HIGH SPEED VARIABLE SQUARE WAVE AC SUBMERGED ARC WELDING

FREQUENCY/BALANCE STUDY

.250" PLAIN CARBON STEEL

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ABSTRACT

Advancements in silicon phase control (SCR) technologies provide an arc welding power supply that has the capability to allow the alteration of the Alternating Current (AC) welding output.
These technologies provide a square wave output involving sixteen frequency selections and multiple balance selections. While an AC out put is known to minimize magnetic disturbances associate with Direct Current (DC), the potentials of a non-sinusoidal waveform have not been explored. The focus of the paper is to determine the effects that the frequency and balance of an AC wave form output will have upon a high speed Submerge Arc (SAW) application. The test matrix of the project includes welding .250" steel plate. Joint type is square groove with a travel speed of 65 IPM. Each of the weld parameters was held constant, only the frequency and/or balance were altered between welds. Each frequency/balance combination involved three-gap spacing. Upon completion of the welds the bead profiles were measured and recorded. A relationships/trends were observed with various frequency and balance values. Optimum frequency and balance values were found for the .250" square groove application which permit consistent weld sizing, ease of slag removal, and minimal plate distortion.

KEYWORDS
Squarewave AC SubArc, Submerged Arc Welding, High Speed Submerged Arc Welding, AC Submerged Arc Welding

1. INTRODUCTION

The concept and procedure to use an Alternating output current (AC) for submerge arc welding (SAW) has been around for a number of years. Using AC output in place of DC output was seen as a remedy for those users who had issue of magnetic disturbance in their arc. These disturbances are known as "Arc Blow" where the arc will actually wonder between the two edges being joined. Arc blow may be caused by a number of reasons including work lead connections and residual magnetic fields in the members being joined. Initial AC power supplies out put was limited to symmetrical sine waves with a fixed frequency of 60 Hz. With the improvements of power sources the limitation of a symmetrical sine wave has advance to a symmetrical or non-symmetrical square wave. The symmetrical wave output frequencies have nine output frequencies. The output frequency is the reciprocal of the time period of one complete cycle. Each positive or negative alteration in a complete cycle consists of one or more 120 degree time increments. The time period of 120 degrees is 5.56 and 6.67 ms for 60 and 50 Hz. input frequencies, respectively. Non-symmetrical square wave frequencies have additional six frequencies between the value of 60 to 10 Hz with 60 Hz. or 50 to 8.33 Hz with 50 Hz. inputs. In addition the non-symmetrical waveforms are not specific polarity dependent, therefore the electrode may be either negative or positive polarity. The non-polarity dependence adds to the further output options and benefits of the power source.

2. PROCEDURE

Weld test matrixes were designed where as the altering of the output frequency and or balance was the only variable. The first two test matrixes involved five output variables. These variables are shown in table 1 and 2 respectively.

Table 1

Frequency	Balance
90 Hz.	50/50 – Pos./Neg.
45 Hz.	50/50 – Pos./Neg.
30 Hz.	50/50 – Pos./Neg.
60 Hz.	66/33 – Pos./Neg.
60 Hz.	33/66 – Pos./Neg.

Table 2

Frequency	Balance
15 Hz.	50/50 – Pos./Neg.
18 Hz.	70/30 – Pos./Neg.
18 Hz.	30/70 – Pos./Neg.
18 Hz.	60/40 – Pos./Neg.
18 Hz.	40/60 – Pos./Neg.

In addition to the five out put variables, three gap spacing were used. The gap sizes were zero, 1/32", and 1/16". The number of welds per each test matrix was fifteen. Following completion of test matrix one and two a third matrix was developed. This third matrix used the optimal frequency, balance, and gap size that was concluded from matrix one and two. In this matrix the voltage, amperage and flux bed varied. The variables of matrix three are shown in table three.

Table 3

Flux bed height	Flux bed pressure	Voltage	Amperage
Flush	20 PSI	32	900
3/32"	15 PSI	33	901
3/8"	7.5 PSI	34	902

From the variables listed in table three, six weld samples were produced.
The base material used for all the welds was .250" hot rolled 1020 steel. The weld coupons were 48" long and 4" in width. Each coupon was sheared cut from a 96" X 48" plate. No edge preparation was done prior to welding therefore all of the welds produced were square groove (butt joint) welds. Pairs of coupons were GMAW tack welded with the desire gap. Following tacking the coupons were place in a "Pandjiris" seamer. The seamer has pneumatic hold down fingers. Root side shielding of the welds was accomplished with a pneumatic flux bed. Air pressures for the pneumatic devices are shown in table 4.

Table 4

Pneumatic device	Air Pressure
Hold down fingers	40 PSI
Flux bed	15 PSI

Following alignment of the weld joint air pressure is given to both the hold down fingers and the flux bed. The flux bed had a 3/8" crown height of the flux granules prior to pressurizing the hold-downs and the flux bed. ESAB welding consumables used for each of the welds, their trade names and AWS classifications are listed in table 5.

Table 5

	Electrode	Flux
ESAB Trade Name	1/8" Spoolarc 29S	Unionmelt 350
AWS Classification	EM 13K	F7A2

Preliminary weld trials were done in an effort to obtain familiarity with the system and to determine weld parameters for the targeted travel speed. The weld parameters include amperage, voltage, and contact tip to work distance (CTWD). The weld parameters will remain constant during the frequency/balance output analysis. The weld parameters are shown in table 6.

Table 6

Travel Speed	Amperage	Voltage	CTWD
65 IPM	900	32	1 inch

Upon completion of each weld coupon eight measurements were made and two notations were taken and inputted to the test matrix. Four caliper measurements each were taken at 16" and 32" distances from the start of the weld. In addition a general comment cell was provide in the matrix. Table 7 lists the measurements and notations of the test matrix

Table 7

Measurements	Notations
Face width and height	Ease of slag removal
Root width and height	Plate distortion

Following completion of the all weld coupons two four-inch samples were sheared from each zero gap weld. The four-inch samples were centered and sheared from the 16" and 32" measuring locations of each weld. A ¾" strip was then saw from the four inch sample. The ¾" strips were polished and etch for evaluation and measuring of weld nugget profiles.

3. RESULTS

Included in the test matrixes are the weld profile surface dimensions, noted slag removal, plate distortion and general weld performance comments. In an effort to maximize space on the matrixes several items (terms) have been shorten. Table 8 explains the meaning of the weld numbering system.

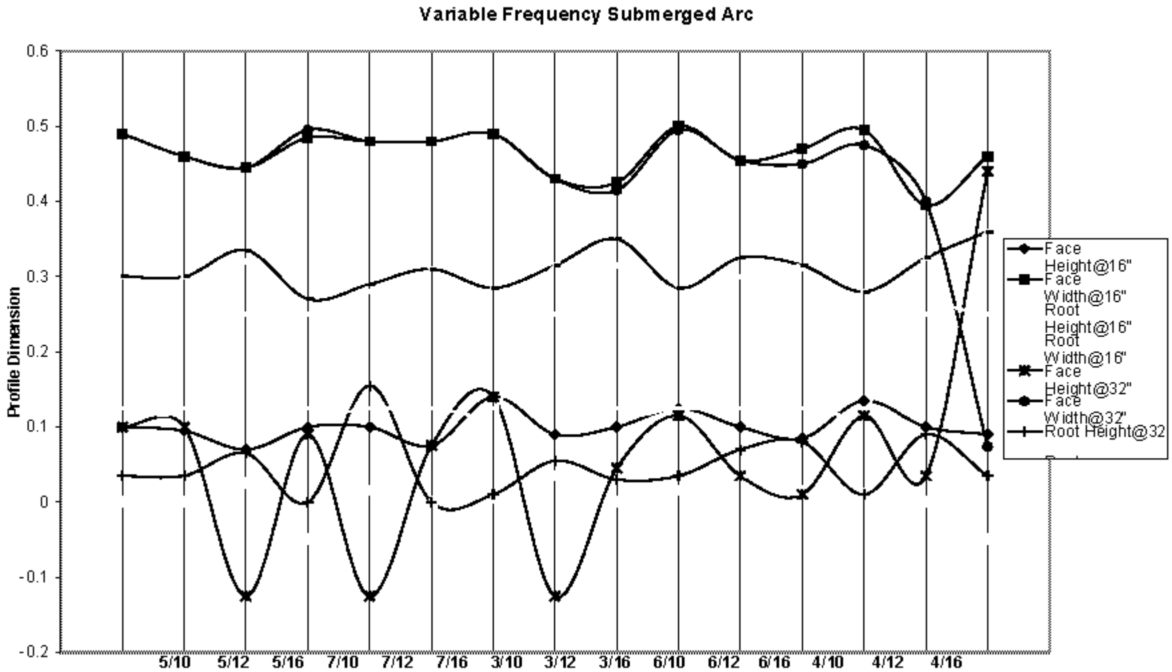
Table 8

1.8S.30.0			
X.X	X	.XX	.XX
Wire Size	Wire Type	Frequency/balance	Plate gap
1.8 = 1/8"	S = solid wire	30 = 30 Hz./50% Pos.	0 = 0" gap

Graphic representations of the dimensional results are shown in the two plots following the matrixes. Table 9 is an explanation of the X-axis numbering system of the two plots.

Table 9

5/10		
Balance	Frequency	Gap width
5 = 50% Pos.	1 = 15 Hz.	0 = 0" gap width


Variable Frequency Submerged Arc
Profile Dimension
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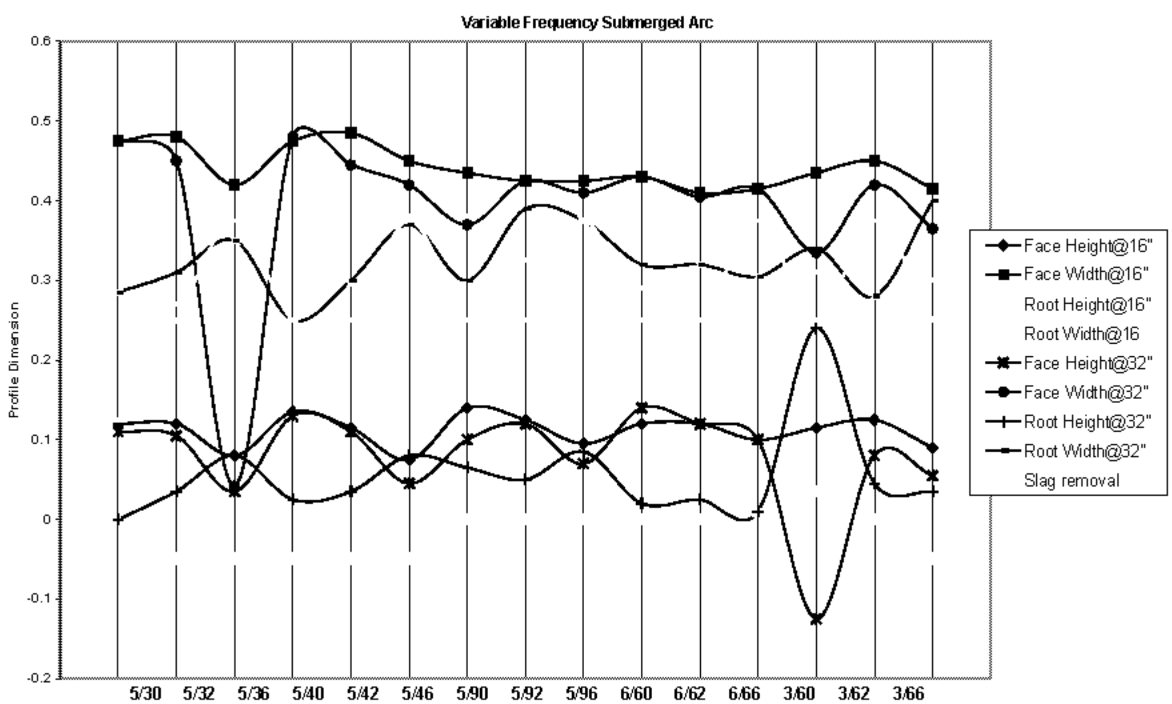
0.4
0.3
0.2
0.1
0
-0.1
-0.2
5/10
5/12
5/16
7/10
7/12
7/16
3/10
3/12
3/16
6/10
6/12
6/16
4/10
4/12
4/16
Face Height@16"
Face Width@16"
Root Height@16"
Root Width@16"
Face Height@32"
Face Width@32"
Root Height@32


Variable Frequency Submerged Arc
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0.6
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-0.2
5/30
5/32
5/36
5/40
5/42
5/46
5/90
5/92
5/96
6/60
6/62
6/66
3/60
3/62
3/66
Face Height@16"
Face Width@16"
Root Height@16"
Root Width@16
Face Height@32"
Face Width@32"
Root Height@32"
Root Width@32"
Slag removal

4. DISCUSSION

Looking at the various inputs of the weld profiles of the two test matrixes one can see that altering the AC output has a dimensional effect upon the weld bead. In addition varying AC waveform balance and frequency also effected the weld characters and performance.

Reviewing back to table 1 and 2 it was seen that for 50/50 wave form balance there are four possible frequencies, with the 66/33, 70/30, and 60/40 there is only one possible frequency for each. Now while the 66/33, 70/30, and 60/40 balances have only one frequency they do have the option to vary the percentage of negative or positive electrode. The frequency and balance combinations are controlled by various plug configurations on main PC board. In the rest of this discussion the term plug refers to a specific, but several frequency and waveform balance combinations

Now looking at the results of the matrix lets begin with the effects of gapping/spacing the weld joint. From our testing there was no real overall benefit or to say desirable weld profile found. This not to say that gapping is not a usable approach to obtaining successful welds qualification, it is just saying that we found no desired weld profile that could not be achieved with a different frequency and or balance with no gap.

The first point observation of weld profiles was consistency of bead quality. In other words, how similar was the bead dimensions at the beginning of the weld as at the end of the weld. It was found that the lower frequency (15/18 Hz) resulted in a more consistent weld profile on the root side of the joint. This common dimension was both a measurement of width and height of the root bead. The second trend that was observed was that with the 70/30 and 60/40 plugs (18 Hz.) it was seen that having the positive percentage of the output a lower value had shown favorable results. These two trends lead us to the three balance and frequency (plugs) combinations that shown the best results. These balance and frequency plugs are 50/50-15Hz, 70/30-18Hz, 60/40-18Hz. In addition to the consistent bead profiles it was observed that the arc characteristic was smoother with one these AC waveform output plug. The 60/40-18Hz plug had the smoothest audio weld characteristic. It was also seen that the amount of plate distortion was reduced along with the effort to remove the slag coating.

5. CONCLUSION

1. Lower frequency (15/18 Hz) values had more consistent weld bead results
2. Lower frequency (15/18 Hz) values had minor reduction of plate distortion
3. Lower frequency (15/18 Hz) values had increase ease of slag removal
4. Lower percentage of DC positive values had more consistent weld bead
5. The optimal plug was found to be 60/40 balance, 18 Hz., with 40 percent positive and 60 percent negative