Factors Influencing Heavy Wall Tube Welding

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Introduction

Induction welding of tube and pipe with increased wall thickness presents manufacturers with new challenges regarding production rates and quality.

In a medium- and thick-wall tube the heat-affected zone (HAZ) is shaped like an hourglass, ie the corners are heated more than the centre of the tube walls. A cold centre can limit the maximum weld speed, even if the mill has additional capacity and the welder has additional power.

Compensating with more power to sufficiently heat the cold centre can overheat the strip edges considerably. Weld quality can deteriorate and the overheated edges may cause molten material to drop onto the impeder, reducing impeder lifetime and performance.

To understand this weld problem better, we have studied parameters influencing the temperature distribution across the weld. These parameters are Vee angle, distance from weld point to induction coil, spring back, weld speed and frequency.

Computer Simulations

Two-dimensional, coupled electromagnetic and thermal FEM analyses enable us to investigate the development of temperature in the cross-section of the weld Vee from induction coil to weld point (see figure 1), as well as the final distribution at the weld point. For details, see ref. [1] and [2]. The metal strip material in all our calculations is low-carbon steel with a wall thickness of 12.7mm (0.5").

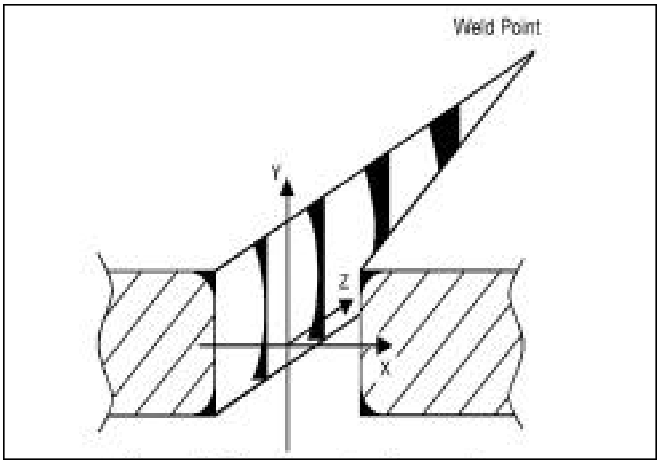

Figure 1: Development of temperature distribution in the weld Vee

The minimum temperature required in the cross-sectional centre of the tube, to avoid cold weld condition, is a function of the applied weld roll pressure. In this case, we use a temperature of 1250°C in the tube wall centre at the weld point.

Some results are presented as colour shade plots of the temperature distribution at the weld point. The temperature scale for these plots is shown in figure 4.

To compare the setups, we have calculated the cross-sections of molten (above 1725°C) and partly molten (above 1550°C) material from the temperature colour shade plots. The size is given in percentage of the cross-section of a reference setup (200kHz, 3° Vee angle and 14.6m/min mill speed).

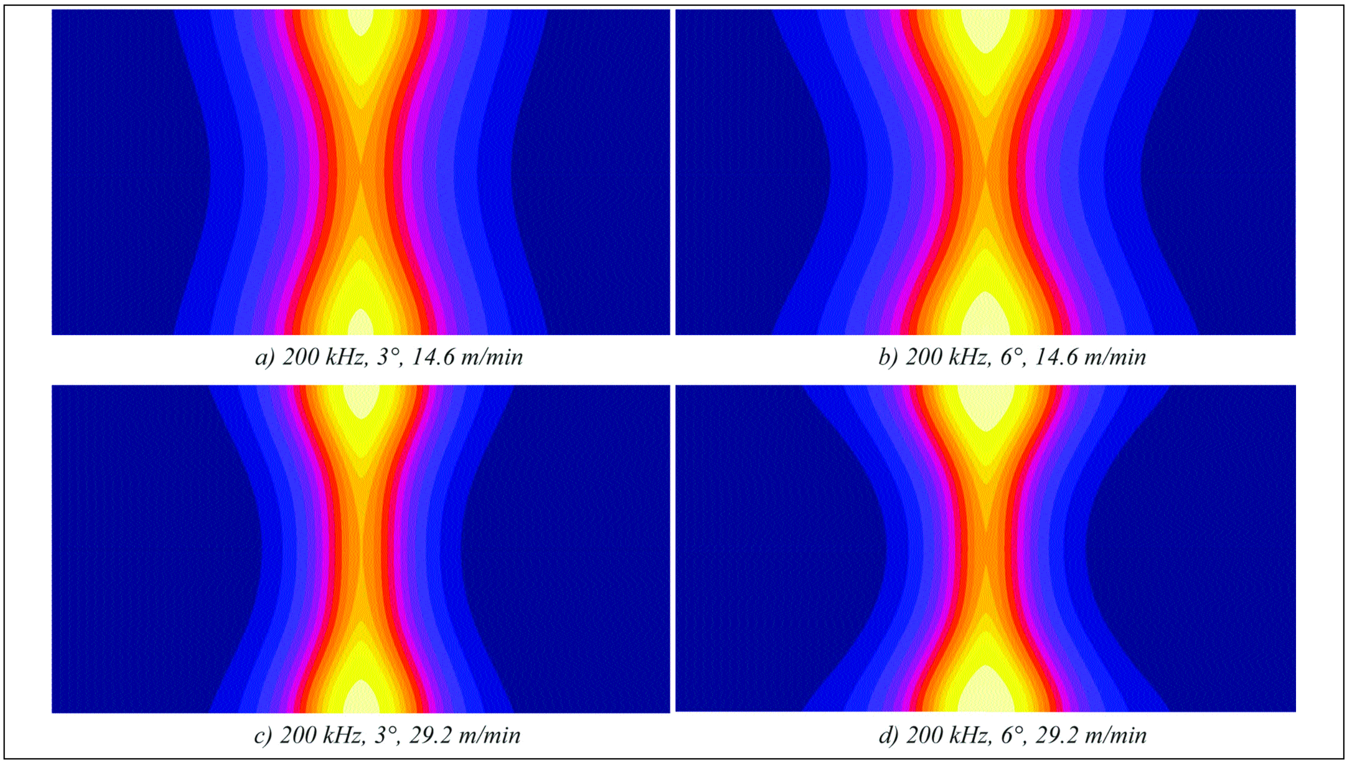

Figure 2: Temperature distribution at the weld point

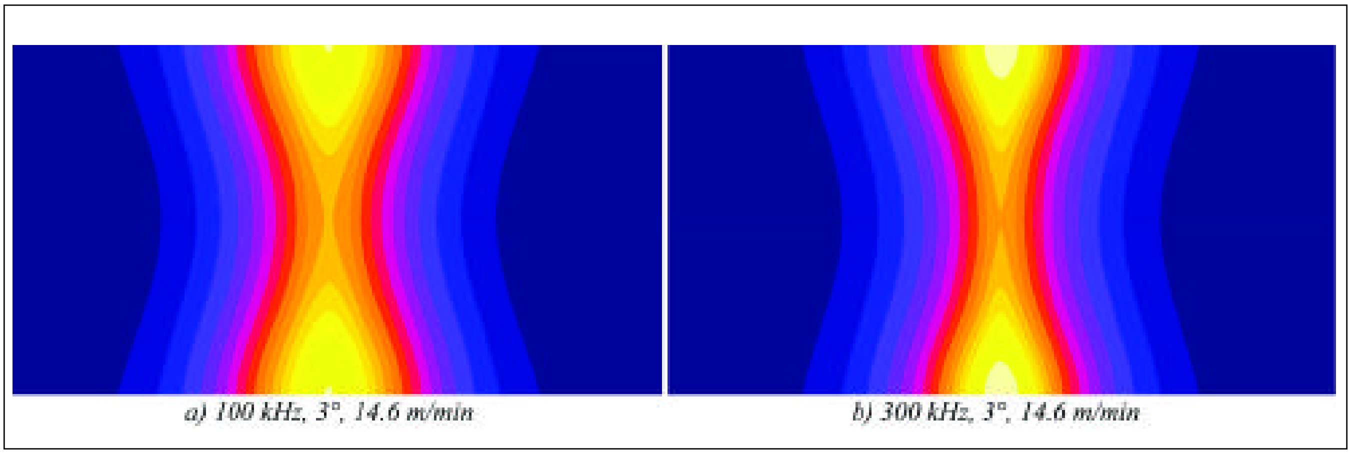

Figure 3: *Temperature distribution at the Weld Point*

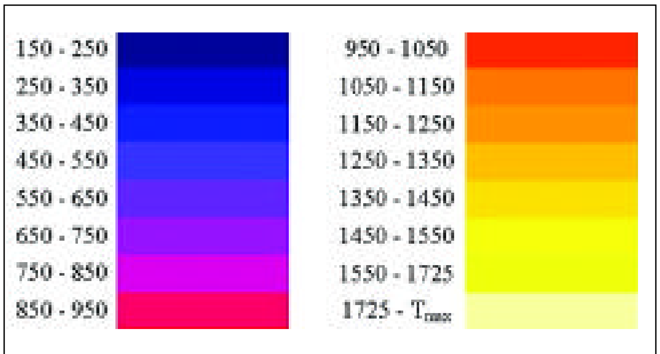

Figure 4: *Temperature [°C] scale in figure 2 and 5*

Vee Angle and Springback

Figure 2 shows some results for a 200kHz setup. An increase in Vee angle from 3° to 6° increases the amount of molten material by about three times at low speed and two times at high speed. The amount of partly molten material increases approximately 50 per cent for both mill speeds.

Figure 5 shows that there is almost a linear relationship between melting and Vee angle. The effect of springback is investigated for 200kHz. This Vee shape is based on measurements on a mill running similar tube dimensions. At the beginning of the calculation, the distance between strip edges is equal to that of a linear Vee with 3° angle. Springback has the same effect on the weld problem as an increased Vee angle. In this case it equals a 4° angle for a linear Vee.

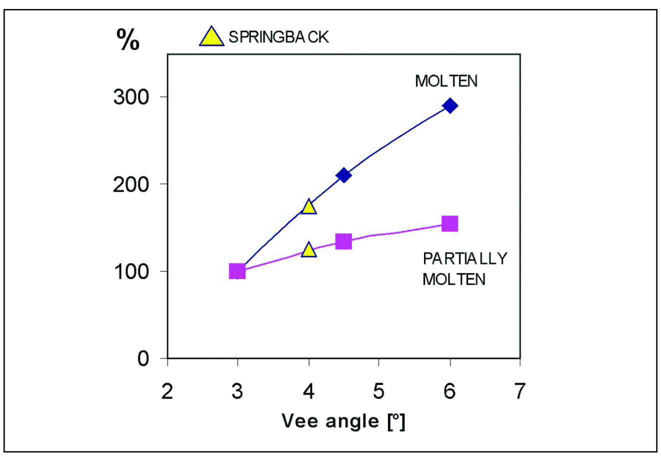

Figure 5: *Melting vs. Vee angle; 200 kHz, 14.6m/min*

Vee Angle and Mill Speed

Temperature distribution along the tube wall centerline (x-axis) is mainly affected by speed and, hence, heating time. Increased speed results in more heating of the tube wall corners. The result is a more pronounced hourglass shaped heated zone.

This effect is most evident in figure 2d, with the combination of high-speed and wide angle. Results show that the 3°, 29.2m/min setup gives less temperature differential in the weld zone than 6° and 14.6m/min. In figure 6 we can see that even a 1.5° reduction in Vee angle gives a better result.

Assuming constant Vee-Welder power ratio, a reduced Vee angle from 6° to 3° reduces Vee-power consumption with 12 per cent. This allows an 18-20 per cent increase in mill speed for the same power.

Vee Angle and Frequency

Figure 3 displays the temperature distributions for 100 and 300kHz at 14.6m/min. There is a distinct difference in the amount of molten material for the two frequencies.

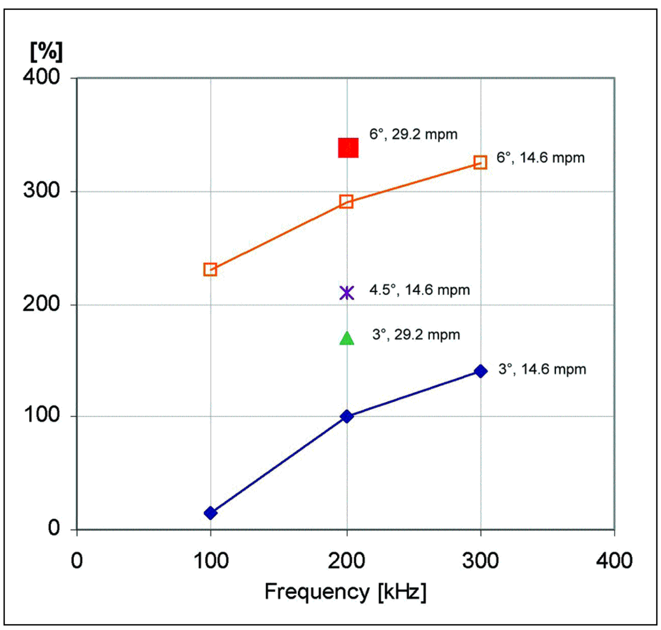

Figure 6: *Molten material vs. Frequency*

Focusing on the increase in Vee angle, (see figure 6) we see that twice the Vee angle has a greater impact on melting than three times the frequency.

The results indicate a narrower heated zone at higher frequencies. Energy input to the weld zone, however, is not correspondingly low [2]. Overheated strip edges increase the energy consumption at higher frequency.

Induction Coil Position

The influence of distance between weld point and induction coil can be investigated by assuming an ideal linear Vee. The results for 6° and 14.6m/min (at nominal distance, as for all simulations) equal the results for 3°, 29.2m/min at twice the nominal distance.

Figure 7 shows melting vs. frequency with distance as parameter. It is evident that the induction coil should not be positioned unnecessarily far away from weld point, independent of frequency.

A long Vee increases both heat flow away from the weld Vee, and stress on the impeder. This gives a higher needed energy input and, in some cases, a matching limitation due to low impedance.

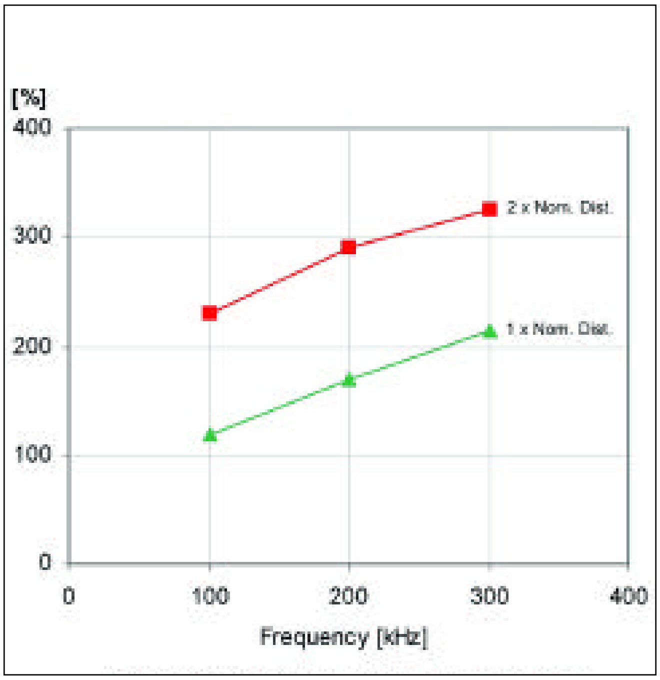

Figure 7: *Molten material vs. Frequency*

Factors Influencing Overall Performance

The requested impeder cross-section is calculated on the basis of Vee voltage and frequency. Both the energy input and necessary impeder cross-section can be reduced by one or more of the following setup changes:

- Reduced Vee angle
- Less springback
- Shorter distance from induction coil to weld point

These three changes work together, or alone, in reducing the area, AV, of the weld Vee; see figure 8. This area should therefore be made smaller in order to increase the throughput due to:

- Reduced problem with cold centre and overheated edges
- Improved overall welding efficiency

These benefits, given by reduction in weld Vee area, are independent of frequency.

For the same mill setup and speed, a lower frequency demands a bigger impeder cross-section. This can be compensated with a reduced weld Vee area. A 1.5° reduction in Vee angle equals a 100kHz step down in frequency.

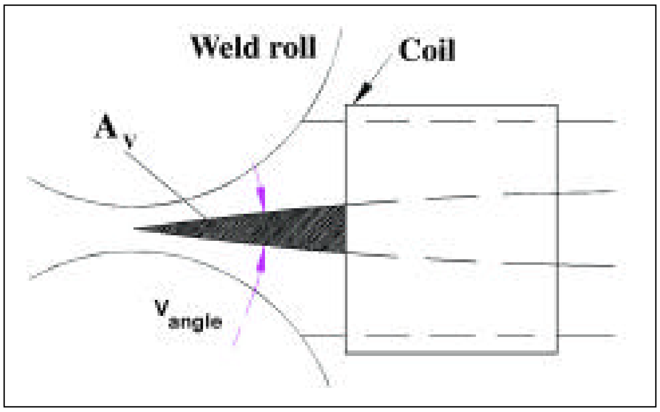

Figure 8 Weld Vee

Low frequency requires a larger impeder cross-section, but for big diameter tube production, this is not the limiting factor. It can therefore be possible to take advantage of the favourable heat-affected zone for 100kHz where there is less temperature differential in the weld zone.

On thick-wall, small diameter tubes, however, impeder space is limited. In addition to optimising impeder position, size and cooling, it might be necessary to reduce the weld Vee area for lower frequencies in order to achieve high-performance production.

Conversion Table

1250°C	=	2280°F
1550°C	=	2822°F
1725°C	=	3137°F
14.6m/min	=	47.9ft/min
29.2m/min	=	95.8ft/min

References

[1] J.I. Asperheim, B. Grande, L. Markegård, J.E. Buser, P. Lombard, *"Temperature distribution in the cross-section of the weld Vee"*, Tube Int., November 1998

[2] John Inge Asperheim, Bjørnar Grande, *"Temperature Evaluation of Weld Vee Geometry and Performance"*, Tube Int., October 2000

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