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EVALUATION OF WELD PARAMETERS FOR OPTIMUM BREAKING LOAD BY USING INDIRECT RESISTANCE SPOT WELDING PROCESS FOR AUTO APPLICATION.

Kancha Sammaiah, Naveen Kumar M, KAMUNI VENKATESH
4.B.SANDHYA, 5.B.JAMES PRASADA RAO
Professor, Department. of Mechanical Engineering, Ellenki College of Engineering and Technology,Hyderabad
Email: kanchasmmh@gmail.com

Abstract

Spot welding is now a very established process in which two sheets to be welded are kept one over the other to get a nugget at the interface. The contact resistance at the interface dictates the quantum of heat that is generated. Indirect resistance welding is the resistance welding process where the weld force and weld current are transmitted by different electrodes unlike conventional spot welding. While weld force is applied in a similar manner as traditional direct resistance spot welding, the weld current is directed along a different path so that a critical interface can be excluded from current path and heating reduced at the bottom sheet at the same time ensuring proper nugget formation.

Trials were conducted using "statistical "design of experiments approach where 2^3 factorial designs was used . The three factors selected are weld force, weld current, and weld time. Each factor was varied with two levels and the tension shear load was taken as response criteria.

Trials were conducted and regression equations were obtained. The effect of parameters on tension shear breaking load was analyzed. This research paper reports the results of the trials and influence of weld parameters. The observations on design of spot weld which requires controlling of the ratio of weld diameter to the sheet thickness (d/t), effect of HAZ, depth of indentation, analysis of strength of joint, effect of nugget / HAZ were all discussed in detail.

Keywords: Indirect spot welding, weld nugget, Tension shear load, peel test, effect of weld parameters

Introduction

Spot welding is now an established technique and widely used for assembly of sheet metals. Two sheets are welded together at points, rather than over the entire area of contact between the parts. Cylindrical electrodes apply pressure and convey electrical current to the work pieces. The contact resistance at the metal interface is very important to decide the quantum of heat required for melting of specified volume. Resistance Spot welding is extensively used in automobile sector due to high level of flexibility, rate of production, high quality and low cost of operations. Vehicle components (body, doors etc) are made of thin sheets (0.8 to 1 mm) connected by spot welds. There are other applications in electrical and domestic appliances. The process details of direct spot welding process are shown in figure 1.

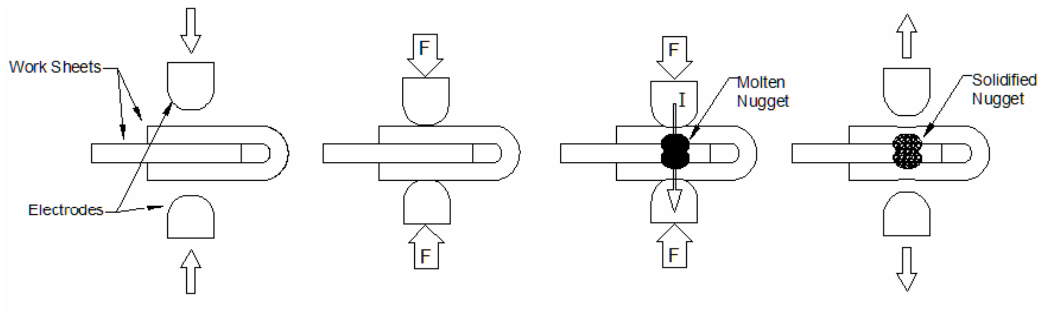

Fig. 1 Schematic diagram showing direct resistance spot welding process (DRSW)

Due to the applied force by the cylindrical electrodes during welding, the thickness of the sheets at the nugget location reduces causing indentation. Indirect resistance welding is the resistance welding process where the weld force and weld current are transmitted by different electrodes [1]. While the weld force is applied in a similar manner as traditional direct RSW, the weld current is directed along a different path so that a critical interface can be excluded from the current path and heating reduced on one side of the sheets. This can be achieved by grounding the current path through another electrode that has good contact with the work sheets. Fixture and location jig can be used to redirect the current path away from the critical inter face.

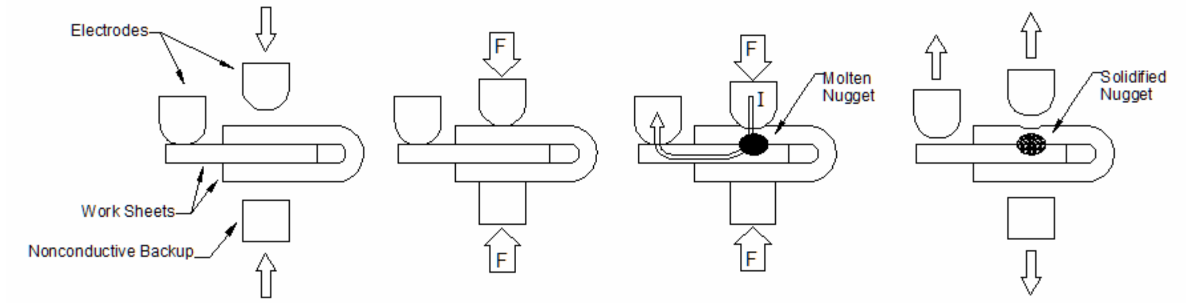

Fig. 2 Schematic diagram showing indirect resistance spot welding process. (IRSW).

The top electrodes apply the weld force, and conduct the weld current through the top sheet and interface, and then are grounded through the tertiary electrode.

2.0 Design &Development of fixture for Indirect Resistance Spot Welding process

Design criteria, like. Path of current, Load application, Indentation on sheets, Nugget size, machine parameters like Weld force, Weld current and Weld time are taken into consideration . A special fixture with less weight is manufactured to conduct the trials by using Indirect Resistance Spot Welding principle. The secondary of the transformer is connected to the top and auxiliary electrode. The minimum current path is ensured for the formation of the weld at the interface (See Fig.3) and experimental set up showed in Fig.4

Fig.3 fixture for indirect spot welding	**Fig.4 View of indirect spot welding process**

1.2 Need of Indirect Resistance spot welding

After Resistance welding the surface appearance on sheets can be critical for applications where the outer surface requires good finishing. Limiting the extent of electrode indentation is traditionally managed by controlling the heat balance and electrode size. By moving the weld nugget away from the critical surface, sheet softening and resultant indentation can be reduced.

3.0 Application of Indirect resistance spot welding

There are several industrial applications where indirect resistance welding results in less indentation on one of the sheets has many advantages

1. No rework for the spot welding operations, by which considerable reduction in cost and improved productivity can be achieved.

2 Automobile industry, Railway coaches, etc. find greater use especially for painting and appearance.

3. The process can be employed using portable indirect resistance spot welding units for critical uses.

4.0 Experimental work

4.1 Equipment

Trials were conducted on a 10 KVA Spot welding machine (3– Phase, 415 Volts, 50Hz,). This machine has a provision for adjustment of two levels of load with mechanical system. Six voltage tap settings are available for setting secondary voltage. A weld timer controls duration of current flow (see fig. 5).

Fig. 5 KVA Spot welding fixture

4.2 Material

Experiments were carried out on cold rolled carbon steel (CRCS), AISI – C1010 sheets, of 0.8 mm thickness which is having very good applications for thin sheet fabrication. The chemical composition and mechanical properties are given in table-1 and 2.

Table 1 Chemical composition for specimen,(AISI, C- 1010) - Cold rolled carbon steel (CRCS)

Element	C	Mn	P	S
Weight Percent (%)	0.1max	O.25-0.5	0.04max	0.05max

Table 2 Mechanical properties of specimen

S. No	Details of properties	Units
1	UTS	30 kg/ mm2
2	yield stress	21kg/mm2
3	Shear strength	15 kg/mm2
4	Elongation	32 – 48%

4.3 Tension – shear test specimen

Spots were made on sheets 0.8 mm thick 25mm width 75 mm length specimens. The same specimens were used for tension- shear testing. (See fig.6.).

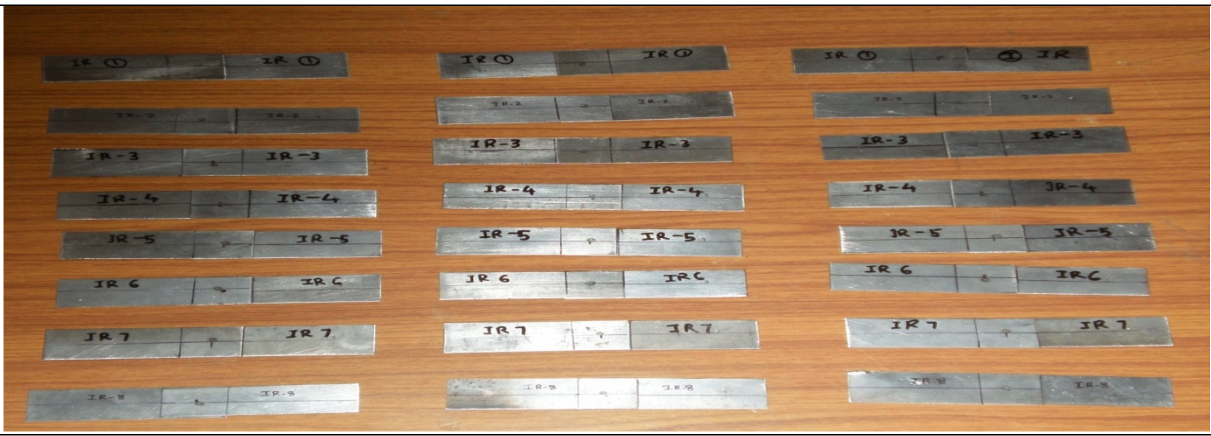

Fig. 6 Specimen samples of indirect resistance spot welding (IRSW)

4.4 Factorial design

This experiment was carried out by using 2^3 factorial design .The three factors are weld force in kgf – X1, weld current in Amps – X2, weld time in seconds – X3, and each factor was varied with two levels. Experimental design levels for the factors are given in table – 3,.

Table 3 Welding parameters in factorial design of experiment for indirect resistance spot welding (IRSW)

S. No	Welding parameters	Factor designation	Design levels	
			Lower (-1)	High (+1)
1	Weld Force-Kgf	X_1	30	45
2	Weld Current-Amp	X_2	1800	2400
3	Weld Time – Sec	X_3	0.1 Sec (5 cycles)	0.3Sec (15cycles)

Table 4 Experimental observations in coded - matrix form and parameters.

S. No	Weld Force X1 (Kgf)	Weld current X2 (Amps)	Weld Time X3 (Sec)	Tension shear Breaking load (Kgf)
1	-1	-1	-1	150
2	+1	-1	-1	208
3	-1	+1	-1	144
4	+1	+1	-1	156
5	-1	-1	+1	206
6	+1	-1	+1	153
7	-1	+1	+1	180
8	+1	+1	+1	226

4.5 Tension – shear test

The specimens were gripped in a specially designed fixture to determine the tension shear load using a 40 T- UTM (see fig.7 and 8).

Fig.7 View of tension shear test on 40 T UTM

Fig.8 for holding the specimen

4.6 Peel test

The specimen was tested by peel test using a bench vice and tongs. The nugget formation was observed for both direct and indirect spot welding. The nugget sizes were determined and the position of failure was noted. (See fig.9)

Fig.9 View of peel test

4.7 Over view of Design of Experiments

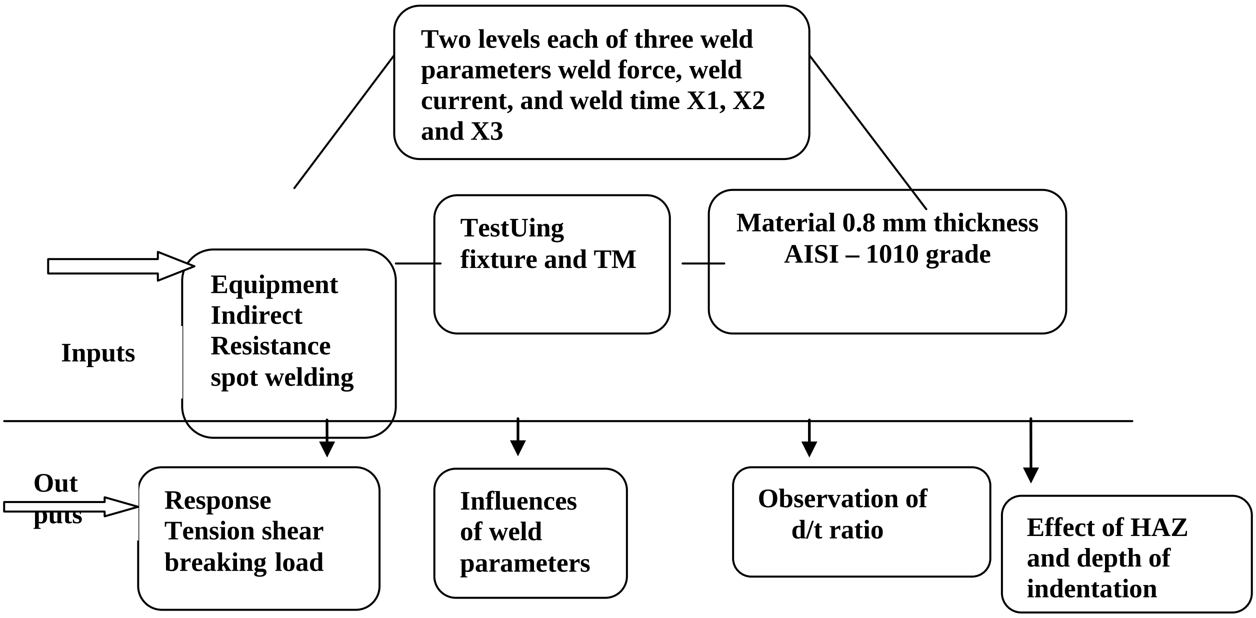

Fig. 10 Over view on design of experiment

5.0 Results and discussions:

Experimental observations, in coded- matrix form are given in table 4 for the treatment combinations conducted for indirect spot welding , where + ve and - ve values denote higher and lower levels of the corresponding parameters .Also corresponding responses (Breaking load or Tension shear load) are given for each treatment combination. To analyze the experimental data,a simple linear regression equation for response, has been assumed and is given by,

$Y = Y_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{123} X_1 X_2 X_3$

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By applying the method of least square to the data of table 5 the co-efficient βi were calculated.

□□= high - □□low / (n/2), for single set of trials, The ‘β” values are tested for significance and were substituted in the equation ,Where “n” is the number of treatment combinations (n = 8).

Positive coefficients of any factor indicate that in increasing this variable, would enhance the response, negative coefficients the opposite.

As per test of significance F (2, 7) = 4.74 considering degree of freedom for error 2 and 7 for treatment combination the test of significance was carried out (obtained from statistical tables). Hence above 4.74 all the regression Co- efficient have greater significance. Accordingly the regression equation obtained is given as:

$$Y = 178 + 15X_1 + 3.5X_2 + 26X_3 + 5.8X_1X_2 + 18.25X_1X_3 + 11.3X_2X_3 + 18.3X_1X_2X_3$$

Peel test was done to find qualitatively, the formation of nugget and nature of failure. These results were shown in table 7 and the Figures 8 show the details of nugget formation.

Table 6 gives the results of (d/t) ratio as per design requirements. Table 9-gives the observations of depth of electrode indentation on top and bottom sheet for the indirect resistance spot welding (IRSW).

Table 10 give the details of spot diameter and HAZ .

5.1 Influence of weld parameters :

From table 5 as per the regression equation and its co-efficients for indirect spot welding the influence of weld force (X1) is more significant (β_1 = 15), the interaction influence of weld force (X1) and weld time (X3) also were more significant (β_{13} = 18.3) and, interaction of weld force, weld current and weld time (β_{123} = 18.3) also were found to be significant.. Specially in this experiment observed Weld current influence is much more significant (β_3 = 26),

5.2 Observation of d/t ratio

The design of spot weld requires control of the ratio of weld diameter to the sheet thickness, d/t = 1.28 X yield stress / shear stress [5] and (appendix 9.1). Table 6, give the results as per design requirement and experimentation by peel of test 7 Indirect spot welding and the experimental results revealed as more safe design. (i.e by using data for the material, UTS = 30 kg/mm^2 , yield stress = 21 kg/mm^2, shear stress = 15kg/mm^{2}with a factor of safety = 2)

5.3 Effect of HAZ and depth of indentation

Table 10 give the details of spot diameter and HAZ for indirect spot welding observations.

5.4 Effect of nugget diameter

The nugget size is proportional to weld current and time, The nugget sizes measured after peel test revealed satisfactory results and are adequate for several applications. (Refer table 7 and see fig .9

5.5 Effect of hardness at the nugget, and HAZ:

Based on the hardness test results (Refer table no 8) the hardness values at the nugget and HAZ for indirect resistance spot welding are not very high. Also visual examination in HAZ showed no cracks.

6.0 Conclusion

1. Indirect spot welds under optimum welded conditions with in the range selected by design of experiments gave very good tension- shear breaking loads.
2. Indirect spot welding carried out by using the specially designed tooling revealed satisfactory welds could be obtained for 0.8mm thick cold rolled carbon steel.
3. Though the tension- shear breaking loads are lower for indirect spot welds (for the optimum conditions with in the range selected) the using design of experiments and the magnitude of load are adequate for majority of Industrial applications. This is confirmed by (d/t) ratio calculations as well as by peel test results.
4. The indentation obtained for indirect spot welding on one side of the sheet is negligible and is satisfactory for any type of painting requirements. This also gives good appearance.
5. It is concluded that the design of experiments approach was very effective in finding the optimum welding conditions for indirect spot welds.

7.0 Acknowledgement

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8.0 References

[1] Kevin R. Chan [1], Pete Edwards [2] SMWC-DETROIT -2006, Lowering cost by simulating design of complex welds. Design of an indent free, indirect resistance projection hem weld on AHSS using simulation soft ware. Huys welding strategies Ltd. Weston, Ontario Canada. Honda Engineering North America inc. Marysville, Ohio USA, Fig.1 and 2, pp. 1 to 3

[2]. M.L Santella, S.S Babu , B.W . Riemer , and Z.Feng Influence of Microstructure on the properties of Resistance spot welds [1] ,Oakridge National Laboratory , Oakridge ,T N 37391, USA and Edison welding institute Columbus, OH 43221-USA. Sponsored by the division of material sciences US department of energy(under contact). Reference no: DE-AC05-960R22464

[3]. Yongjoon Cho, Insung Chan, and Heuibom Lee (yongjoon@hyundai- motor.com) – 26 AUGUST 2006. Single sided Resistance spot welding for Auto body Assembly Single side access holds promises for application that normally are difficult to resistance spot weld such as hydro formed and closed section parts.

[4]. March Taylor, Success with single sided Resistance spot welding, www.bodyshopbusiness.com/bb/bbo10634.htm

[5]. Design of weld , pp. 452 to 453 Welding technology and design, author V.M. Radhakrishan, revised 2nd Edition 2005,New Age international publishers.

[6]. Davies.ed, The design and analysis of Industrial experiments (long man group limited New York, 1978 2nd Edition London) and Design and analysis of experiments by Douglas C. Montgomery.

[7]. Tange ,Toshiyuki, Etoh,Hideyuki, Indirect spot welding method , publication date 07/09/1991 doc.type and number, United states patent 5030814 http//www.free patent on line .com /5030814 fig .2 , sheet of 1 of 5 ,indirect spot welding method, pp. 1 to 8.

[8].Swantec Software and Engineering Aps, Denmark, www.swantec.com, www.metal forming Technology.com Bangalore, India.

[9]. Lee, yung –Li, Wehner; Morrissett; Thomas, dated Feb 11, 1997, Test Fixture for spot welds US patent number : 5,602,341, testing the strength of resistance spot weld connecting two test strips comprising two identical clamps , pp. 1 to 6.

[10]. Spot welding data, optimum conditions schedules for spot welding low carbon steels -SAE 1010. www.cmwinc.com/catlog_pdfs/136.pdf

[11].H.Nishibata,S.Kikuchi,M.fukumoto,single side resistance spot welding process for joining pipes and sheets-Quaterly journal of the japan welding society march 2016

[12].Insung Chang,Heuibom Lee,single sided resistance spot welding for auto assembly Quaterly journal of the japan welding society ,85(8);26-29,august 2009

[13].Muneo matsushita,Development of Single side ressitance spot welding technology applying in process welding current and electrode force controls ,Welding international ,volume 30,2016-issue 12,(JEE technical reportn0.20,Jan 2015)

[14].Gajana S..A review on effect of process parameters of ressitance welding ,5th International conference on recent trends in Engineering science &mgt.ICRTEM -16,during 9th -10th December 2016

[15].MATSUSHITA Muneo,Development of Next generation resistance spot welding Technologies contributing to auto body weight reduction ,JFE Technical report No.18-march 2013

[16].SM Manladan,A review on the application of resistance spot welding of automotive sheets JET ,Journal of Engineering and Technology Vol.10(2) 2015,20-37

[17].MADA-Resistance Welding – Fundamentals of small parts resistance welding-MIYACHI –UNITECH,page No: 1/8 to 8/8

Table 5 Regression equation and coefficients.

Trial	Factors			Tension – shear Breaking load (Y)	Treatment combinations	Coefficients	Values	Remarks
	X1	X2	X3					
1	30	1800	0.1	150	1			
2	45	1800	0.1	208	X_1	β_1	15	**Weld Force More effective**
3	30	2400	0.1	144	X_2	β_2	-3.5	
4	45	2400	0.1	156	X_1X_2	β_{12}	5.75	
5	30	1800	0.3	206	X_3	B_3	26	**Weld time More effective**
6	45	1800	0.3	153	X_1X_3	β_{13}	0.8	
7	30	2400	0.3	180	X_2X_3	β_{23}	11.25	**Weld ccurrent and weld time more effective**
8	45	2400	0.3	226	$X_1X_2X_3$	β_{123}	18.25	**Weld force, weld current, and Weld time, are more effective**

Note: General equation and calculation methodology for coefficients:

$Y = Y_0 + \square_1 X_1 + \square_2 X_2 + \square X_3 + \square_{12} X_1X_2 + \square_{13} X_1X_3 + \square_{23} X_2X_3 + \square_{123} X_1X_2X_3$□

□□□ = □□ high - □□ low / (n/2) , for single set of trials, □□□ high $= Y_2 + Y_4 + Y_6 + Y_8$ and □□ low $= Y_1 + Y_3 + Y_5 + Y_7$

□□ = □ (Y - Y_o)^2 / n - 1 , Y = Y_0 = □□□ shear load , β^r = coefficients ,

n = number of trials ,Test of significance F (2, 7) = 4.74 (from statistical tables)

$Y = 178 + 15X_1 + 3.5X_2 + 26X_3 + 5.8X_1X_2 + 18.25X_1X_3 + 11.3X_2X_3 + 18.3X_1X_2X_3$□

Table 6 Observations of d/t ratio.

Yield stress as per AISI 1010	As per design requirement	As per experiment by peel test
	d/t Ratio for	d/t Ratio
21 kg/mm2 (maximum)	0.9	1.9 / 0.5 = 3.8 (considering minimum nugget diameter)

Remarks: Very safe as per design requirement

Table 7 Details of peel test results.

S.No	Weld Force X1 (Kgf)	Weld current X2 (Amps)	Weld time X3 (Sec)	Nugget diameter D (mm)
1	30	1800	0.1	2.1
2	45	1800	0.1	2.2
3	30	2484	0.1	1.9
4	45	2484	0.1	2.3
5	30	1800	0.3	2.4
6	45	1800	0.3	2.3
7	30	2484	0.3	2.2
8	45	2484	0.3	2.4

Table 8 Details of hardness test results.

S .No	Details of the average Hardness in Hv (Test results from 8 nos of specimen samples)		
	At the Nugget zone	At the HAZ	Parent material zone
1	215	195	155

Table 9 External Observations of depth of indentation on top and bottom specimens

Trial	Depth of indentation	
	Top sheet (mm)	Bottom sheet (mm)
1	0.03	0.01
2	0.04	0.01
3	0.030	0.01
4	0.05	0.01
5	0.035	0.01
6	0.040	0.01
7	0.045	0.01
8	0.06	0.015

Table 10 Details of observation of spot diameter and HAZ for top and bottom specimens.

Trial	Top side Sheet details		HAZ at Bottom sheet (change of colour indication in mm)
	Spot diameter(mm)	HAZat top sheet (mm)	
1	1.9	2.0	2.1
2	1.7	2.8	2.7
3	1.3	2.5	2.5

4	1.6	2.4	2.2
5	2.0	3.5	2.6
6	2.2	3.0	2.3
7	2.1	3.4	2.4
8	2.6	3.8	2.1

9 - Appendix - Calculations

9.1 - Calculations for the d/t ratio for the tested specimen of direct and indirect welding [5].

Design of weld with reference to Welding technology and design; author V.M. Radhakrishan, the ratio of d/t = 1.28 (yield stress / shear stress). The bending stress in the spot weld by considering the weld nugget features are d = diameter of the weld nugget and t = thickness of the weld nugget

Bending stress = p / d t

= shear stress (d2 / 1.28 d t)

= d / 1.28 t

Or d / t = 1.28 (Bending load / Shear load)

Thus ratio of (d / t) will be governed by the maximum permissible shear strength in the spot weld and yield strength of the base material, under the assumptions on yield stress = bending stress ,

Thus we have, (**d / t) = 1.28 (yield stress / shear stress)**

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