TECHNICAL BULLETIN 21

BLUESCOPE

AUGUST 2013 | Rev 5

This issue supersedes all previous issues

Resistance spot welding of BlueScope Steel metallic-coated steel sheet

INTRODUCTION

High volume welding industries require simple and cost effective joining technology for thin steel sheet. Resistance spot welding meets these requirements and is also adaptable in that it can be easily incorporated with robotic systems. In the past, spot welding parameter selection was considered relatively simple for uncoated steel. However, the range of metallic-coated steels now available as superior replacement products means parameter selection is far more critical.

While it is possible to achieve many thousands of welds from one set of electrodes employed on an uncoated steel sheet before replacement or redressing of electrodes is necessary, features of individual metallic coated steel coatings means as little as only 250 welds may be achievable if inappropriate parameters are chosen.

The information presented in this Technical Bulletin is a result of a number of detailed weldability studies on the more commercially available electrode chemistries used in conjunction with those metallic coated steels most commonly spot welded, namely ZINCALUME® aluminium/zinc/magnesium alloy-coated steel, GALVABOND® zinc-coated steel, ZINCANNEAL® zinc/iron alloy-coated steel and ZINCSEAL® zinc/iron alloy-coated steel.

THE MECHANISM OF ELECTRODE DEGRADATION

The rate of degradation of resistance spot welding electrodes during welding of metallic coated steels is typically far greater than that experienced during welding of uncoated steels. Due to the lower contact resistances of zinc coatings, welding times and current levels are required to be higher in order to produce satisfactory weld sizes. This provides the driving force for alloying to take place between the electrode working face and the metallic coating. The conventional truncated cone electrode tip diameter (see *Figure 1*) increases as welding progresses due to alloy build up around the periphery of the electrode. If incremental increases are not made to the applied current in order to compensate for this, then current density will fall off resulting in production of smaller and smaller welds. Secondly, the metallic coating alloys directly to the electrode working face and metallic alloy phases can develop. These phases can be stripped away from the electrode when the electrode is removed from the sheet surface after completion of each weld. This stripping process leaves pits or holes in the electrode face and generally erodes the electrode contact face. This is most severe when welding ZINCALUME® steel followed by GALVABOND® steel, ZINCANNEAL® steel and least severe with ZINCSEAL® steel. It is important that these effects are minimised through selection of appropriate parameters in order to extend electrode life.

THE EFFECT OF WELDING CURRENT UPSLOPE

Upsloping is the term given to gradually increasing the welding current to the maximum preset level during spot welding rather than instantaneously applying the maximum preset current. Through the addition of a few extra cycles of welding time in current upslope, electrode life is extended considerably when welding both ZINCANNEAL® steel and ZINCSEAL® steel. Upsloping has the tendency to remove some of the metallic coating prior to the application of the maximum preset current. This assists the electrode to bed-in to the sheet surface and means that less coating is available for alloying to take place. There is no added benefit in using upsloping when welding ZINCALUME® steel or GALVABOND® steel.

THE EFFECT OF ELECTRODE TIP ANGLE

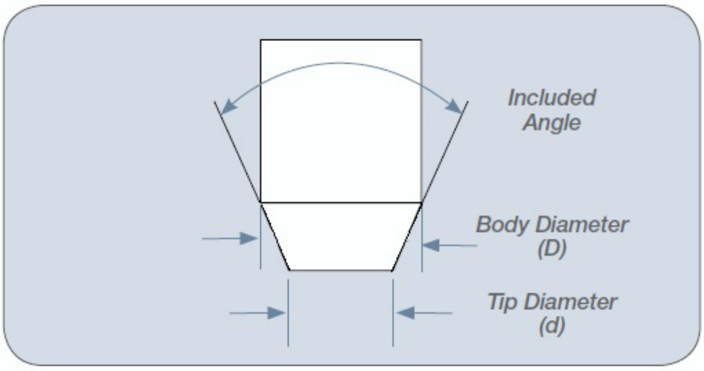
Decreasing the electrode tip included angle (see *Figure 1*) benefits electrode life when welding all BlueScope Steel metallic coated steels. Decreasing the included angle from the commonly employed 120° angle to 90° allows reduction of welding current by about 0.4kA, which in turn will increase electrode tip life. It is not recommended however that included angles less than this be employed since mechanical strength of the electrode tip may be lost.

THE EFFECT OF ELECTRODE TIP DIAMETER

Selection of the electrode tip face diameter depends upon the weld size desired, sheet thickness and, in some cases, design of the component (flange widths). It should be noted that electrode alignment becomes more difficult with increasing tip diameter and that even the slightest misalignment may result in metal expulsion from the sheet surface scarring the workpiece and damaging the electrodes. It is important then not to employ electrode tip diameters well beyond recommended sizes. These are usually in the region of $5\sqrt{t}$ to $6\sqrt{t}$ where t is the thickness of a single steel sheet.

Only electrodes that are used to weld ZINCALUME® steel may benefit by way of increased life with increasing tip diameter.

Figure 1: Truncated cone electrode tip profile.



With larger tip diameters the increase in life can be up to four-fold. The mechanisms for this are not yet clearly understood.

Using tip diameters beyond those recommended for GALVABOND® steel, ZINCANNEAL® steel and ZINCSEAL® steel result in inefficient use of welding power which is uneconomical.

THE EFFECT OF ELECTRODE CHEMISTRIES

Resistance Welder Manufacturers Association Class II (Cu-0.8%-Cr) electrode composition also referred to as J47 alloy, is the most commonly used in Australian manufacturing industries. Other compositions are also available including Cu/Cr and Cu/Cr/Zr. While the Class II electrode composition is suitable for spot welding ZINCALUME® steel, GALVABOND®steel, ZINCANNEAL® steel and ZINCSEAL® steel, electrode life can be extended when welding ZINCANNEAL® and ZINCSEAL® steel using the Cu/Cr/Zr electrode composition. The more aggressive nature of the electrode erosion process encountered during welding of ZINCALUME® steel and GALVABOND® steel appears to outweigh any influence that electrode alloying elements may have on electrode life. The iron-rich zinc coating on ZINCANNEAL® steel and ZINCSEAL® steel however, being far less aggressive on electrodes, takes full advantage of the Cu/Cr/Zr electrode composition. Al_2O_3 dispersion strengthened copper alloy will also extend electrode life considerably but is more costly.

These features are summarised in *Table 1* below:

Table 1: Spot welding electrode considerations.

STEEL TYPE	USE CURRENT UPSLOPE	USE 90° INCLUDED TIP ANGLE	USE INCREASED TIP DIAMETERS	ELECTRODE CHEMISTRY
ZINCALUME®	No	Yes	Yes	Cu/Cr
GALVABOND®	No	Yes	No	Cu/Cr
ZINCANNEAL®	Yes	Yes	No	Cu/Cr or Cu/Cr/Zr
ZINCSEAL®	Yes	Yes	No	Cu/Cr or Cu/Cr/Zr

To assist in the weld set-up procedure, the table below (*Table 2*) provides recommended spot welding practice for hot-dip zinc-coated steel sheet. These conditions are provided as a **GUIDE ONLY**. Fine tuning will be necessary to achieve optimum parameters. Note also that for ZINCANNEAL® and ZINCSEAL® zinc-iron alloy coated steels, the addition of upslope where possible is recommended.

Recommendations

DO take care in machining of electrode working faces. Ensure they are relatively flat and smooth.

DO employ automatic electrode tip redressing tools where possible.

DO take care in accurately aligning electrodes in the welding machine to avoid producing undersized welds, damaging electrodes and scarring of workpiece surface through metal expulsion. Carbon paper placed between blank sheets of paper as shown below in *Figure 2* can be used to obtain an impression of electrode faces. Once in the welding machine, the electrodes can be brought together with the paper in between. The resulting impression will indicate alignment.

Impression should be circular and at same diameter as the electrode. If not, adjust alignment. Ensure welding current is turned off during this procedure.

DO try and work within the welding lobe window for the particular steel type, but just below the point of metal expulsion.

Figure 2: Electrode alignment test set-up.

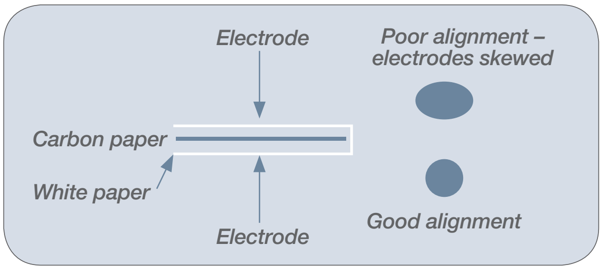


Table 2: Recommended spot welding practice for hot-dip zinc-coated steel sheet.

STEEL BASE THICKNESS (mm)	ELECTRODE DIAMETER		NET ELECTRODE FORCE (kN)	WELD TIME (CYCLES)	WELD CURRENT (1000 A)	MINIMUM CONTACT OVERLAP (mm)	MINIMUM WELD SPACING (mm)	APPROXIMATE SHEAR STRENGTH (kN)
	BODY D (mm)	TIP[i] d (mm)						
0.40	16	3	1.5	5	8	10	10	1.2
0.50	16	4	1.8	6	9	10	10	2.2
0.60	16	4	2	7	9	10	10	3.1
0.80	16	5	2.5	9	11	10	15	5.4
1.0	16	5	3	12	12	15	15	6.8
1.2	16	6	3.6	14	13	15	20	8.6
1.6	20	7	5	19	16	15	25	12.2
2.0	20	8	6.6	25	19	15	30	16.0
2.5	20	9[ii]	9.3	35	24	20	40	20.6
3.0	22	10[ii]	12.6	45	28	20	40	25.1

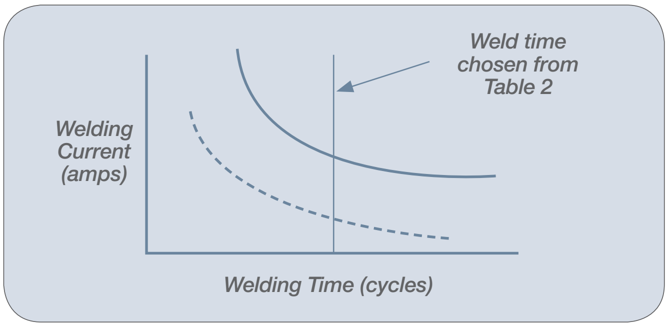
NOTE:
i. Electrode tip diameter based on approximately $6\sqrt{t}$ where t = sheet thickness
ii. Tip life may be increased with increasing tip diameter for ZINCALUME® aluminium/zinc/magnesium alloy coated steel

SETTING THE WELD TIME

Weld time is measured in cycles. In optimising electrode life when welding metallic coated steels, weld time is chosen at a point in the middle of the "Welding lobe" as shown below in *Figure 3*. Weld time increases as material thickness increases and the lobe will shift.

- Working above the solid line produces metal expulsion – deleterious to electrode life.
- Working below the dotted line produces undersized welds <80% electrode tip diameter.
- Working with conditions between the lines will produce acceptable welds.

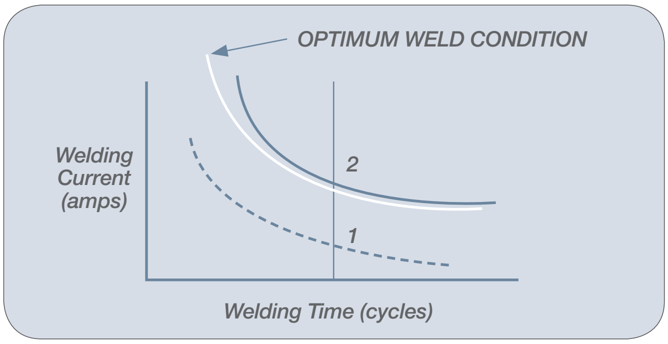
Figure 3: Setting the weld time.



ESTABLISHING OPTIMUM CURRENT

- At constant weld time and lower transformer tapping, conduct weld tests on coupon samples until metal expulsion is reached (Point 2). If not reached, step up the transformer tapping and repeat the procedure. Optimum weld condition is a weld current level just below the exulsion point.
- Minimum weld size equal to 80% of electrode tip diameter is reached at Point 1. Diameter measured after peel test with verniers (average of 2 measurements at 90° apart).

Figure 4: Establishing optimum current.



Recommendations

DO conduct regular inspection of weld quality and replace or redress electrodes as necessary. A simple peel test on offcuts should suffice.

DON'T use hand files to redress worn electrodes. This will promote electrode misalignment.

DON'T use excessive welding current. Electrode/metallic coating alloying rates will be accelerated and metal expulsion will further degrade the electrode.

DON'T use excessively long welding times. It is far better to use short weld times and to adjust the welding current for optimisation of weld size.

DON'T use radiused electrodes unless part fit-up is a problem. Radiused electrodes degrade more quickly than truncated electrodes when used on metallic coated steels.

WELDING FUME

It is the employer's responsibility to ensure that a suitable and sufficient assessment is made of the risk to health created by welding fume. Since no arc is used in resistance spot welding, it is considered a low fume level welding process. It is advisable however, when welding zinc-coated steels under a production type of environment, to conduct a fume assessment and where necessary, install suitable ventilation/extraction equipment to reduce risk. The Welding Technology Institute of Australia's Fume Minimisation Guidelines publication will assist in workplace fume assessment.

Note also that Material Safety Data Sheets for BlueScope Steel's metallic coated products are available on the internet at: **www.bluescopesteel.com.au** (see *Technical Library*)

If you have any questions regarding this Bulletin, please contact BlueScope Steel Direct on 1800 800 789.

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