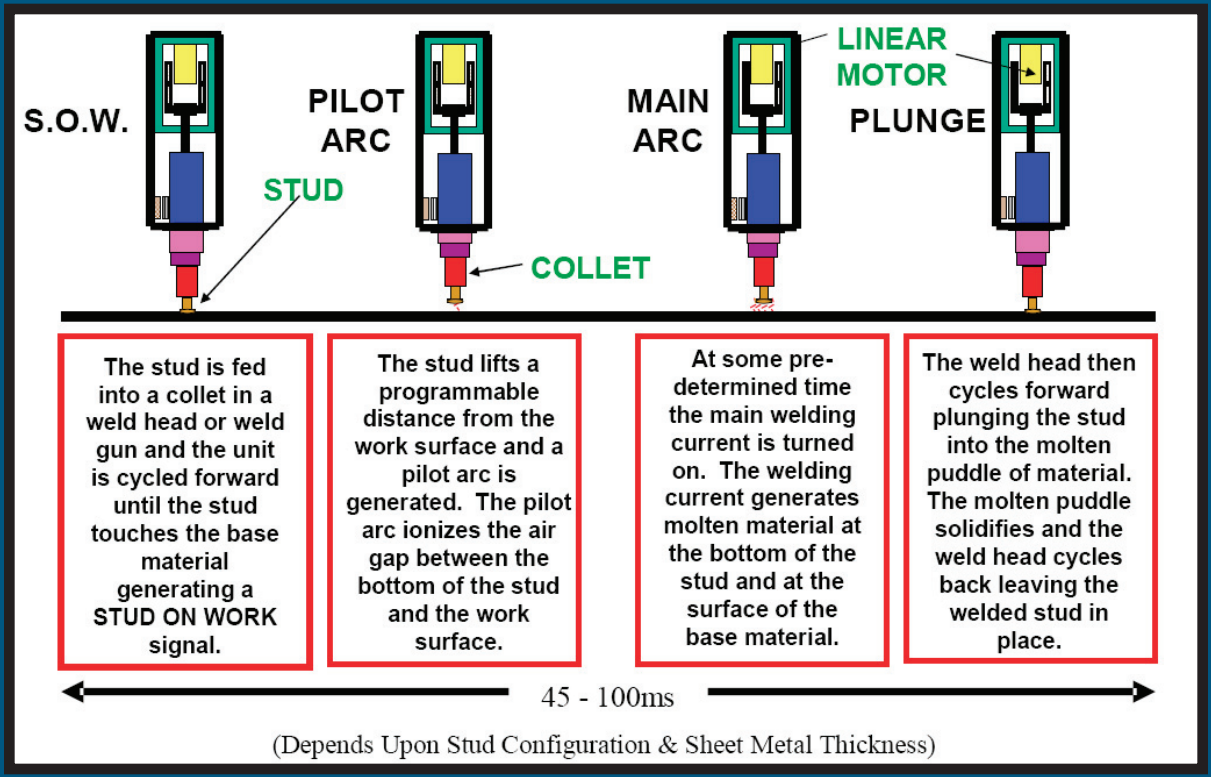

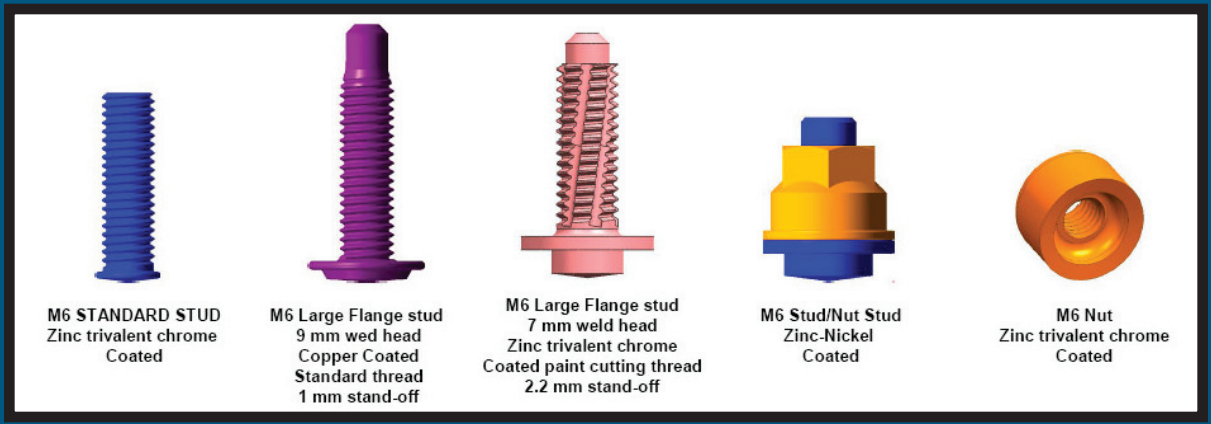

Weld Lobe Development and Assessment of Weldability of Common Automotive Fasteners (Studs and Nuts) using Drawn Arc Welding Process

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Weld Lobe Development and Assessment of Weldability of Common Automotive Fasteners (Studs and Nuts) using Drawn Arc Welding Process

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1.0 Introduction

Drawn arc welding (DAW) is a well established process for attaching fasteners (studs and nuts) to a variety of material type, thickness and coating combinations in automotive construction. The application of drawn arc welding is consistent with new automotive designs and manufacturing strategies that continually focus on ways to reduce costs. This is provided by a combination of short cycle time for fastener attachment (high productivity) and adaptability to automation. Technological improvements in drawn arc welding equipment have resulted in increased application of the process. However, there are concerns whether stud/nut welding can be performed on a consistent basis to the new advanced high strength materials like dual phase steel and press hardened (hot stamped boron) steels. This study was conducted to determine the feasibility of welding fasteners to galvannealed coated cold rolled mild and dual phase (DP 980) steel and aluminum silicon coated hot stamped boron steel, compare performances with the above mentioned steels, and develop weld matrices for specific stud/nut to sheet material combinations.

The principal objective was to determine the feasibility of welding various fasteners to different base materials and also develop weld lobe for the particular fastener/material combination.

2.0 Drawn Arc Welding Process

Let us examine the basic drawn arc welding sequence: As illustrated in Figure 1, the fastener, in this case illustrated as a weld stud, is held in the tool by a spring fingered device often referred to as a collet, or chuck.

The welding tool is then positioned against the work piece, completing what is commonly known as a stud on work signal. After receiving this signal the control begins a number of very precise timing functions. A pilot arc current is allowed to flow through the work piece and stud while the stud is still on the work piece. Once this current flow is established, usually in a matter of microseconds, the control turns on another power supply which energizes a linear motor, or servo motor, inside of the welding tool (commonly referred as weld head). This linear motor is mechanically linked to the fastener to be welded. As the linear motor is energized it begins pulling the stud away from the work piece. As the stud is drawn away from the work piece, the pilot arc current serves to ionize the air gap created in this sequence. The maximum distance that the fastener is drawn away from the work piece is pre-programmed, dependant on a number of variables such as; fastener design (geometry, diameter), material composition, coating, and base material thickness. Any potential contamination of the work surface must also be considered when establishing this optimum lift dimension. Once the fastener is moved to its furthest point away from the work surface, a much more robust current, often hundreds of amperes, begins to flow across the ionized gap. This high current, commonly referred to as the weld current, creates the arc which begins melting the fastener head surface and the surface of the work piece (sheet metal). After a predetermined period of arc time (weld time), dependant on some of the variables discussed earlier, the fastener is then brought back into contact with the molten surface of the work piece. The arc process is complete and the fastener is held in the proper place as the molten metal solidifies. While this drawn arc stud welding process took a minute or two, the average weld cycle time from start of welding to completion of welding averages around 100 milliseconds. During this extremely short weld cycle, the state of the art welder control is monitoring the critical elements of the cycle every 70 micro seconds and instantaneously adjusting the parameters to match a preprogrammed reference value. Using a closed loop feedback system, this parameter monitoring and adjustment virtually assures optimum fusion of the fastener to the work piece.

3.0 Equipment Specifications

Typical drawn arc welding system components are shown in Figure 2. The specification of the equipment that was used to perform welding is mentioned below.

DCE (Digitally Controlled Energy) 1500 Welder Control

Dimensions:	965mm H x 560mm W x 565mm D
Mounting:	Freestanding with locking wheels
User Interface:	Graphical, Menu driven
Construction:	Modular, Fiber Optic Communications
Thermal Rating:	130 A RMS
Weight:	100kg (220 lbs)
Input Voltage:	480vac 3phase (575vac optional)
Welding Current:	100 to 1500 amperes (10A increments)
Welding Process:	Short Duration Drawn Arc
Welding Time:	6 to 100ms (1ms increments)
Power Supply:	High frequency switching (SMPS)
Control Interface:	32 Input 24vdc/ 32 Output Discrete
Network:	DCE Link via Ethernet (optional)
Optional Int.:	DeviceNet, Control Net, Profibus,
Weld Schedules:	127 per outlet maximum
Interbus-S Weld Outlets:	5 (standard)
Enclosure:	NEMA 1(IP 23)
Process Control:	Closed loop utilizing arc voltage, weld current and linear displacement feedback. Built-in self compensation features including actual weld energy monitoring.

ETF Series Vibratory Stud Feeders (Dual stage hopper)

Dimensions:	1384mm H x 648mm W x 693mm D
Weight:	166kg (365 lbs)
Controls:	Microprocessor / Pneumatic
Air Source:	5.5 bar (80 psi) minimum (non-lubricated)
Interface:	Fiber optic via weld control
Mounting:	Freestanding with leveling feet
Feed Rate:	45 studs per minute nominal
Stud Capacity:	34L (1.2 cubic ft.)

LM (Linear Motor) Weld Head

Dimensions:	350mm L x 127mm H x 90mm W (nom.)
Weight:	5.5kg (12 lbs)
Head Stroke:	50mm
Compensation:	12mm maximum
Construction:	Stainless Steel / Aluminum Body
Mounting:	Quick mount 2 section wedge
Operation:	Linear Motor / Optical Encoder Feedback
Interface:	Self contained multi-cable including weld power, Pneumatics and control signals. (feed tube separate)

4.0 Experimental Procedure

Five different types of fasteners as shown in Figure 3 and three different material types were considered for this weld testing study. The fasteners that were chosen are M6 standard (Zinc trivalent chrome coated), M6 Large Flange(LF) (Copper coated – 9 mm weld head, and Zinc coated paint cutter – 7 mm weld head), M6 stud/nut (Zinc Nickel coated), M6 nut (Zinc trivalent chrome coated). The base materials were Galvannealed coated Cold Rolled mild steel (1.1 mm thick) and Dual Phase steel (DP 980 -1.0 mm thick), and Aluminum Silicon coated Hot Stamped Boron steel (USIBOR- 1.25 mm thick). Visual Inspection (non-destructive testing) and mechanical destructive testing - bend test and tensile testing were used to evaluate the stud welded joints, and Peel test and Push-out tests were used for nut welding. No shielding gas was used for either stud or nut welding. However, air blow through the nut was used at 30 liters per minute (lpm) to prevent weld spatter on the threads. The size of the hole on the base material for the M6 nut was 8.5 mm diameter. The procedure for developing the weld lobe is shown in Figure 4.

4.1 Visual Inspection

Visual inspection was used to check for the following:

Cracked weld: A weld is considered defective if the weld stud or adjacent steel part is cracked in the weld area or adjacent to the weld area.

Holes: Welded parts shall be free of holes or burn-through. Parts that contain holes that extend through any of the welds or sheets are considered non-conforming.

Flash in the external threads: Drawn arc welded fasteners with threads shall be free of flash or spatter on the threaded sections. Fasteners that exhibit flash or spatter on the threaded section are unacceptable.

For nut welding three additional criteria's were evaluated:

Thread Distortion: The weld nut attachment is considered defective if the top of the weld nut is indented to the extent of causing distortion of the thread or of changing retaining torque characteristics weld nuts, screws or bolts.

Flash in Internal Threads: The weld nut attachment is defective if the weld flash in the threads causes excessive variations in the assembly driving torque values. In addition, the weld nut attachment is considered defective if the weld flash interferes with the application of bolt into the nut.

Alignment: The weld nut attachment is defective if the thread major diameter is in interference with the clearance hole in the adjacent part it is welded.

4.2 Bend Test for Stud Welding (Simulated Manual Fatigue Test)

Secure the welded sample in the appropriate fixture. See Figure 5. Place appropriate size tube over stud. Tube should be 18-24 inches in length and the inside diameter should be 5% greater than the major thread diameter of the stud. Apply simulated bending fatigue motion to the stud through a 120° arc until the stud separates completely from the base material, or the stud itself breaks. When the stud is removed from its base material by an oscillating side-to-side motion, a button will be formed on the head of the stud. The button is that part of the weld, including all or part of the weld nugget that tears out in a bend test. See Figure 6. The average button diameter is calculated by adding the measurement of the major axis to the measurement of the axis perpendicular to the first axis and dividing by 2. The weld matrix was summarized using acceptance criteria of >70% of the fused area as shown in Table 1.

Table 1. Summary of Acceptance Criteria

Weld Nugget Size		
Preferred	6	Stud Broke
	5	100% - 91 %
	4	90 % - 81 %
Acceptable	3	80 % - 71 %
Unacceptable	2	70 % - 61 %
	1	60% - 0%
M	Head Melted Off (Important when Weld Size = 6)	

4.3 Tensile (Pull) Test for Stud Welding

Secure the welded sample in the appropriate fixture that has a clearance hole exactly 3.0 mm larger in diameter than the stud head diameter. See Figure 7. Close jaws over stud. Apply ultimate tensile pull load normal to the plain of attachment at a rate of 2.0 inches/min. until the stud separates completely from the base material.

4.4 Peel Test for Nut Welding

The nut is either pulled or peeled from the base metal. To pass this test, the following criteria must be met: Interface fracture with weld fusion equal to or greater than 70% of the circumference face area of the welded nut (For drawn arc nut welding it is a hollow cylindrical cross-section). See Figure 8.

Weld fusion will be indicated by evidence of severe strain, distortion or partial tearing of the base metal. The fracture may be tensile-granular crystalline appearance or shear-clear wiped metallic somewhat grainy appearance.

4.5 Push-Out Test (Tensile Test)

Secure the welded sample in the appropriate fixture. See Figure 9. The hole in the back-up block should be approximately 10% larger than the outside diameter of the nut being tested. Seat properly push-out pin into the hole in the weld nut. Apply ultimate tensile push-out load normal to the plain of attachment at a rate of 2.0 in/min. Apply load until the nut separates completely from the base material. The weld matrix was summarized using acceptance criteria of >70% of the fused area as shown in Table 1.

5.0 Results and Discussion

5.1 Weld Lobe Development using Bend Test

All the fasteners were welded to the given base material with stud negative polarity. The weld current vs. weld time matrix for all the studs and the nut are shown in Tables 2 thru 16. The results of these tests clearly illustrate two very important characteristics of the drawn arc stud/nut welding to different sheet materials.

First, it is evident that the drawn arc welding process exhibits a fairly wide flexibility in welding current and weld time combinations that result in the production of satisfactory welds. These test results illustrate the fact that drawn arc welding quality is determined primarily by the proper coordination of welding current and weld time.

The second important characteristic is that the cutoff relationship between welding energy input and the weld integrity is difficult to precisely define. This is because there is a broad range of welding current and welding time at which quality welds were obtained, and within this broad range there are settings at which weld quality is consistent.

Two important observations were noticed on Hot Stamped Boron material. First, M6 nut welding on HSB, the fracture acceptance criteria was 1 under bend test, which is unacceptable. This is because shear strength of the Hot Stamped Boron steel is much higher than the strength of the weld. This leads to fracture pulling the top surface of the base material. See Figure 10. Second, the M6 LF stud with higher standoff (Figure 3-C) welded with consistency to the HSB. The molten metal produced during the welding is displaced during the plunge part of the welding process. Comparatively, during welding of M6 LF stud with 1mm stand off (Figure 3-B), the molten metal is trapped under the flange portion of the stud preventing the stud from achieving full penetration depth. This results in porosities leading to inconsistent welds. See Figure 11.

For a given fastener/base material combination, the recommended weld schedule (Table 17) is the blue highlighted point of the nine box window (150 Amps x 15 ms) (Tables 2 - 16) that was developed during the weld lobe development. See Figure 4.

Table 17 Summary of recommended weld schedule for a given fastener/base material

S.No.	Base metal type and thickness (mm)	Fastener type	Lift height (mm)	Recommended weld schedule
1	CRS – 1.1	M6 Nut	0.8	1350 A, 55 ms
2	DP Steel – 1.0	M6 Nut	0.8	1350 A, 55 ms
3	HSB Steel – 1.25	M6 Nut	0.8	1350 A, 55 ms
4	CRS – 1.1	M6 Stud/Nut	1.2	1200 A, 40 ms
5	DP Steel – 1.0	M6 Stud/Nut	1.2	1200 A, 40 ms
6	HSB Steel – 1.25	M6 Stud/Nut	1.2	1200 A, 40 ms
7	CRS – 1.1	M6 Cu LF	1.2	1350 A, 45 ms
8	DP Steel – 1.0	M6 Cu LF	1.2	1350 A, 45 ms
9	HSB Steel – 1.25	M6 Cu LF	1.2	1450 A, 40 ms
10	CRS – 1.1	M6 Std	1.2	900 A, 30 ms
11	DP Steel – 1.0	M6 Std	1.2	900 A, 30 ms
12	HSB Steel – 1.25	M6 Std	1.2	900 A, 30 ms
13	CRS – 1.1	M6 Zn LF	1.2	1050 A, 40 ms
14	DP Steel – 1.0	M6 Zn LF	1.2	1050 A, 40 ms
15	HSB Steel – 1.25	M6 Zn LF	1.2	1050 A, 40 ms

5.2 Mechanical Properties of the Welds

The mechanical properties of the fasteners were evaluated in terms of tension test (or pull test) is summarized in Table 18. The sample size for the tensile test was around 50. The recommended weld schedule for a given fastener/base material combination are shown in appropriate tables.

Table 18 Summary of the Mechanical Properties for Different Fastener/Base Material

S.No.	Base metal type	Base metal thickness (mm)	Fastener Type	Average Pull Strength (lbs)	Fracture Mode
1	CRS	1.1	M6 Nut	2655	Base metal
2	DP Steel	1.0	M6 Nut	3014	Base metal
3	HSB Steel	1.25	M6 Nut	2120	Weld
4	CRS	1.1	M6 Stud/Nut	1494	Base metal
5	DP Steel	1.0	M6 Stud/Nut	1809	Base metal
6	HSB Steel	1.25	M6 Stud/Nut	2007	Base metal
7	CRS	1.1	M6 Cu LF	1839	Base metal
8	DP Steel	1.0	M6 Cu LF	1951	Base metal
9	HSB Steel	1.25	M6 Cu LF	2373	Base metal
10	CRS	1.1	M6 Std	1449	Base metal
11	DP Steel	1.0	M6 Std	2022	Base metal
12	HSB Steel	1.25	M6 Std	2158	Base metal
13	CRS	1.1	M6 Zn LF	1478	Base metal
14	DP Steel	1.0	M6 Zn LF	1961	Base metal
15	HSB Steel	1.25	M6 Zn LF	1916	Base metal

6.0 Conclusions/Summary

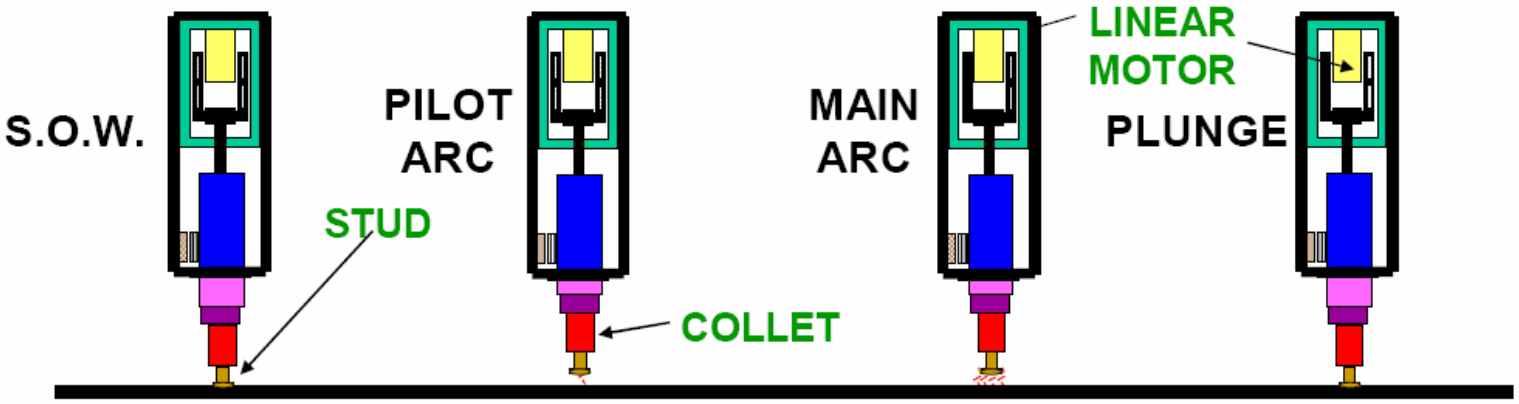
Based on the results obtained from this study, the following conclusions can be drawn:

- The fasteners chosen for this study can be welded to the galvannealed coated cold rolled mild and dual phase (DP 980) steels and aluminum silicon coated hot stamped boron steel.
- Large Flange stud with higher standoff is the recommended stud for welding to hot stamped boron material.
- The fracture mode for the M6 nut welding on hot stamped boron was a partial sheet metal fracture surface.

7.0 Acknowledgement

The authors would like to acknowledge the technical support of Metal & Machine-Shop of DaimlerChrysler, and they are thankful for the financial support provided by the Auto/Steel Partnership Material Joining Technologies Committee. For more information: www.a-sp.org.

Figure 1. Drawn Arc Stud Welding Sequence



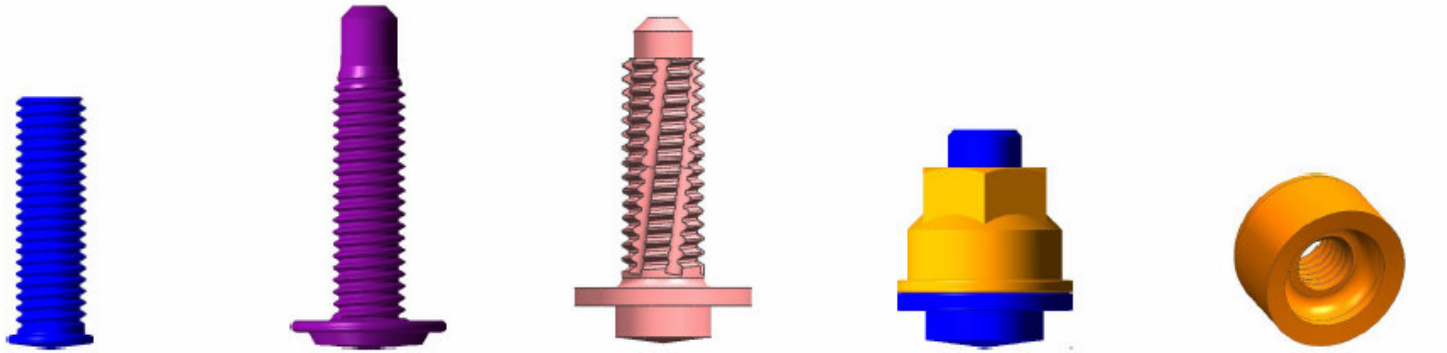
The stud is fed into a collet in a weld head or weld gun and the unit is cycled forward until the stud touches the base material generating a STUD ON WORK signal.	The stud lifts a programmable distance from the work surface and a pilot arc is generated. The pilot arc ionizes the air gap between the bottom of the stud and the work surface.	At some pre-determined time the main welding current is turned on. The welding current generates molten material at the bottom of the stud and at the surface of the base material.	The weld head then cycles forward plunging the stud into the molten puddle of material. The molten puddle solidifies and the weld head cycles back leaving the welded stud in place.

45 - 100ms

(Depends Upon Stud Configuration & Sheet Metal Thickness)

Figure 2. Stud welding system components

Figure 3. Types of fasteners used



M6 STANDARD STUD
Zinc trivalent chrome
Coated

A

M6 Large Flange stud
9 mm wed head
Copper Coated
Standard thread
1 mm stand-off

B

M6 Large Flange stud
7 mm weld head
Zinc trivalent chrome
Coated paint cutting thread
2.2 mm stand-off

C

M6 Stud/Nut Stud
Zinc-Nickel
Coated

D

M6 Nut
Zinc trivalent chrome
Coated

E

Figure 4. Weld Lobe Development Procedure

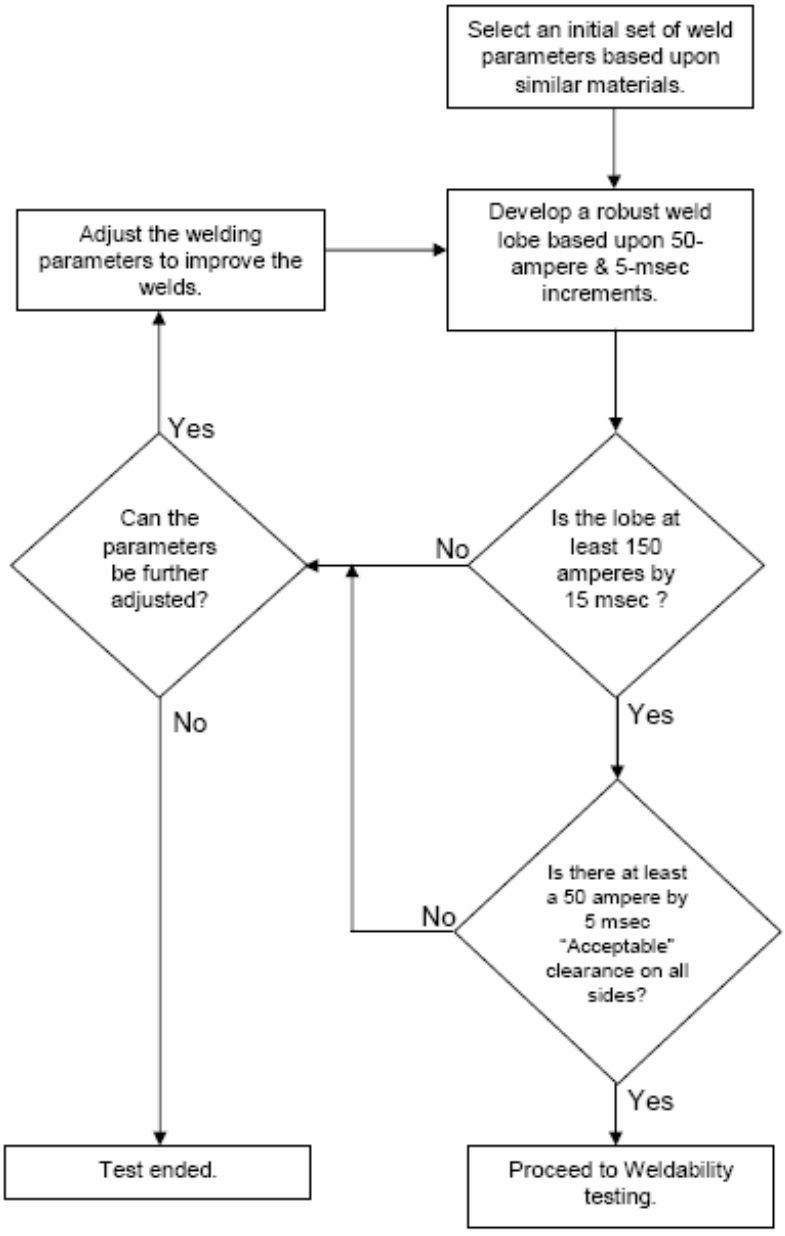


Figure 5. Bend Test (Simulated manual fatigue test)

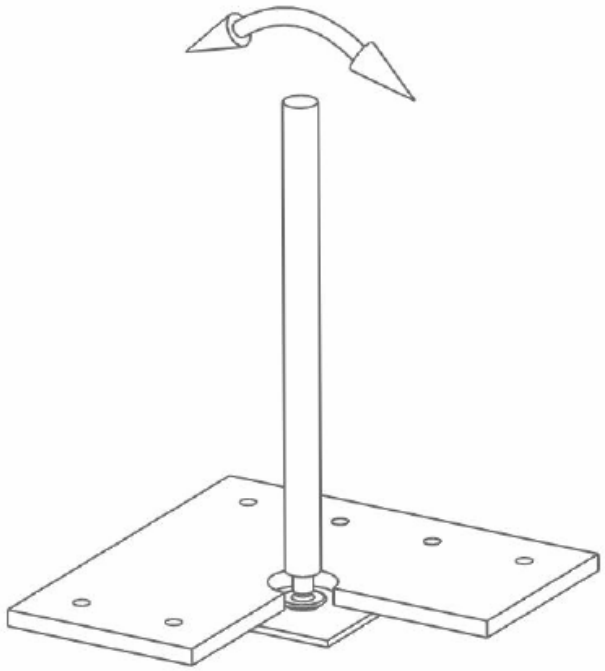


Figure 6. Weld nugget from drawn arc stud welding during Bend test

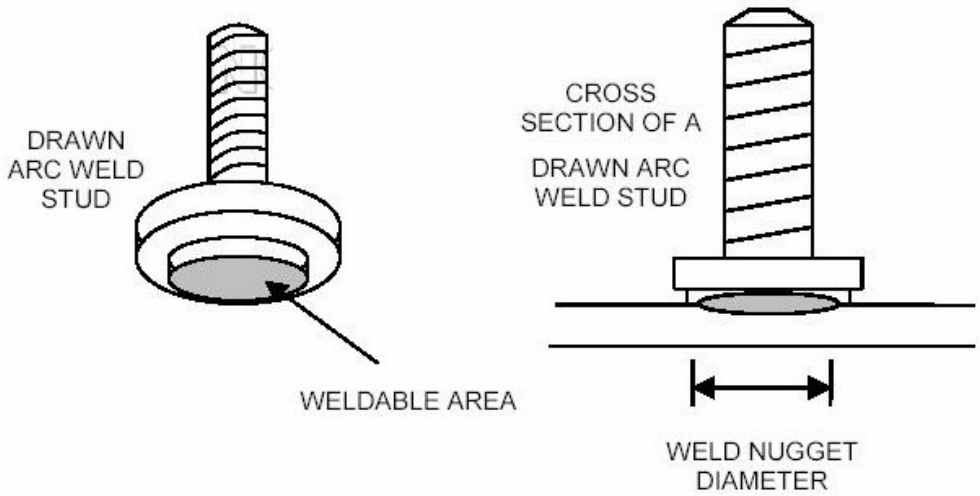


Figure 7. Tensile (Pull) test

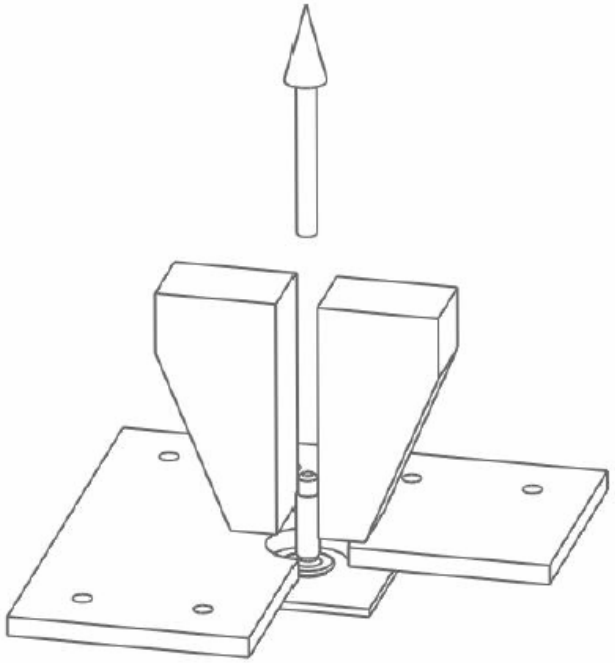
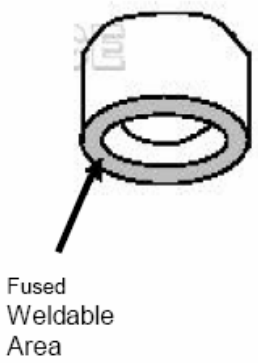
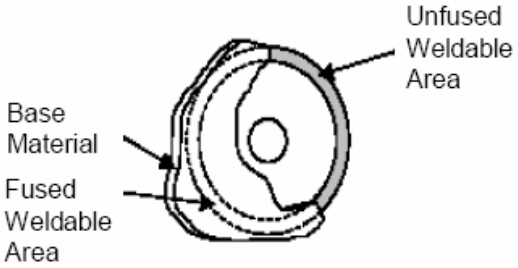


Figure 8. Measurement of Fused Area in a Drawn Arc Weld Nut



Ideal Weldable Area



Typical Weldable Area

Figure 9. Push-out (tensile test) destructive test for nut welding

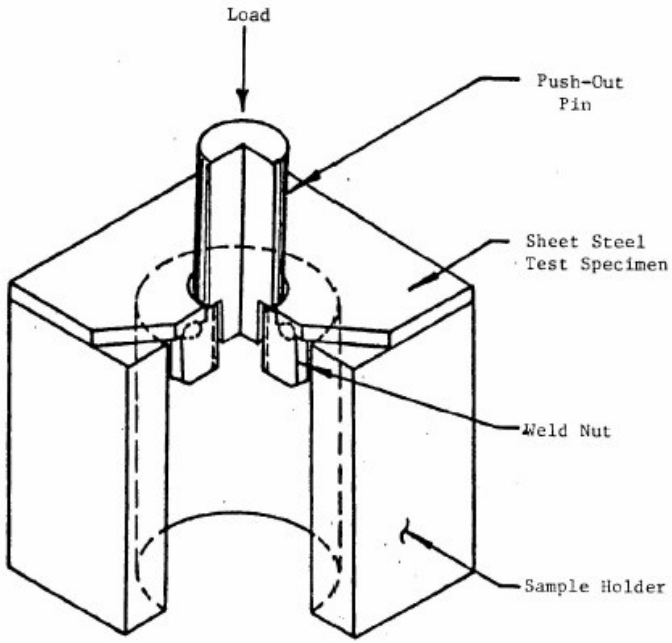


Figure 10. M6 nut welding failure mode with HSB Steel

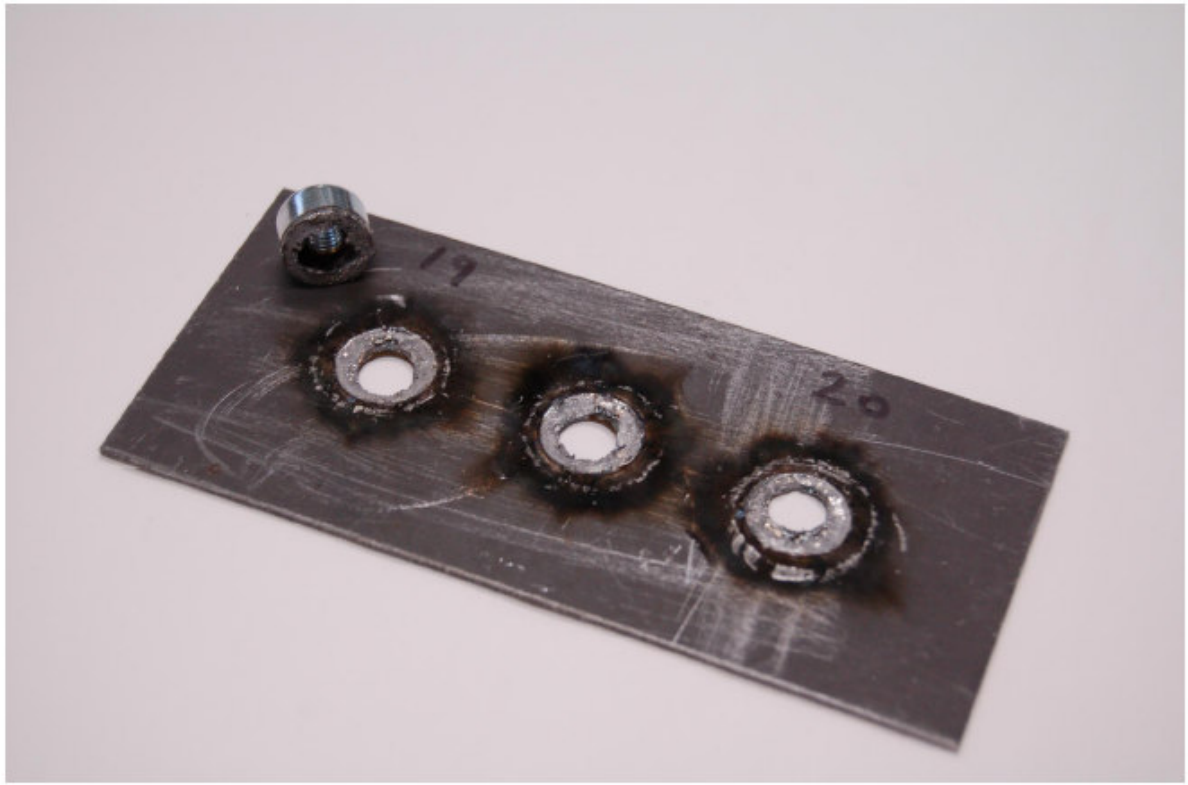
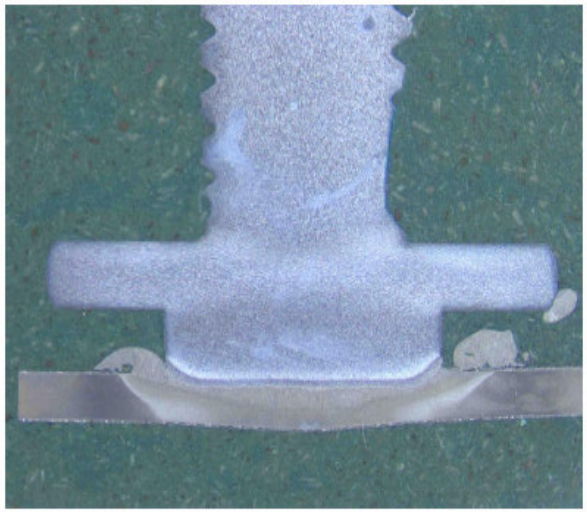
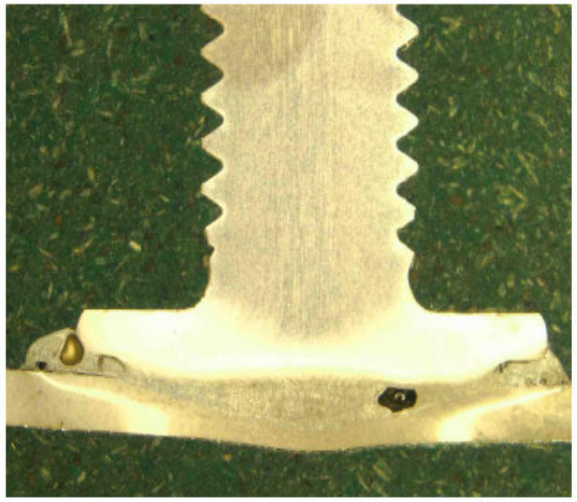


Figure 11. M6 Large Flange Stud Welded to HSB Steel



M6 Large Stud with
higher stand-off



M6 Large Stud with
standard stand-off

AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 2

FASTENER DESCRIPTION:	M6 NUT
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	
BASE MATERIAL TYPE:	Mild Steel
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.1 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400				1	1	3	5	5	5
1350				1	1	1	4	5	5
1300				1	1	1	4	5	5
1250				1	1	1	5	5	5
1200				1	1	1	1	3	5
1150				1	1	1	1	3	5
1100				1	1	1	1	1	5
1050									
1000									
950									
900									
850									
800									
750									
700									
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT
DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

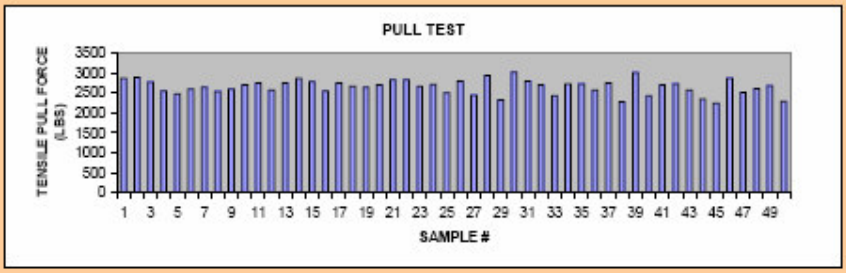
WELD PROGRAMMING PARAMETERS	
LIFT	0.80mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	
AIR BLOW	30 lpm

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1350A 55ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	2863	B	11	2752	B	21	2834	B	31	2797	B	41	2703	B	Average (X)	2655.2
	2	2891	B	12	2572	B	22	2827	B	32	2709	B	42	2730	B	Std. Dev. (s)	183.5
	3	2776	B	13	2756	B	23	2670	B	33	2432	B	43	2569	B	X-3s:	2104.6
	4	2549	B	14	2863	B	24	2713	B	34	2726	B	44	2345	B	Minimum	2250
	5	2478	B	15	2783	B	25	2507	B	35	2730	B	45	2250	B	Maximum	3015
	6	2605	B	16	2546	B	26	2801	B	36	2570	B	46	2872	B	Range	765
	7	2643	B	17	2744	B	27	2443	B	37	2753	B	47	2518	B	* Fracture Mode	
	8	2544	B	18	2662	B	28	2938	B	38	2275	B	48	2612	B	Nut	0 pcs.
	9	2596	B	19	2643	B	29	2326	B	39	3008	B	49	2682	B	Base	50 pcs.
	10	2707	B	20	2705	B	30	3015	B	40	2438	B	50	2290	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 3

FASTENER DESCRIPTION:	M6 NUT
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	
BASE MATERIAL TYPE:	DP980
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.0 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400				1	1	5	5	5	5
1350				1	1	4	5	5	5
1300				1	1	1	5	5	5
1250				1	1	1	5	5	5
1200				1	1	1	1	3	5
1150				1	1	1	1	5	5
1100				1	1	1	1	1	5
1050									
1000									
950									
900									
850									
800									
750									
700									
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

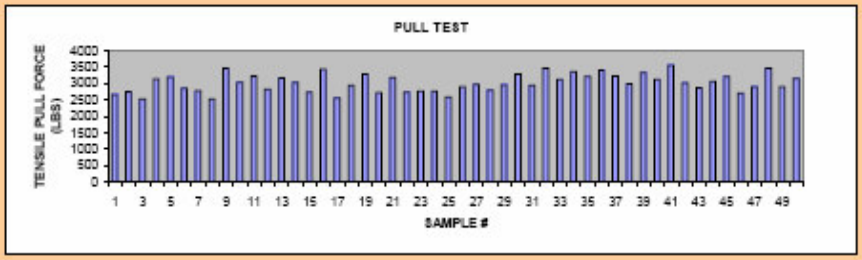
LIFT	0.80mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD	NEGATIVE POLARITY
AIR BLOW	30lpm

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1350A 55ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	2667	B	11	3232	B	21	3179	B	31	2945	B	41	3554	B	Average (X)	3014.4
	2	2754	B	12	2830	B	22	2730	B	32	3455	B	42	3015	B	Std. Dev. (s)	273.7
	3	2521	B	13	3168	B	23	2766	B	33	3110	B	43	2868	B	X-3s:	2193.2
	4	3129	B	14	3028	B	24	2765	B	34	3356	B	44	3066	B	Minimum	2521
	5	3197	B	15	2733	B	25	2578	B	35	3212	B	45	3211	B	Maximum	3554
	6	2848	B	16	3432	B	26	2858	B	36	3400	B	46	2709	B	Range	1033
	7	2773	B	17	2548	B	27	2973	B	37	3230	B	47	2907	B	* Fracture Mode	
	8	2521	B	18	2945	B	28	2791	B	38	2981	B	48	3455	B	Nut	0 pcs.
	9	3459	B	19	3289	B	29	2960	B	39	3323	B	49	2858	B	Base	50 pcs.
	10	3030	B	20	2714	B	30	3289	B	40	3122	B	50	3154	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 4

FASTENER DESCRIPTION:	M6 NUT
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	
BASE MATERIAL TYPE:	USIBOR HSB
BASE MATERIAL PLATING:	AISI
BASE MATERIAL THICKNESS:	1.25 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400				5	5	5	5	5	5
1350				5	5	5	5	5	5
1300				5	5	5	5	5	5
1250				5	5	5	5	5	5
1200				5	5	5	5	5	5
1150				5	5	5	5	5	5
1100				5	4	5	5	5	5
1050									
1000									
950									
900									
850									
800									
750									
700									
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT
DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

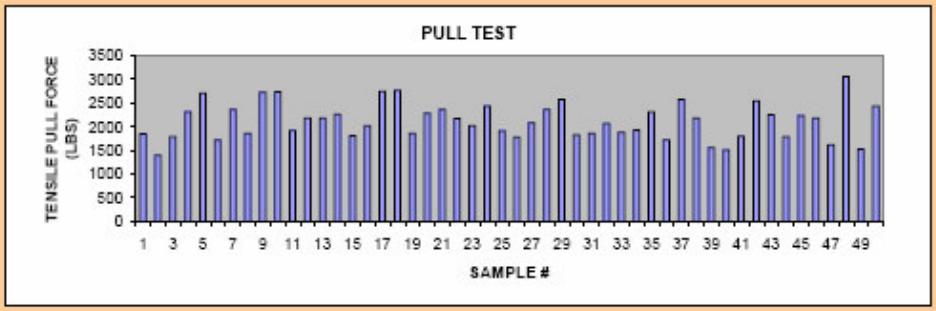
WELD PROGRAMMING PARAMETERS	
LIFT	0.80mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	
AIR BLOW	30lpm

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M
5	Different Mode	

RECOMMENDED WELD SCHEDULE: 1350A, 55ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at	1	1850	B	11	1919	B	21	2365	B	31	1863	B	41	1799	B	Average (X)	2120.6
RECOMMENDED	2	1395	B	12	2185	B	22	2170	B	32	2067	B	42	2542	B	Std. Dev. (s)	382.0
WELD SCHEDULE	3	1786	B	13	2180	B	23	2024	B	33	1875	B	43	2256	B	X-3s:	974.8
	4	2314	B	14	2260	B	24	2439	B	34	1928	B	44	1788	B	Minimum	1395
	5	2703	B	15	1812	B	25	1917	B	35	2309	B	45	2234	B	Maximum	3055
	6	1717	B	16	2021	B	26	1777	B	36	1723	B	46	2181	B	Range	1660
	7	2356	B	17	2746	B	27	2081	B	37	2569	B	47	1621	B	* Fracture Mode	
	8	1858	B	18	2768	B	28	2365	B	38	2180	B	48	3055	B	Nut	0 pcs.
	9	2727	B	19	1862	B	29	2579	B	39	1551	B	49	1530		Base	48 pcs.
	10	2742	B	20	2279	B	30	1825	B	40	1511	B	50	2427		Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 5

FASTENER DESCRIPTION:	M6 Stud/Nut
FASTENER PLATING:	Zinc-Nickel
EMHART FASTENER PART#:	3S050
BASE MATERIAL TYPE:	Mild Steel
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.1 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250			5	5	5	5			
1200			5	5	5	5			
1150			5	5	5	5			
1100			4	5	5	5	5		
1050			3	4	5	5	5		
1000			3	5	5	5	5		
950			3	4	4	1	5		
900			2	4	4	4	5		
850			2	2	3	4	5		
800			2	1	1	5	5		
750			2	2	2	1	3		
700			1	1	1	1	1		
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

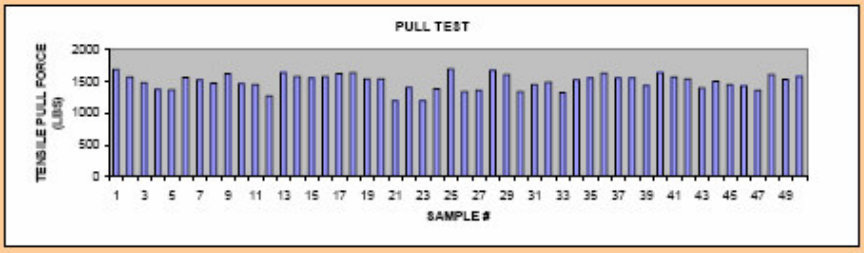
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1200A 40ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	1691	B	11	1445	B	21	1198	B	31	1443	B	41	1571	B	Average (X)	1494.4
	2	1565	B	12	1269	B	22	1401	B	32	1482	B	42	1543	B	Std. Dev. (s)	121.7
	3	1477	B	13	1634	B	23	1192	B	33	1322	B	43	1393	B	X-3s:	1129.4
	4	1374	B	14	1572	B	24	1381	B	34	1521	B	44	1497	B	Minimum	1192
	5	1365	B	15	1552	B	25	1695	B	35	1548	B	45	1449	B	Maximum	1695
	6	1560	B	16	1573	B	26	1336	B	36	1628	B	46	1424	B	Range	503
	7	1526	B	17	1624	B	27	1361	B	37	1551	B	47	1357	B	* Fracture Mode	
	8	1468	B	18	1630	B	28	1674	B	38	1548	B	48	1605	B	Stud	0 pcs.
	9	1616	B	19	1537	B	29	1601	B	39	1436	B	49	1529	B	Base	50 pcs.
	10	1464	B	20	1537	B	30	1334	B	40	1634	B	50	1581	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 6

FASTENER DESCRIPTION:	M6 Stud/Nut
FASTENER PLATING:	Zinc-Nickel
EMHART FASTENER PART#:	39050
BASE MATERIAL TYPE:	DP980
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.0 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250			5	5	5	5			
1200			5	5	5	5			
1150			5	4	5	5			
1100			2	5	5	5	5		
1050			5	5	5	4	5		
1000			1	5	5	5	5		
950			2	5	5	4	5		
900			3	1	5	3	5		
850			2	1	1	4	5		
800			1	1	1	2	1		
750			1	1	1	1	5		
700			1	1	1	1	4		
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

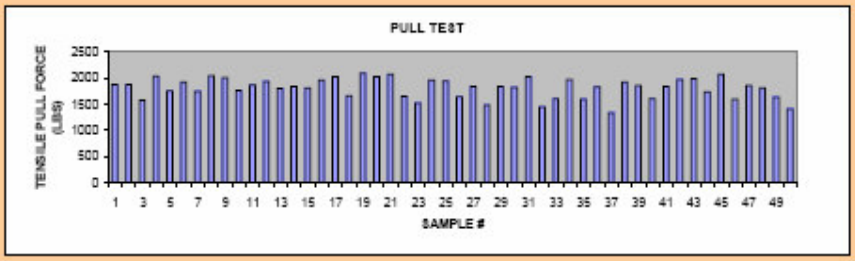
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1200A 40ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	1879	B	11	1865	B	21	2067	B	31	2025	B	41	1838	B	Average (X)	1809.3
	2	1872	B	12	1934	B	22	1648	B	32	1450	B	42	1976	B	Std. Dev. (s)	189.4
	3	1573	B	13	1803	B	23	1524	B	33	1604	B	43	1987	B	X-3s:	1241.1
	4	2032	B	14	1834	B	24	1960	B	34	1969	B	44	1732	B	Minimum	1336
	5	1759	B	15	1814	B	25	1938	B	35	1596	B	45	2072	B	Maximum	2090
	6	1922	B	16	1961	B	26	1637	B	36	1831	B	46	1590	B	Range	754
	7	1749	B	17	2028	B	27	1842	B	37	1336	B	47	1856	B	* Fracture Mode	
	8	2040	B	18	1663	B	28	1483	B	38	1925	B	48	1806	B	Stud	0 pcs.
	9	2001	B	19	2090	B	29	1840	B	39	1852	B	49	1633	B	Base	50 pcs.
	10	1763	B	20	2024	B	30	1823	B	40	1609	B	50	1410	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 7

FASTENER DESCRIPTION:	M6 Stud/Nut
FASTENER PLATING:	Zinc -Nickel
EMHART FASTENER PART#:	39050
BASE MATERIAL TYPE:	USIBOR HSB
BASE MATERIAL PLATING:	AISI
BASE MATERIAL THICKNESS:	1.25 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250			5	5	5	5			
1200			4	5	5	5			
1150			5	5	5	5			
1100			5	5	5	5	5		
1050			3	4	5	4	5		
1000			3	5	5	4	5		
950			1	4	5	4	5		
900			1	4	5	5	5		
850			1	1	1	5	5		
800			1	1	1	4	5		
750			1	1	1	5	5		
700			1	1	1	1	3		
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

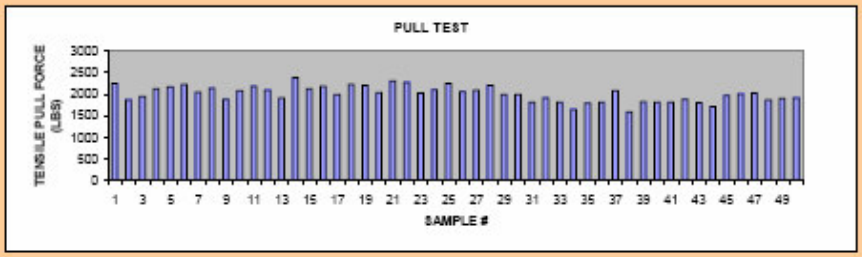
Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1200A 40ms

TENSILE TEST at RECOMMENDED WELD SCHEDULE	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*
	1	2255	B	11	2188	B	21	2313	B	31	1813	B	41	1808	B
	2	1870	B	12	2099	B	22	2274	B	32	1916	B	42	1878	B
	3	1949	B	13	1911	B	23	2027	B	33	1812	B	43	1805	B
	4	2125	B	14	2393	B	24	2102	B	34	1651	B	44	1708	B
	5	2172	B	15	2129	B	25	2251	B	35	1784	B	45	1970	B
	6	2223	B	16	2179	B	26	2058	B	36	1815	B	46	2008	B
	7	2043	B	17	1989	B	27	2089	B	37	2082	B	47	2023	B
	8	2142	B	18	2223	B	28	2207	B	38	1584	B	48	1865	B
	9	1879	B	19	2211	B	29	1995	B	39	1824	B	49	1900	B
	10	2082	B	20	2035	B	30	1989	B	40	1812	B	50	1918	B

Statistical Evaluation	
Average (X)	2007.56
Std. Dev. (s)	181.3
X-3s:	1463.6
Minimum	1584
Maximum	2393
Range	809
* Fracture Mode	
Stud	0 pcs.
Base	50 pcs.
Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 8

FASTENER DESCRIPTION:	M6 Large Flange (9 mm head) CLASS 8.8
FASTENER PLATING:	Copper
EMHART FASTENER PART#:	29853
BASE MATERIAL TYPE:	MILD STEEL
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.1 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450				5	5	5	5M	5M	
1400				5	5	5	5	5M	
1350				5	5	5	5	5M	
1300				5	5	5	5	5M	
1250				4	4	4	5	5	5
1200				4	4	4	5	5	4
1150				2	2	4	4	5	4
1100				1	2	4	4	4	5
1050				2	1	3	3	3	4
1000				2	2	2	1	3	2
950				1	2	2	2	2	4
900				1	1	1	1	1	
850									
800									
750									
700									
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

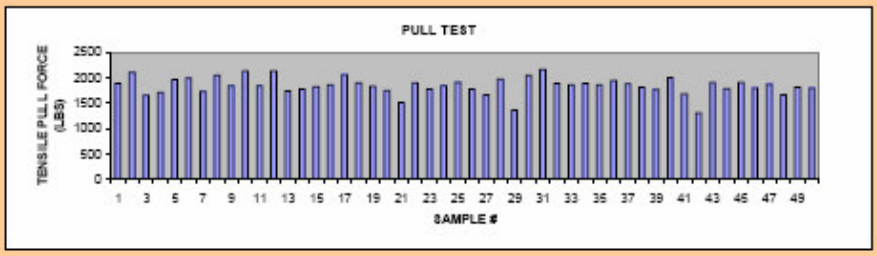
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1350A 45ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at	1	1883	B	11	1845	B	21	1506	B	31	2156	B	41	1675	B	Average (X)	1839
RECOMMENDED	2	2102	B	12	2122	B	22	1858	B	32	1884	B	42	1301	B	Std. Dev. (s)	169.6
WELD SCHEDULE	3	1652	B	13	1732	B	23	1773	B	33	1859	B	43	1899	B	X-3s:	1330.2
	4	1708	B	14	1778	B	24	1837	B	34	1886	B	44	1780	B	Minimum	1301
	5	1956	B	15	1819	B	25	1907	B	35	1855	B	45	1900	B	Maximum	2156
	6	1991	B	16	1857	B	26	1774	B	36	1940	B	46	1794	B	Range	855
	7	1730	B	17	2058	B	27	1659	B	37	1874	B	47	1867	B	* Fracture Mode	
	8	2044	B	18	1897	B	28	1970	B	38	1811	B	48	1659	B	Stud	0 pcs.
	9	1845	B	19	1822	B	29	1364	B	39	1765	B	49	1807	B	Base	50 pcs.
	10	2122	B	20	1748	B	30	2048	B	40	1996	B	50	1795	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 9

FASTENER DESCRIPTION:	M6 Large Flange (9 mm head) CLASS 8.8
FASTENER PLATING:	Copper
EMHART FASTENER PART#:	29853
BASE MATERIAL TYPE:	DP980
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.0 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450				5	6	5	5M	5M	
1400				4	5	5	5	6M	
1350				4	5	5	5	5M	
1300				5	4	4	5	6M	
1250				4	5	4	5	5M	
1200				2	2	4	4	4	5
1150				2	1	3	4	5	5
1100				1	2	3	3	3	3
1050				1	1	1	1	1	3
1000				1	1	1	1	1	1
950				1	1	2	1	1	1
900				1	1	1	1	1	1
850									
800									
750									
700									
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

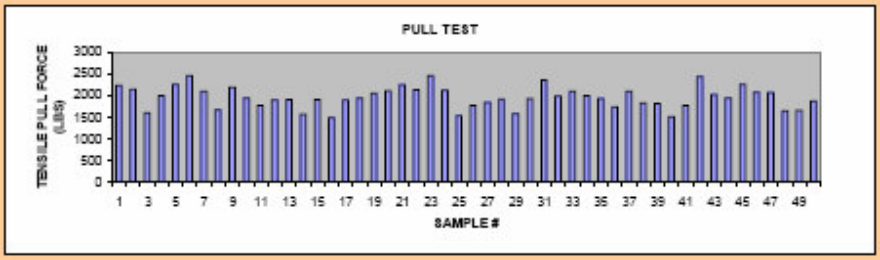
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1350A 45ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at	1	2231	B	11	1764	B	21	2240	B	31	2354	B	41	1772	B	Average (X)	1950.9
RECOMMENDED	2	2137	B	12	1894	B	22	2133	B	32	1980	B	42	2423	B	Std. Dev. (s)	247.1
WELD SCHEDULE	3	1603	B	13	1900	B	23	2450	B	33	2093	B	43	2016	B	X-3s:	1209.7
	4	1993	B	14	1565	B	24	2114	B	34	1988	B	44	1938	B	Minimum	1486
	5	2246	B	15	1904	B	25	1530	B	35	1933	B	45	2255	B	Maximum	2456
	6	2456	B	16	1486	B	26	1771	B	36	1728	B	46	2075	B	Range	970
	7	2089	B	17	1895	B	27	1838	B	37	2090	B	47	2059	B	* Fracture Mode	
	8	1664	B	18	1938	B	28	1915	B	38	1821	B	48	1640	B	Stud	0 pcs.
	9	2183	B	19	2052	B	29	1581	B	39	1814	B	49	1654	B	Base	50 pcs.
	10	1938	B	20	2106	B	30	1921	B	40	1506	B	50	1869	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 10

FASTENER DESCRIPTION:	M6 Large Flange (9 mm head) CLASS 8.8
FASTENER PLATING:	Copper
EMHART FASTENER PART#:	29853
BASE MATERIAL TYPE:	USIBOR HSB
BASE MATERIAL PLATING:	AISI
BASE MATERIAL THICKNESS:	1.25 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500			5	6	6	6M			
1450			1	5	6	6	6M		
1400			1	3	6	5	1M		
1350				1	6	4	6M	1M	
1300				6	1	3	1M	1M	
1250				1	1	6	6	6M	6M
1200				6	6	6	1	1	6
1150				5	1	6	1	1	6
1100				1	6	6	6	1	6
1050				1	6	1	1	1	6
1000				1	6	1	1	1	6
950				1	1	1	1	6	6
900				1	1	1	1	1	6
850									
800									
750									
700									
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

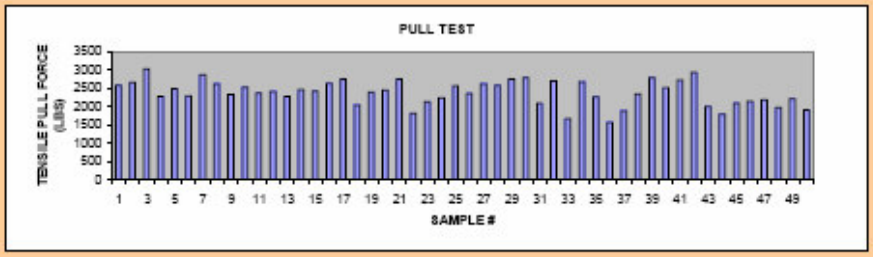
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1450 A, 40 ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	2579	B	11	2370	B	21	2741	B	31	2085	B	41	2713	B	Average (X)	2373.12
	2	2647	B	12	2404	B	22	1815	B	32	2689	B	42	2923	B	Std. Dev. (s)	335.9
	3	3020	B	13	2278	B	23	2126	B	33	1667	B	43	1991	B	X-3s:	1365.5
	4	2268	B	14	2455	B	24	2235	B	34	2671	B	44	1788	B	Minimum	1569
	5	2486	B	15	2411	B	25	2553	B	35	2264	B	45	2090	B	Maximum	3020
	6	2285	B	16	2630	B	26	2350	B	36	1569	B	46	2134	B	Range	1451
	7	2654	B	17	2746	B	27	2611	B	37	1888	B	47	2176	B	* Fracture Mode	
	8	2616	B	18	2044	B	28	2581	B	38	2336	B	48	1965	B	Stud	0 pcs.
	9	2317	B	19	2392	B	29	2749	B	39	2776	B	49	2213	B	Base	50 pcs.
	10	2517	B	20	2446	B	30	2785	B	40	2502	B	50	1905	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 11

FASTENER DESCRIPTION:	M6 Standard Flange Stud
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	39026
BASE MATERIAL TYPE:	Mild Steel
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.1 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250									
1200									
1150									
1100									
1050	5	5	5	5M					
1000	5	5	5	5M					
950	5	5	5	5					
900	5	5	5	5					
850	5	5	5	5					
800	2	5	5	5					
750	1	4	5	5					
700	1	3	5	5					
650	1	1	4	5					
600	1	1	2	5					
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT
DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

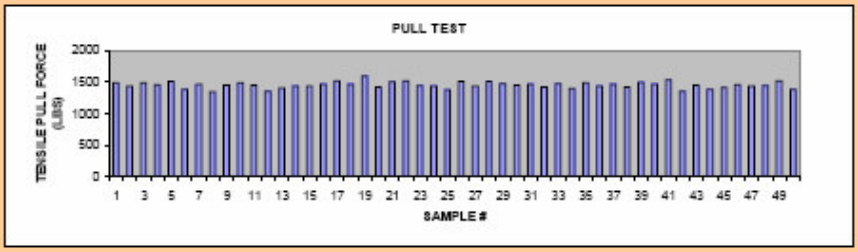
WELD PROGRAMMING PARAMETERS	
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 900A 30ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	1487	B	11	1452	B	21	1457	B	31	1465	B	41	1533	B	Average (X)	1449.36
	2	1433	B	12	1354	B	22	1515	B	32	1417	B	42	1353	B	Std. Dev. (s)	50.1
	3	1484	B	13	1401	B	23	1442	B	33	1467	B	43	1447	B	X-3s:	1298.9
	4	1456	B	14	1434	B	24	1436	B	34	1397	B	44	1378	B	Minimum	1336
	5	1509	B	15	1430	B	25	1372	B	35	1482	B	45	1412	B	Maximum	1568
	6	1382	B	16	1466	B	26	1509	B	36	1437	B	46	1454	B	Range	250
	7	1461	B	17	1510	B	27	1429	B	37	1464	B	47	1430	B	* Fracture Mode	
	8	1338	B	18	1462	B	28	1507	B	38	1414	B	48	1442	B	Stud	0 pcs.
	9	1444	B	19	1588	B	29	1474	B	39	1495	B	49	1513	B	Base	50 pcs.
	10	1483	B	20	1421	B	30	1448	B	40	1465	B	50	1379	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 12

FASTENER DESCRIPTION:	M6 Standard Flange Stud
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	39026
BASE MATERIAL TYPE:	DP980
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.0 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250									
1200									
1150									
1100									
1050	6	6	6	6M					
1000	6	6	6	6M					
950	6	6	6	6					
900	6	6	6	6					
850	2	6	6	6					
800	1	6	6	6					
750	1	6	6	6					
700	2	2	6	6					
650	1	3	6	6					
600	1	2	4	5					
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

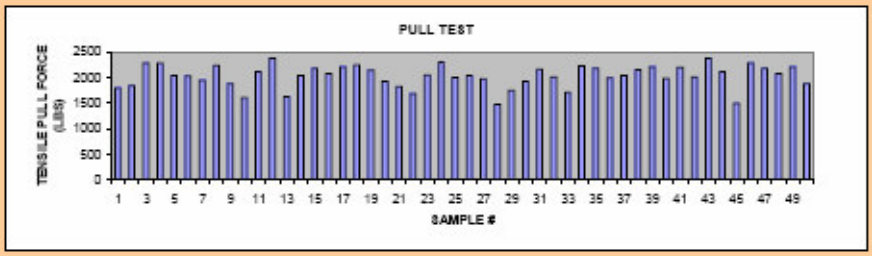
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 900A 30ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at	1	1792	B	11	2106	B	21	1821	B	31	2153	B	41	2196	B	Average (X)	2022.5
RECOMMENDED	2	1834	B	12	2369	S	22	1680	B	32	2003	B	42	2008	B	Std. Dev. (s)	218.3
WELD SCHEDULE	3	2278	B	13	1619	B	23	2044	B	33	1707	B	43	2374	B	X-3s:	1367.6
	4	2274	B	14	2031	B	24	2234	B	34	2221	B	44	2106	B	Minimum	1470
	5	2036	B	15	2174	B	25	1996	B	35	2176	B	45	1496	B	Maximum	2374
	6	2024	B	16	2074	B	26	2031	B	36	1993	B	46	2279	B	Range	904
	7	1944	B	17	2208	B	27	1968	B	37	2034	B	47	2176	B	* Fracture Mode	
	8	2230	B	18	2236	B	28	1470	B	38	2148	B	48	2075	B	Stud	1 pcs.
	9	1874	B	19	2133	B	29	1738	B	39	2207	B	49	2205	B	Base	49 pcs.
	10	1601	B	20	1921	B	30	1921	B	40	1972	B	50	1875	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 13

FASTENER DESCRIPTION:	M6 Standard Flange Stud
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	39026
BASE MATERIAL TYPE:	USIBOR HSB
BASE MATERIAL PLATING:	AISI
BASE MATERIAL THICKNESS:	1.25 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250									
1200									
1150									
1100									
1050	6	6	6	4M					
1000	6	6	6	6					
950	6	6	6	6					
900	1	6	6	6					
850	1	6	6	6					
800	1	6	6	6					
750	6	1	6	6					
700	1	1	6	6					
650	1	1	6	6					
600	1	1	1	1					
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

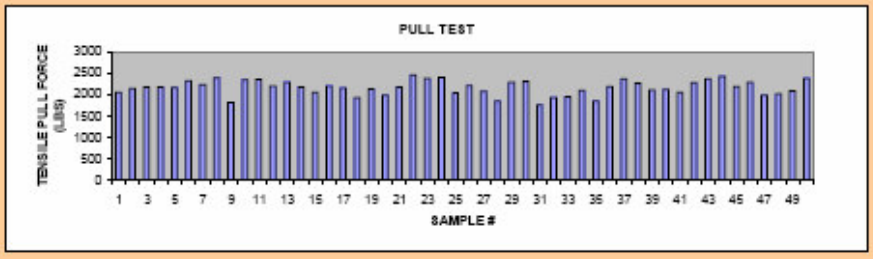
Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 950A 30ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	2050	B	11	2353	B	21	2166	B	31	1756	B	41	2042	B
	2	2138	B	12	2187	B	22	2447	S	32	1933	B	42	2266	B
	3	2172	B	13	2290	B	23	2369	S	33	1944	B	43	2361	B
	4	2177	B	14	2168	B	24	2395	S	34	2085	B	44	2420	B
	5	2161	B	15	2055	B	25	2040	B	35	1854	B	45	2183	B
	6	2317	B	16	2195	B	26	2209	B	36	2183	B	46	2282	B
	7	2232	T	17	2150	B	27	2072	B	37	2362	B	47	1980	B
	8	2393	B	18	1923	B	28	1841	B	38	2260	B	48	2011	B
	9	1808	B	19	2126	B	29	2281	B	39	2101	B	49	2079	B
	10	2342	B	20	1981	B	30	2302	B	40	2114	B	50	2373	B

Statistical Evaluation	
Average (X)	2158.6
Std. Dev. (s)	170.6
X-3s:	1646.8
Minimum	1756
Maximum	2447
Range	691
* Fracture Mode	
Stud	3 pcs.
Base	46 pcs.
Weld	0 pcs.
Threads	1 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 14

FASTENER DESCRIPTION:	M6 Large Flange Stud (7 mm head) Paint cutting threads
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	29956
BASE MATERIAL TYPE:	Mild Steel
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.1 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250									
1200		5	5	5	5	5			
1150		5	5	5	5	5			
1100		5	5	5	5	5			
1050		5	5	5	5	5	5		
1000		5	5	5	5	5	5		
950		5	5	5	5	5	5		
900		1	5	5	5	5	5		
850		3	4	5	5	5	5		
800		2	5	5	5	5	5		
750		2	2	2	4	5	5		
700		1	2	1	3	4	5		
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

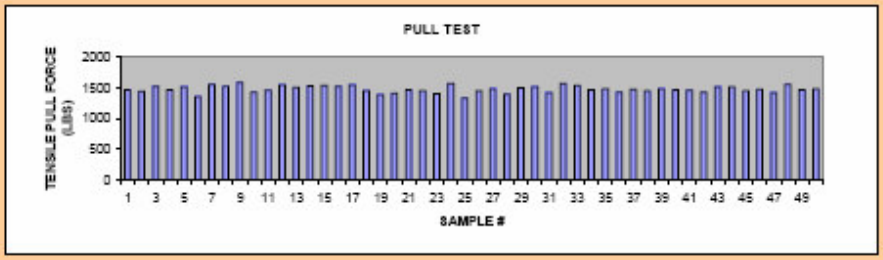
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1050A 40ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	1465	B	11	1460	B	21	1466	B	31	1420	B	41	1460	B	Average (X)	1478.4
	2	1442	B	12	1547	B	22	1449	B	32	1567	B	42	1430	B	Std. Dev. (s)	56.3
	3	1523	B	13	1508	B	23	1405	B	33	1540	B	43	1516	B	X-3s:	1309.6
	4	1472	B	14	1533	B	24	1573	B	34	1473	B	44	1509	B	Minimum	1334
	5	1514	B	15	1541	B	25	1334	B	35	1481	B	45	1448	B	Maximum	1590
	6	1358	B	16	1521	B	26	1452	B	36	1429	B	46	1474	B	Range	256
	7	1558	B	17	1548	B	27	1487	B	37	1474	B	47	1420	B	* Fracture Mode	
	8	1528	B	18	1457	B	28	1393	B	38	1448	B	48	1555	B	Stud	0 pcs.
	9	1590	B	19	1390	B	29	1499	B	39	1487	B	49	1468	B	Base	50 pcs.
	10	1424	B	20	1417	B	30	1516	B	40	1472	B	50	1479	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 15

FASTENER DESCRIPTION:	M6 Large Flange Stud (7mm head) Paint cutting threads
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	29956
BASE MATERIAL TYPE:	DP980
BASE MATERIAL PLATING:	Galvanneal
BASE MATERIAL THICKNESS:	1.0 mm

WELD CURRENT (I) in Amps	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250									
1200		5	5	5	5	5			
1150		5	5	5	6	5			
1100		5	5	5	5	5			
1050		5	5	5	5	6	5		
1000		5	5	5	5	6	5		
950		5	5	5	5	5	5		
900		1	5	5	5	5	5		
850		4	5	5	5	5	5		
800		1	1	5	5	5	5		
750		4	5	5	5	5	5		
700		1	1	1	5	5	5		
650									
600									
550									
500									

WELD TIME (t) in milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
LM WELD HEAD

WELD PROGRAMMING PARAMETERS

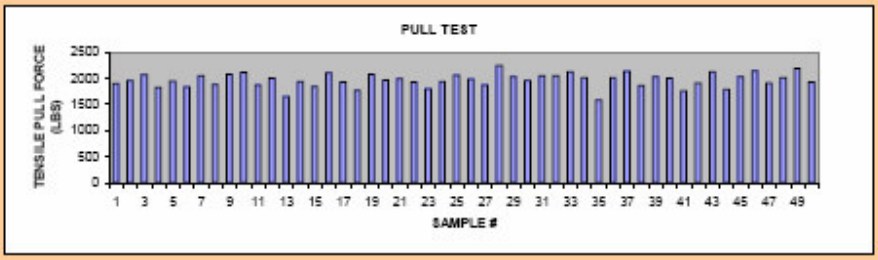
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1050A 40ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	1839	B	11	1870	B	21	1992	B	31	2042	B	41	1756	B	Average (X)	1961.2
	2	1950	B	12	2001	B	22	1928	B	32	2047	B	42	1903	B	Std. Dev. (s)	132.3
	3	2066	B	13	1647	B	23	1795	B	33	2117	B	43	2118	B	X-3s:	1564.2
	4	1822	B	14	1936	B	24	1932	B	34	2013	B	44	1783	B	Minimum	1582
	5	1940	B	15	1837	B	25	2058	B	35	1582	B	45	2024	B	Maximum	2239
	6	1831	B	16	2102	B	26	1981	B	36	2003	B	46	2141	B	Range	657
	7	2044	B	17	1921	B	27	1867	B	37	2132	B	47	1901	B	* Fracture Mode	
	8	1872	B	18	1764	B	28	2239	B	38	1861	B	48	2009	B	Stud	0 pcs.
	9	2075	B	19	2079	B	29	2020	B	39	2031	B	49	2185	B	Base	50 pcs.
	10	2110	B	20	1961	B	30	1952	B	40	1999	B	50	1921	B	Weld	0 pcs.



AUTO STEEL PARTNERSHIP - DRAWN-ARC WELDING STUDY 2006

Emhart Teknologies

Table 16

FASTENER DESCRIPTION:	M6 Large Flange Stud (7mm head) Paint cutting threads
FASTENER PLATING:	Zinc trivalent chrome
EMHART FASTENER PART#:	29868
BASE MATERIAL TYPE:	USIBOR HSB
BASE MATERIAL PLATING:	AISI
BASE MATERIAL THICKNESS:	1.25 mm

WELD CURRENT (I) in Amps

	20	25	30	35	40	45	50	55	60
1500									
1450									
1400									
1350									
1300									
1250									
1200		6	6	6	6	6			
1150		6	6	6	6	6			
1100		6	6	6	6	6			
1050		6	6	6	6	6			
1000		6	6	6	6	6	6		
950		6	1	6	6	6	6		
900		1	6	6	6	6	6		
850		1	2	6	6	6	6		
800		1	6	6	6	6	6		
750		1	1	6	6	6	6		
700		1	1	1	6	6	6		
650									
600									
550									
500									

WELD TIME (t) In milliseconds

EQUIPMENT

DCE 1500 WELD CONTROL
ETF12 FEEDER
IM WELD HEAD

WELD PROGRAMMING PARAMETERS

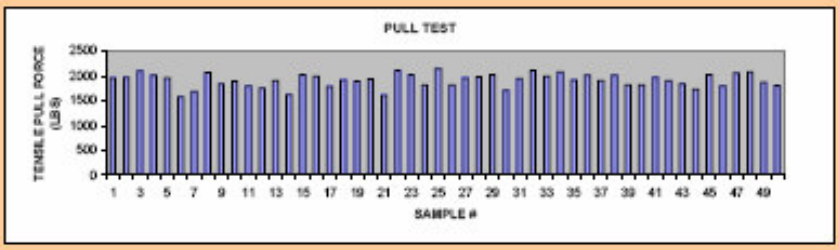
LIFT	1.20mm
PENETRATION	-1.8 mm
START DELAY	250ms
Varc PILOT LIMIT	15.0V to 33.0V
Varc WELD LIMIT	15.0V to 33.0V
WELD TIME	+/- 6ms
WELD CURRENT	+/- 30Amps
STUD NEGATIVE POLARITY	

Acceptance Criteria

Stud Broke	Preferred	6
100%-91%	Preferred	5
90%-81%	Preferred	4
80%-71%	Acceptable	3
70%-61%	Unacceptable	2
60%-0%	Unacceptable	1
Overmelting of Stud or Base Material		M

RECOMMENDED WELD SCHEDULE: 1050A 40ms

	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	#	DATA	*	Statistical Evaluation	
TENSILE TEST at RECOMMENDED WELD SCHEDULE	1	1966	B	11	1788	B	21	1816	B	31	1966	B	41	1873	B	Average (X)	1916.3
	2	1970	B	12	1762	B	22	2117	B	32	2116	B	42	1907	B	Std. Dev. (s)	138.1
	3	2108	B	13	1909	B	23	2032	B	33	1995	B	43	1846	B	X-3s:	1502.1
	4	2017	B	14	1824	B	24	1818	B	34	2089	B	44	1739	B	Minimum	1583
	5	1967	B	15	2091	B	25	2146	B	35	1926	B	45	2036	B	Maximum	2146
	6	1583	B	16	1999	B	26	1824	B	36	2015	B	46	1796	B	Range	563
	7	1886	B	17	1791	B	27	1984	B	37	1907	B	47	2062	B	* Fracture Mode	
	8	2071	B	18	1927	B	28	1980	B	38	2026	B	48	2062	B	Stud	0 pcs.
	9	1844	B	19	1900	B	29	2027	B	39	1816	B	49	1874	B	Base	50 pcs.
	10	1896	B	20	1946	B	30	1716	B	40	1817	B	50	1807	B	Weld	0 pcs.



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