from experimental outcomes [10]. There are three S/N ratio of basic interest for the improvement of static issue, i.e., the higher the better (HB), the lower the better (LB), and the nominal the better (NB). The larger S/N ratio represents to better performance characteristic.

The mean S/N proportion at each level for different variables was figured. Besides, the optimal level, that is the biggest S/N ratio among every one of the levels of the factors, can be resolved. A statistical Analysis of variance (ANOVA) was additionally performed to show which handle parameters are statistically significant; the ideal blend of the process parameters can then be reproduced. In order to validate the methodology, the confirmation experiments must be performed using optimal process parameters to verify the predicted results. In the event that the anticipated outcomes are affirmed, the recommended optimum working conditions should be received.

2.4. Conducting the experiments as per design matrix

Rolled plate produced using 6 mm thick base metal was cut into little required plates (100 mm _ 150 mm) by abrasive cutters and after that they were ground. Square butt joint design, as appeared in Fig 4, is set up to manufacture the joints by tungsten inert gas (TIG) welding utilizing activated flux without expansion of any filler material In this review, the welding was done utilizing a normal marked activated flux. The branded activated flux is a penetration enhancing activating flux. It is made of different kinds of inorganic oxide materials which change the surface activity and primarily reduces the heat energy required for penetration. Surface active elements in the weld pool ensure that the joint penetration increases drastically. Arc is constricted by the flux coated on the surface of the plate, and the concentrated arc energy increases weld penetration. The initial joint setup was acquired by securing the plates in position utilizing tack welding. The direction of welding was typical to the moving heading. All important care was taken to cancel joint distortion, and the joints were made after the plates were clipped in a welding installation. The welding was completed utilizing a TIG welding machine.

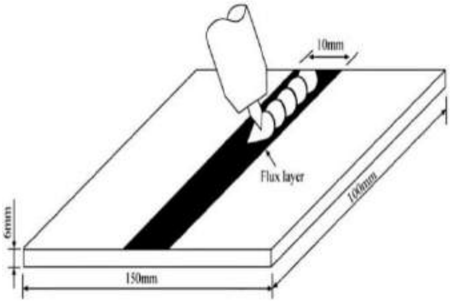

Fig4 Joint configuration

2.5. Evaluating the signal-to-noise (S/N) ratios

In this study, an L_9 (3^4) OA with 4 columns and 9 rows was used. This array can handle three-level process parameters. Nine experiments were necessary to study the welding parameters using the L_9 (3^4) OA. In order to evaluate the influence of each selected factor on the responses, the S/N ratios for each control factor was calculated.

Taguchi technique utilizes the S/N ratio to gauge the quality characteristics deviating off from the desired esteem. The S/N ratios are diverse as indicated by the kind of characteristics. Reasonable S/N ratio must be picked utilizing knowledge, expertise and understanding of the procedure. At the point when the objective is settled and there is a trivial or missing signal element (static plan), it is conceivable to pick the S/N ratio, depending upon the objective of the outline. By using the below equation S/N ratio can be calculated.

$$\frac{S}{N} = -10\log\left(\frac{1}{n}\sum_{i=0}^{n}\frac{1}{Y_i^2}\right) \quad (1)$$

Table 2 Process parameters and their levels

Parameters/factors	Units	Notation	levels					
			Original			coded		
			Low	Medium	High	Low	Medium	High
Electrode gap	mm	A	1	1.5	2	1	2	3
Travel speed	mm/min	B	100	120	140	1	2	3
current	Ampere (A)	C	140	160	180	1	2	3
Voltage	Volts(V)	D	14	16	20	1	2	3

Trail no	Parameters / Factors							
	Electrode Gap [A] / (mm)		Travel Speed [B]/ (mm.min^{-1})		Current [C]/ Ampere(A)		Voltage [D]/ volts (V)	
	Original value	Codded value	Original value	Codded value	Original value	Codded value	Original value	Codded value
1	1	1	140	3	180	3	20	3
2	1.5	2	140	3	140	1	16	2
3	2	3	140	3	160	2	14	1
4	1	1	120	2	160	2	20	3
5	1.5	2	120	2	180	3	16	2
6	2	3	120	2	140	1	14	1
7	1	1	100	1	140	1	14	1
8	1.5	2	100	1	160	2	16	2
9	2	3	100	1	180	3	20	3

Table 3 Experimental Layout using L_9 (3^4) orthogonal array (OA) with coded and original level values.

Where S/N, defined as the signal-to- noise ratio (S/N unit: dB); n is the number of repetitions for an experimental combination; and Yi is a performance value of the ith experiment. Table 4 shows the experimental results for S/N ratio.

Notch tensile test and the corresponding S/N ratios calculated from Eq. (1). The total mean S/N ratio for tensile test is η_m =(total S/N ratio)/ (number of experimental runs) = 58.88 dB.

It is then conceivable to isolate out the effect of every parameter at the distinctive levels since the trial outline is orthogonal [12].Actually, the normal execution (mean S/N ratio) of a factor at certain level is the impact of the variable at this level on the mean reaction of the investigations. In the case of notch tensile test, in order to compute the average performance of the factor B at Level 1 (denoted as B1), the results for trials including factor B1 are added and then divided by the number of such trials

B_1 = (S/N_1 +S/N_2+S/N_3) / 3= (58.52+59.52+59.11) / 3 =59.05 Db

The mean S/N ratio for each level of alternate parameters can be figured similarly. The mean S/N ratio for each level of the parameters is summarized, and the S/N response table for tensile strength of weld joint of DSS is listed in Table 5. Rank 1 in Table 5shows that Current has more significant effect on the toughness of the welding joint of DSS followed by voltage, travel speedand electrode gap. Also, it is inferred that electrode gap does not have much influence on the welding toughness of DSS.

2.6 Analysis of variance (ANOVA)

The learning of the commitment of individual variables is fundamentally essential for the control of the final reaction. The ANOVA is a typical statistical system to decide the percent contribution of each variable for the experimental outcomes [13]. It is used to calculate the parameters known as sum of squares (SS), corrected sum of squares (SS'), degree of freedom (D), variance (V), and percentage of the contribution of each factor (P). Since the method of ANOVA is extremely confused and utilizes an impressive number of statistical formulae, only a brief description is given as follows.

$$SS_T = \sum_i^m \eta_i^2 - \frac{1}{m}\left[\sum_{i=1}^m \eta_i\right]^2 (2)$$

Where SS_T is the total sum of squares; m is the total number of the experiments; and hi is the S/N ratio at the i^{th} test.

$$SS_p = \sum_{j=1}^t \frac{\left(S_{nj}\right)^2}{t} - \frac{1}{m}\left(\sum_{i=i}^m \eta_i\right)^2 \quad (3)$$

WhereSSp represents the sum of squares from the tested factors; p is the one of the tested factors, j is the level number of this specific factor p; t is the repetition of each level of the factor p; and Shj is the sum of S/N ratio involving this factor and the level j.

$$V_p(\%) = \frac{SS_p}{D_p} \times 100 \quad (4)$$

WhereVp is the variance from the tested factors; and Dp is the degree of freedom for each factor.

Basically, the degrees of freedom (DOF) for OA should be greater than or at least equal to those for the parameters [10]. For example, a five-level design parameter counts for four- DOF.In this study, the experimental DOF is 8 (number of trails minus one); while parameters - DOF is 2 (number of parameter levels minus one).

Table 4 Experimental results and corresponding S/N ratio

$$SS'_p = SS_p - D_pV_e (5)$$

WhereSS'_prepresents the corrected sum of squares from thetested factors; and V_e is the variance for error.

$$P_p(\%) = \frac{SS'_p}{SS_T} \times 100 (6)$$

WhereP_P is the percentage of the contribution to the total variation of each individual factor.

The ANOVA results are presented in Table 6. As seen in Table 6, the current is the most significant factor on tensile test with contribution of 45.66%, followed by voltage with contribution of 24.39%. The travel speed and electrode gap are insignificant with contribution of 20.44% and 9.02%, respectively.

2.7 Pooled ANOVA

In the ANOVA analysis, if the commitment percent is high, the commitment of the components to that specific reaction is more. Likewise, the smaller the commitment percent is, the lower the commitment of the variables on the measured response is. In this way, another investigation is led by pooling the insignificant elements to mistake (see Table 7).The process of disregarding an individual factor contribution and then adjusting the contribution of the other factor is known as pooling [14]. The results of ANOVA after pooling for tensile strength are presented in Table 7. Pooled ANOVA values reveal that the current (30.67%) is a significant factor for the tensile strength in the ATIG welding process.

Trail no	Process parameters				Responses			S/N ratio (dB)
	Electrode Gap [A] / (mm)	Travel Speed [B]/ (mm.min^{-1})	Current [C]/ Ampere(A)	Voltage [D]/ volts (V)	Ultimate Tensile Strength			
					Trail 1 (Mpa)	Trail 2 (Mpa)	Trail 3 (Mpa)	
1	1	140	180	20	800.8	875.9	860	58.2
2	1.5	140	140	16	938.3	959.7	940	59.52
3	2	140	160	14	900.3	903.8	904	59.11
4	1	120	160	20	964.9	958	960	59.65
5	1.5	120	180	16	864.1	861	858	58.70
6	2	120	140	14	986.7	982	980	59.85
7	1	100	140	14	954	958.2	952	59.6
8	1.5	100	160	16	850	853	849	58.6
9	2	100	180	20	699.7	631.6	650	56.37

Table 5 S/N response table

Parameters	Notation	Level1	Level2	Level3	Delta(Δ) $= Maxmimum - Minimum$	Rank
Electrode gap	A	**59.25**	58.94	58.44	0.81	4
Travel speed	B	59.05	**59.4**	58.19	1.21	3
Current	C	57.86	**59.65**	59.12	1.79	1
Voltage	D	58.18	58.94	**59.52**	1.34	2

Table 6 Results of ANOVA

Character	Parameters	Degree of freedom	Sum of squares (SS)	Variance	Corrected sum of squares	Contribution %	Rank	significant
A	Electrode gap	2	1002.3	501.15	9.02	9.02	4	No
B	Travel speed	2	2326.2	1163.1	20.94	20.94	3	No
C	Current	2	5072.7	2536.35	45.66	45.66	1	Yes
D	Voltage	2	2709.6	1354.8	24.39	24.39	2	Yes
Error		0	0	0	0			
Total		8	11110.8					

2.9. Checking the adequacy of the optimum process parameters through confirmation test

Once the optimal level of the outline parameters is chosen, the last stride is to predict and check the change of the quality characteristic utilizing the optimal level of the plan parameters [12]. The S/N ratio anticipated utilizing the optimal level of the design parameters can be calculated by utilizing the underneath condition [12]:

$$\hat{\eta} = \eta_m + \sum_{i=1}^{n}(\overline{\eta}_i - \eta_m) \quad (7)$$

Where$\eta_m$is the total mean S/N ratio; η_{iis} the mean S/N ratioat the optimal level; and n is the number of the main designparameters that affect the quality characteristic. The S/N ratio predicted using the optimal ATIG parameters for tensile strength can then be obtained and the corresponding tensile strength can also be calculated using Eq. (1).

Table 8shows the comparison of the predicted tensile strength with the experimental results using the optimal conditions. There is good agreement between the predicted and experimental tensile strengths being observed. However, the improved parameters acquired for welding ASTM/UNS S32205 DSS in this review should be supported for its utilization continuously designing application and are represented below.

Table 7 Results of pooled ANOVA

Character	Parameters	Degree of freedom	Sum of squares (SS)	Variance	Corrected sum of squares	Contribution%
A	Electrode gap	(2)	(1002.3)	Pooled		
B	Travel speed	(2)	(2326.2)	Polled		
C	Current	2	5072.7	2536.35	3408.45	30.67
D	Voltage	2	2709.6	1354.8	1045.35	9.41
Error		4	3328.5	832.125		59.92
Total		8	11110.8			100

Table 8 Evaluation of predicted tensile strength the experimental result

Parameters	A	B	C	D	S/N ratio (dB)		Performance values of tensile strength (Mpa)	
	Electrode gap (mm)	Travel speed (mm/min)	Current (A)	Voltage (V)				
					Prediction	Experiment	Prediction	Experiment
Optimum coded value	1	1	2	3	61.18	59.85	1071.56	931.66
Optimum original value	1	140	160	20				

CONCLUSION

In this study the ATIG welding parameters were optimized for ASTM/UNS S32205 DSS joints to obtain desirable tensile strength and the results were analyzed in detail.

1. The current is the significant factor that affects thetensile strength of DSS welds fabricated using ATIG welding process
2. The optimum process parameters are found to be 1 mm electrode gap, 140 mm/min travel speed, 160A current and 20V voltage.
3. The confirmation experimental results for tensile strength of the welded joints is in good agreement with the data analyzed by the Taguchi method.
4. The tensile strength is found to be 931 Mpa for the joints fabricated using the optimized process parameters

REFERENCES

1. **Davis JR.**ASM specialty handbook-stainless steels. Materials Park,OH: ASM International;1996, ISBN 0-87170-503-6
2. **Farnoush H, Momeni A, Dehghani K, AghazadehMohandesi J, Keshmiri H**. Hot deformation characteristics of 2205 duplex stainless steel based on the behavior of constituent phases. Mater Des 2010;31(1):220e6.
3. **Eriksson H, Bernhardsson S.** The applicability of duplex stainless steels in sour environments. Corrosion 1991;47(9):719e27.
4. **Muthupandi V, Bala Srinivasan P, Seshadri SK**. Effect of Weld metal chemistry and heat input on the structure and properties of duplex stainless steel Weld. Mater SciEng A 2003;358(1e2):9e16.
5. Iris **Alvarez-Armas** duplex stainless steels: brief history and some recent alloys recent patents on mechanical engineering1; 2008. p. 51e7.
6. **ChernTsann-Shyi, Tseng Kuang-Hung, Tsai Hsien-Lung**. Study of the characteristics of duplex stainless steel activated tungsten inert gas welds. Mater Des 2011;32(1):255e63.
7. **Huang HY, Shyu SW, Tseng KH, Chou CP**. Effects of the process parameters on austenitic

stainless steel by TIG-flux welding. J Mater SciTechnol 2006;22(3):367e74.

8. **Tseng Kuang-Hung, Hsu Chih-Yu**. Performance of activated TIG process in austenitic stainless steel welds. J Mat Proc Tech 2011;211(3):503e12.
9. **Ozbay E, Oztas A, Baykasoglu A, Ozbebek H.** Investigating mix proportions of high strength self compacting concrete by using Taguchi method. Constr Build Mater 2009;23(2):694e702.
10. **Yousefieh M, Shamanian M, Saatchi A.** Optimization of the pulsed current gas tungsten arc welding (PCGTAW) parameters for corrosion resistance of super duplex stainless steel (UNS S32760) welds using the Taguchi method. J Alloys Compd 2011;509(3):782e8.
11. **Ross P**, Taguchi J. Techniques for quality engineering. McGraw-Hill International Editions, New York, give the press; 1988.
12. **Yang WH, Tarng YS.** Design optimization of cutting parameters for turning operations based on the Taguchi method. J Mater Process Technol 1998;84(1e3):122e9.
13. **Yang k, Teo EC, Fuss FK**. Application of Taguchi method in optimization of cervical ring cage. J Biomech 2007;40(14):3251e6.
14. **Ma Y, Hu H, Northwood D, Nie X.** Optimization of the electrolytic plasma oxidation processes for corrosion protection of magnesium alloy AM50 using the Taguchi method. J Mater Process Technol 2007;182(1e3):58e64.
15. **Outokumpu.** How to weld type 2205 code plus two duplex Stainless steel, lack of basic info? www.outokumpu.com/stainless/na.