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MILITARY TECHNICAL COLLEGE

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ESTIMATING TECHNIQUE FOR OPTIMUM WELDING LENGTH AND POSSIBILITY TO APPLY IT IN SHIPBUILDING

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ABSTRACT

It is known that the welding process in the production field must be applied in a certain welding sequence. Accordingly, residual stresses as well as deformation can be controlled by temperature distribution on welded plates. In this case the welding length (length of block) must be suitable in order to control interpass temperature between a weld and other (block and other) on the same weld line. Where the interpass temperature has a great influence with heat input.

This paper presents a new technique for the estimation of optimum welding length as a function of heat input.

This method depends on the calculation of cooling rates as a function of heat input. Then the time required for cooling to a certain temperature can be determined. The calculations are transferred into figures from which any date such as cooling rate and welding time can be obtained. The deduced time will be the total welding time till certain cooling time.

The optimum welding length can be estimated on the basis of the electrode specifications such as size, kg weld metal per kg electrode, number of electrodes per kg weld metal, burn off time per electrode and welded length per burn off time per electrode.

The possibility of application of such technique in shipbuilding is investigated.

It is concluded that the proposed technique for estimating of optimum welding length can be applied effectively for controlling the residual stresses and deformation due to welding.

1. WELDING SEQUENCE

In welding a long butt joint, various types of welding sequences such as back step, block, built-up, cascade etc, are used in an attempt to reduce residual stresses and distortion. The selection of proposed welding sequence is important, especialy in welding joints with high restrain, such as joints involved in making patches.

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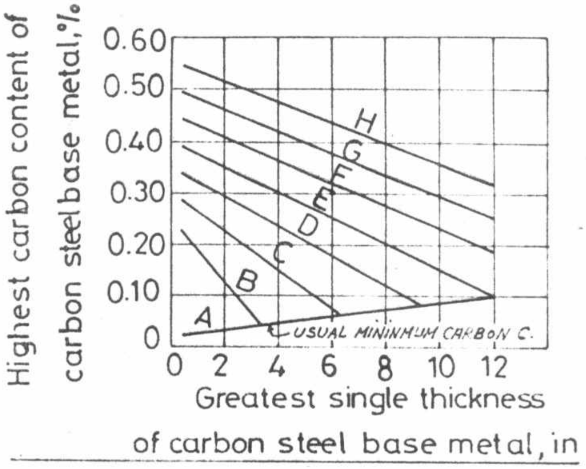
It is found that [1] the welding sequence has large influence on the deformation and residual stresses as well as the length of the weld. Accordingly, it is important to execute welding process by using sequence of welding with suitable welding length which leads to control the residual stresses and deformation.

2. PREHEATING AND INTERPASS TEMPERATURE

There are several reasons for the application of supplementary heat to a joint before and during welding, these reasons are:

1- The preven-tion of cold cracks.
2-Reduction of hardness in heat-affected zone.
3-Reduction of residual stresses.
4-Reduction of deformation.

The need for preheating and interpass of carbon steel is based not on carbon content alone, but rather on the combination of carbon, manganese, silicon and residual alloy contents with various aspects of joint configuration. Chiefly section thickness. Likewise, the selection of a preheating and interpass temperature is determined largely by this contribution.



	Range of preheating and interpass temperatures, F	
	Welding with high-hydrogen electrodes(a)	Welding with low-hydrogen electrodes
A	50 to 100	50 to 100
B	100 to 200	50 to 100
C	200 to 300	100 to 200
D	250 to 400	150 to 300
E	300 to 500	200 to 400
F	350 to 600	250 to 500
G	400 to 700	300 to 600
H	450 to 800	400 to 800

Fig"1" Effect of base-metal carbon content and thickness on preheating and interpass temperatures. [2]

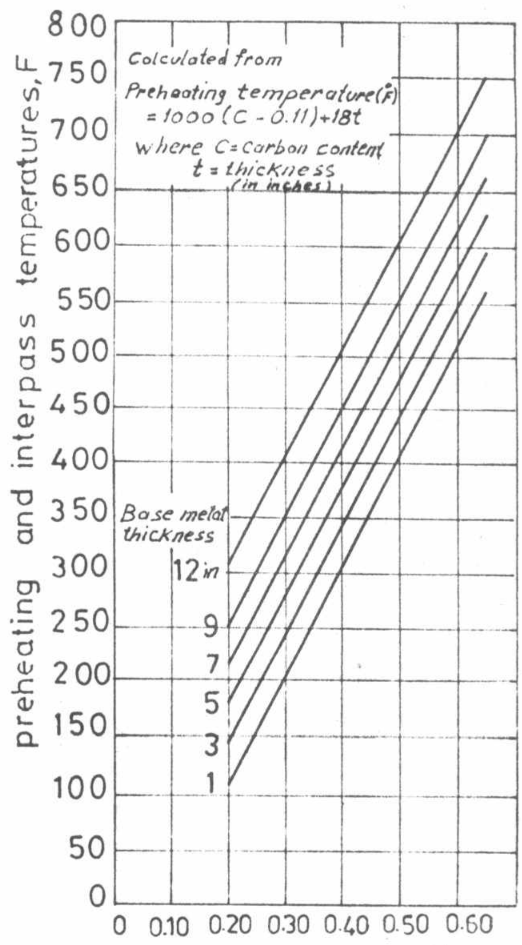


Fig "2" Effect of base metal carbon content on preheating and interpass temperatures. [2]

Figures 1 and 2 relate the selection of preheating and interpass temperatures to carbon content and section thickness of carbon steel welded by the shield metal arc process.

3. COOLING RATE

The length of the block(welding length) must be determined in order to lead to minimize the deformation and limit the residual stress due to weld.

The estimation of the optimum length will be as a function to the parameters which have influence on the deformation and residual stresses.
These parameters are heat input(including all availables of wel ding condit- ion such as Ampere, Volt, travel speed and type of welding process), cooling rate, initial temperature(preheating and interpass temperature).

In order to determine the cooling rate, it is helpful to define a dimenionl- ess quatity called "the relative plate thickness" " [3] .

$$\tau = t\sqrt{\frac{\rho c(T_c-T_o)}{H_{net}}} \qquad (1)$$

Where.

t= Thickness of sheet or plate, mm.

ρ= Density of material, g/mm^3

c= specific heat of solid metal, j/g. C°

ρc= Volumetric specific heat, j/mm^3. c°

Tc= temperature of interest, c°

H_{net}= Net energy input=

$= \eta \frac{VI}{v}$ (V= Volts, I=Amperage, η =heat transfer efficiency v travel speed of heat source)

The thick plate equation applies when τ is greater than 0.9, and the thin plate equation when τ is less than 0.6. When τ falls between 0.6 and 0.9, the thick plate equation gives a cooling rate which is too high, and the thin plate equation gives one which is too low.However ,if an arbitrary division is made at τ=0.75, larger values being regarded as thick and smaller as thin, the maximum error may not exceed 15 percent in a cooling rate calculation. For example, for low alloy steel, if the thickness of welded plate is 14mm. The relative plate thickness will calculate as follow:-

$$\tau = 14\sqrt{\frac{0.0044\ (550-100)}{945}}$$

$$\tau = 0.63$$

There fore, the thin equation applies

$$R = 2\pi k \rho c \left(\frac{t}{H_{net}}\right) (T_c-T_o)^3 \qquad (2)$$

Where.

R= The cooling rate at a point on the weld center line, c°/s, at just that moment when the point is cooling past the temperature, Tc.

K= Thermal conductivity of the metal j/mm.sc°.

Figure 3 is drawn containing maximum and minmum limits of energy deposited per unit length of weld.

Figure 3 is divided into two parts ...

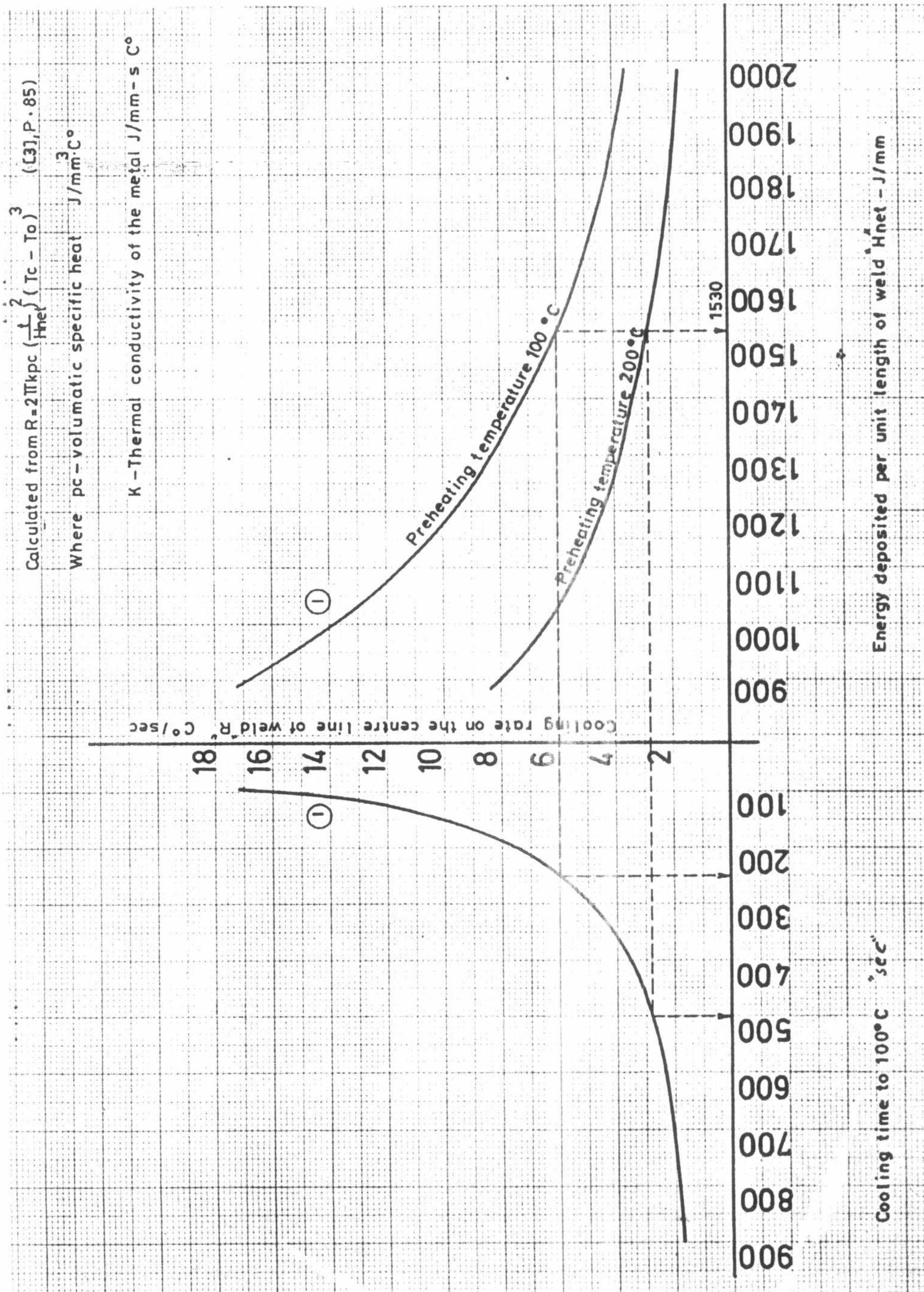


Fig. 3 Estimation of cooling time to 100 °C

heat input and cooling rate as a function to preheating or interpass temperatures 100and 200 c°.

The second part is showing the relation between cooling rates and the time required to cool to 100 c° .

4. DETERMINATION OF OPTIMUM WELDING LENTH

The time which can be obtained from figure 3.is considered the total time required for executing the welding of a length in order to get the least deformation when preheating or interpass temperature 100 c°is used ie, manufacturing time.

This time is equal to the summation of all time requared for welding.

$$Ti = t_t + t_p \qquad (3)$$

Where.

Ti= The total time required for welding a length till cooling temperature 100 c°.

$t_t = t_a + t_r$

t_t=Technological time

t_a=Machine time ,time of arc burning

t_r=Manual work time

t_p=Auxiliary time

The manual work time is divided into the following:

t_{r1}=Substitution of electrodes

t_{r2}=Cleaning of welded layer or seam

t_{r3}=Regulation of the current intensity

The auxiliary time"t_p" is the time of preheating if it required.

It is found that [4,5] ,the welding time "Ti" in a rough estimation range between the double and triple value of the arc burning time "t_a".

The type of electrodes used condition directly the time values t_a, t_{r1}, t_{r2} [6], while the other time values not change or change to a smaller extent.This means that while calculation required for welding certain length in order to control deformation and residual stresses, first we should consider these three times.

From welding time analysis mentioned above and with the aid of electrode specifications such as size, kg weld metal per kg electrode, number of electrode per kg weld metal, burn off electrode and welded length per burn off time per electrode, the optimum welding length can be determined .

5. APPLICATION IN SHIPBUILDING

In shipbuilding, almost shipyard define the times which depend upon the type of electrodes used, as shown in Table 1. as an example of estimating of the optimum length of the block, when the AWS classification: E 7018 electrode is used for welding has diameter 4mm with the following condition, 170Ampere, 24Volt, 2.0mm/sec travel speed and shielded metal arc welding process.

Table .1. Deposition data at max. welding current of electrode E 7018 Aws Classification [7]

Size Diam. mm	Length mm	N kg weld metal per kg electrodes	B number of electrodes per kg weld metal	H kg weld per hour arc time	T burn off time per electrode secs	Weight of weld metal/ electrode g	Power consumption per kg weld metal kWh	WELDED LENGTH PER BURN OFF TIME PER ELECTRODE "mm"
3.25	450	0.66	30	1.5	90	33	2.7	220
4	450	0.68	20	2.1	100	50	2.2	260
5	450	0.66	14.5	3.0	110	69	2.3	270
6	450	0.67	10.5	4.4	120	95	2.2	300

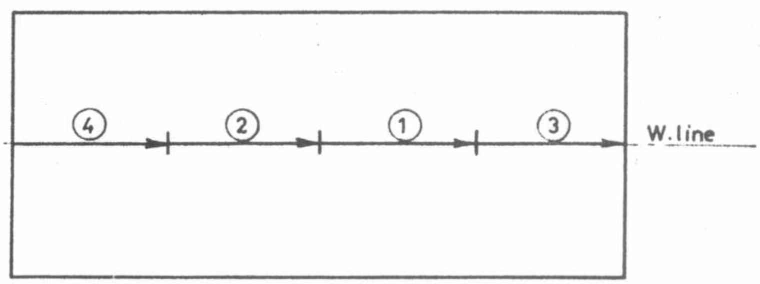
Accordingly, heat input equals 1530 J/mm (heat input= $\eta \frac{VI}{v}$, η =heat transfer efficiency). By going with known heat input from Fig. 3. the time required for cooling to 100 C° may be determined, which is found to be 365 sec. From Table 1. burn off electrode (for electrode has 4mm) is equal to 100 sec while welded length per burn off time per electrode equals 260mm. The additional time (losses) can be calculated by considering the deposition factor [5] , which is found to be 1.5. Therefore , the welding time requires 150 sec for each electrode; this time is resulting from burning time as well as additional time which is needed to excute weld with length of 260mm. Therefore, 300 sec are required for welding two electrodes of total length 520mm; hence, for excuting optimum welding length 550mm for the mentioned block, it is needed 365 sec according to type of electrode E7018 AWS classification with diameter 4mm and with the foregoing mentioned conditions.

When the length of weldment equal 1500mm, by using the same welding condtion mentioned above, the optimum welding length will be equal to 550mm. Consequently, the length of weldment will divide into three equal lengthes, where each one equals 500mm.

If the length of weldment less than 1500mm, then it will divide into three lengths. In this case the length of the block will be less than the optimum length (550mm).

If the length of weldment more than 1500mm, then it will divide into several lengths each length equals or less than the optimum length.

Fig. 4.Welding seguence for more than three block



In any case the location of the first block will lie between one block at least from right and left sides., as shown in figure 4.

When the length of weld is long enough and according to the possibilities of shipyard, the welding process can be applied on several positions using more than one welder in the same time.
Consequently, the stresses due to welding can be balanced around the principal axis Xand Y depending on the distribution of welders on the welded plates.

6. CONCLUSIONS

The following main conclusions may be mentioned.
1- It is possible to determine the optimum welding length as a function to the parameters which have influence on the deformation and residual stresses.

2- By using welding sequences with certain welding length for performing the weld, minimizing of the deformation and limiting of the residual stresses can be obtained.

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