The Other Resistance Process: Cross Wire Welding

Cross wire welding — perhaps the most common nonautomotive application for resistance welding — can be used for many everyday products ranging from toaster guides to fences

BY NIGEL SCOTCHMER

Cross wire welding is used in many everyday applications. It is perhaps the most common nonautomotive application for resistance welding. There are many everyday uses for products made with cross wire welding, including shopping carts, toaster guides, wire meshes for reinforcing concrete, fences, and jail bars. In fact, our world would be unrecognizable without the reinforcing mesh used in buildings, roads, tunnels, and prefabricated components. It is used around the world in all types of products, even in the nanoscale cross wire welding of micro joints in electronic applications.

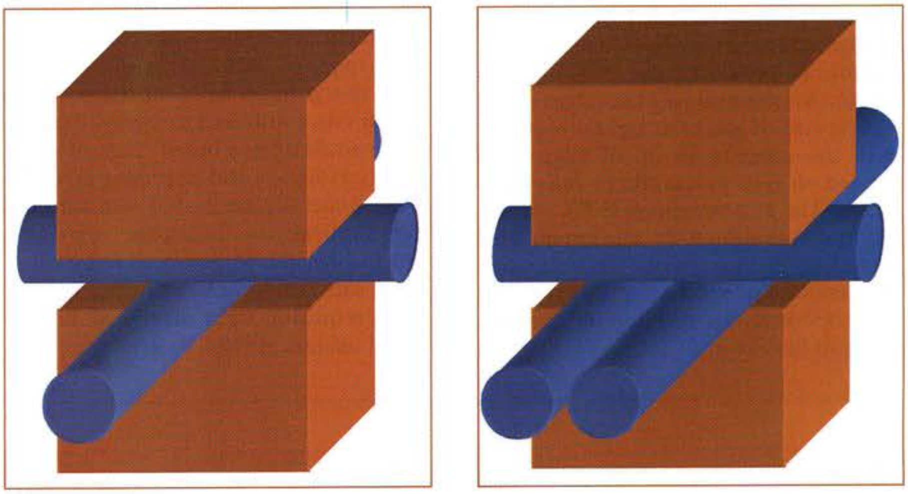

Fig. 1 — 'Single' and 'double knot' cross wire welds.

Features of Cross Wire Welding

Most people are familiar with spot welding, which is heavily used in joining automotive sheet body parts together, but fewer people are familiar with the ubiquitous presence and properties of cross wire welding. Cross wire welding is actually a type of projection welding. Projection welding is a unique form of resistance welding that uses the resistance heating of a small cubic area prior to, and during, its collapse under pressure to weld frequently different thicknesses of metal together. In this process, the size and shape of the projection is very important, as is the speed of the movement of the cylinder applying the pressure. If the metal of the projection collapses too quickly, before the resistance melting occurs, then there may be no fusion weld, or nugget, formed as the heat generated may be diffused over too large an area. If there is too much heat generated on the projection before its collapse, or if the cylinder is moving too slowly to follow the collapse, then there may only be expulsion and also no weld. Thus, it is imperative that the electrode force is maintained at the appropriate level during the collapse of the projection. It is also worth noting that it is an inexpensive and quick process, taking only a fraction of a second, and does not require shielding gases or filler metals.

These similar characteristics occur in cross wire welding. Generally, there are two wires or rods welded together, and their combined radii present a challenge and act like the projections in projection welding. The heating is rapid, and deformation occurs almost instantaneously.

One of the ways to improve quality has been the increasing use of automation. The last thirty years have seen an increase in the quantity of mesh welding machines, which attempt to mass produce and keep consistent the quality of production cross wire welding. At the same time, there has been an increase in the number of the types of reinforcing steels used, and it has become a challenge to effectively fabricate these new reinforcing meshes by resistance welding. Mesh welding machines are available in various sizes for the production of reinforcing mesh. These machines are computer controlled and can be automated with an assortment of loading, feeding, straightening, cutting-to-length, and pay-off features in order to form an automatic production line. Rods and wires can be welded one on top of the another in practically any arrangement. Exact, reproducible control of the current, time, and welding force is assured by the welding process control system. Figure 1 shows a typical setup for a single and double knot cross wire weld.

Cross wire welding is performed by direct welding (Fig. 4) or indirect welding (Fig. 2). The definition of direct welding is that only one weld per current flow is produced. Indirect welding uses the current flow through the actual workpiece to facilitate other welds or for heat management, weld appearance, or material property reasons.

NIGEL SCOTCHMER (nscotchmer@huysindustries.com) *is the president of Huys Industries, Weston, Ont., Canada.*

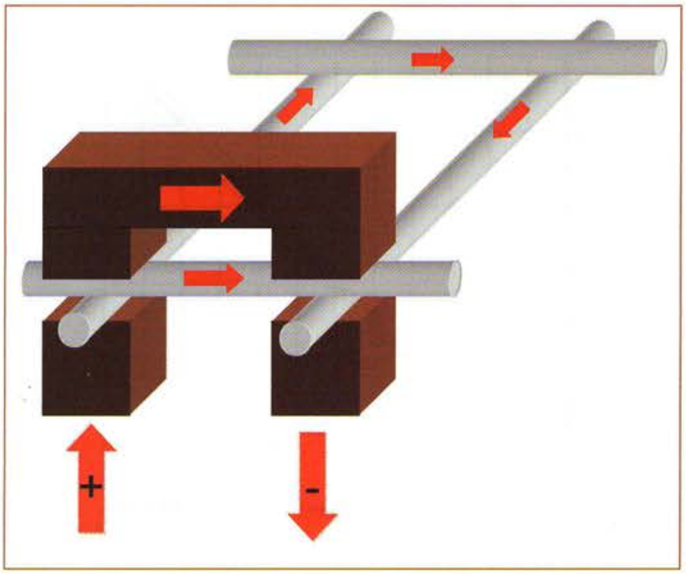

Fig. 2 — Series welding.

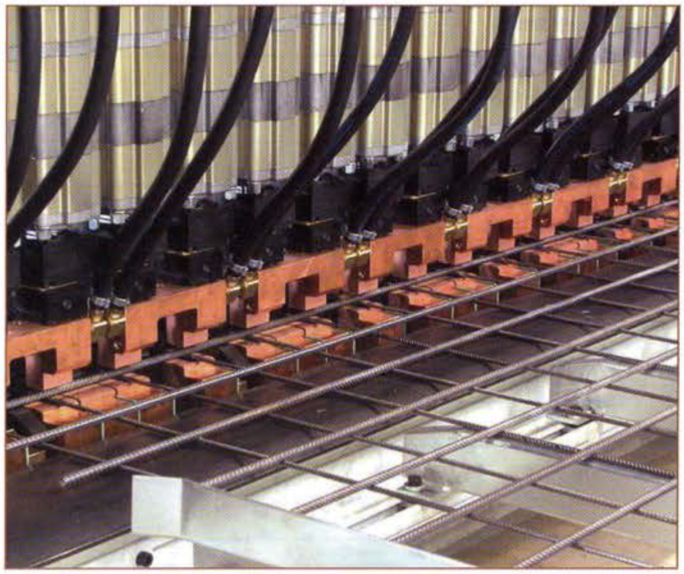

Fig. 3 — A series welding machine.

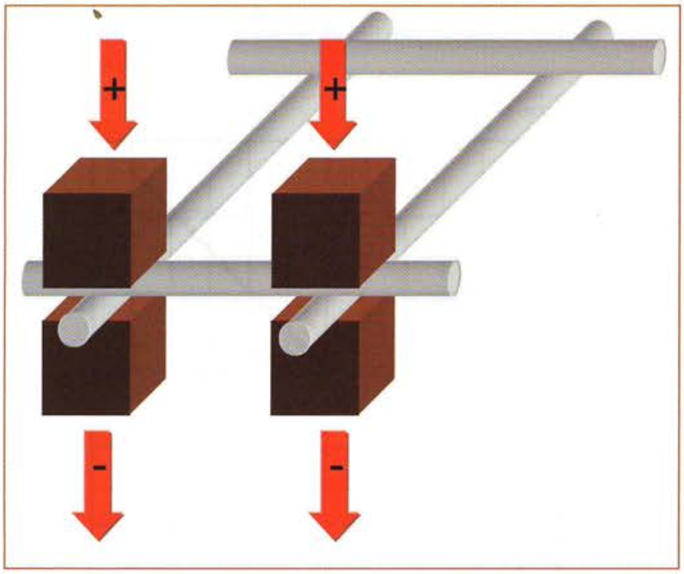

Fig. 4 — Direct welding.

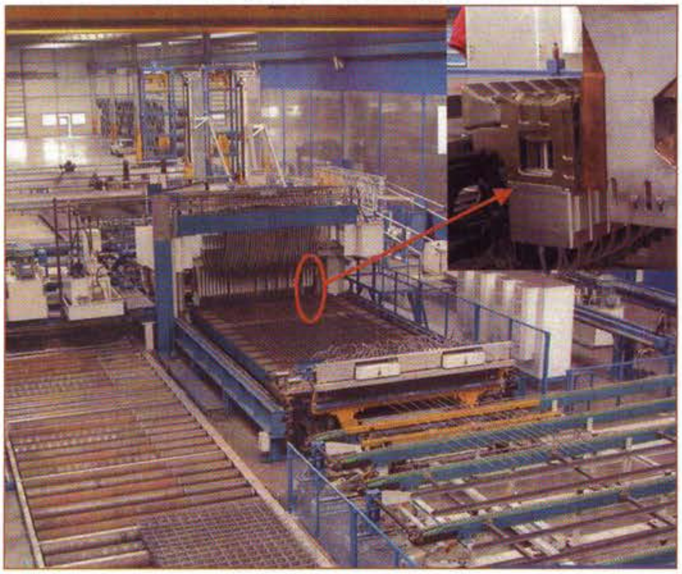

Fig. 5 — A direct welding machine.

Looking at Series Welding (One-Sided Welding)

A common type of indirect cross wire mesh machine employs series welding or one-sided welding. They are often used for making storage meshes as they are limited in how longitudinal bars are divided. In this case, both electric poles are on the same side of the mesh. Usually, two welds per current flow are made. This method tends to melt material at the electrode contact area of the longitudinal rod. This effect is generally agreed to be caused by the systematic bypass of the welding current along the transverse bar of the last weld — see the arrows in Fig. 2. Naturally, the amount and rate of the bypass current depends on the rod diameter and the position of the next transverse rod. This bypass current has to be compensated for by a higher total current (Table 1).

Thus, the power supply for the welding machine, and of the power of the transformer, becomes very important and a limiting variable. A series welding machine has a simple construction with an open mesh plane that allows the feeding of the cross rod or wire in or toward the production direction. Figure 3 shows a high-speed series welding machine with the transfer rods inserted over the longitudinal rods just prior to welding.

Details of Direct Welding

The most impressive direct welding machines are made up of any number of floating, independent welding assemblies — Fig. 5. Each welding assembly is a self-sufficient system consisting of transformer, welding press, and power supply. A floating system allows for different diameters of longitudinal rods to be welded quickly and accu-

Table 1 — Bypass Factors for Series Welding

Diameter of Wire (mm)	Division (mm)	Bypass Factors I_{tot}/I_x
4 + 4	25/25	1, 25
5 + 5	25/25	1, 4
5 + 5	40/40	1, 33
5 + 5	50/50	1, 3
6 + 6	50/50	1, 42
8 + 8	50/50	1, 65
10 + 10	100/100	1, 34

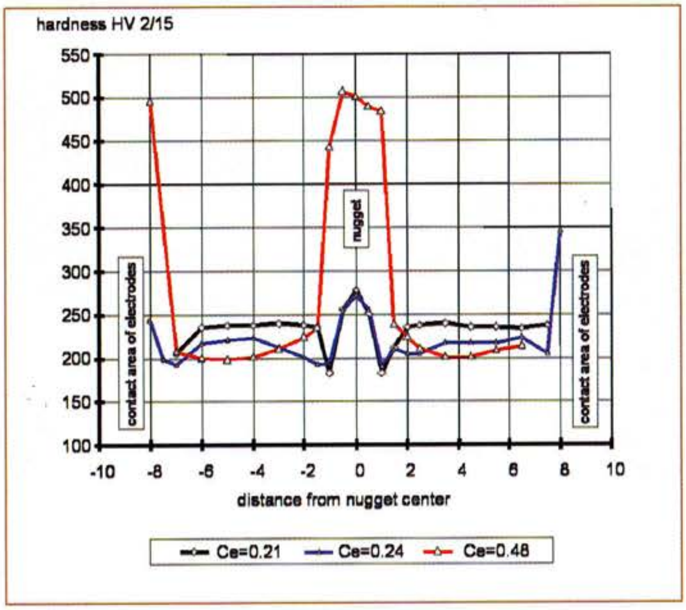

Fig. 6 — Cross-section hardness of a weld of different carbon equivalent (CE) steels.

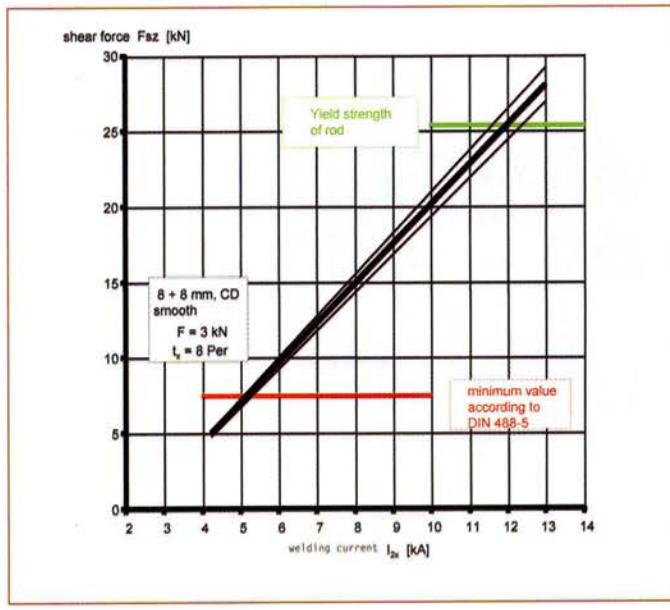

Fig. 7 — Reinforcing steel, cold drawn, carbon equivalent CE = 0.21.

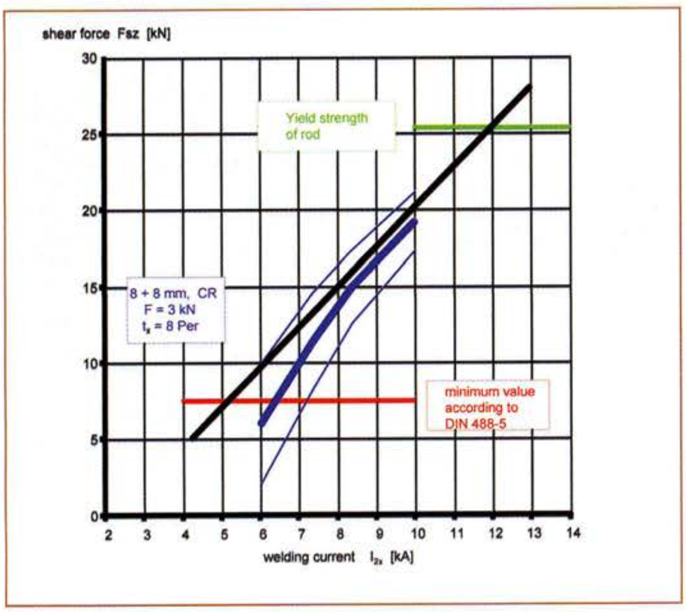

Fig. 8 — Reinforcing steel, cold rolled, carbon equivalent CE = 0.24.

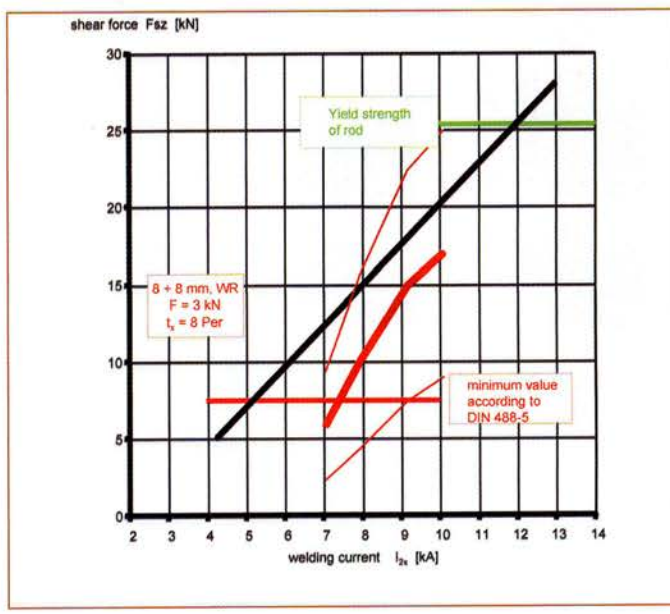

Fig. 9 — Reinforcing steel, hot rolled, carbon equivalent CE = 0.48.

rately, even with very small and varying distances between cross wires or rods.

Generally, such machines are more expensive and are capable of producing a wider range of manufactured parts. They are designed to allow for variable adjustment in longitudinal bar division. This would mean that the mesh could be adjusted during production to create a mesh with different material properties with more frequent, or less frequent, cross welds. Except where 'double knots' (two longitudinal wires are welded between an electrode pair, as in Fig. 1) are used, only direct welding is used.

The Need for Standards to Improve Quality

The aim is always to improve quality. The easier a material is to weld, the better is its 'weldability.' The better its weldability, the less effort is expended to get consistently good welds. In spot welding, a sheet steel's weldability is usually measured by its welding current range (lobe), electrode life in use, and the tendency of the material to harden. The weldability of reinforcement bars in cross wire welding is given by its chemical components, surface condition, and rib formation. In current national and international standards, the focus is limited to the chemical components of the material, and there is no differentiation of the weldability between the welding processes of arc welding and resistance welding.

With the recent wave of new steels coming on the market, many believe that there is an increasing need to create a standardized procedure to determine the weldability of reinforcing steel for resistance wire welding (as is already the case for spot welding). Such a tool for evaluating the weldability of materials for pro-

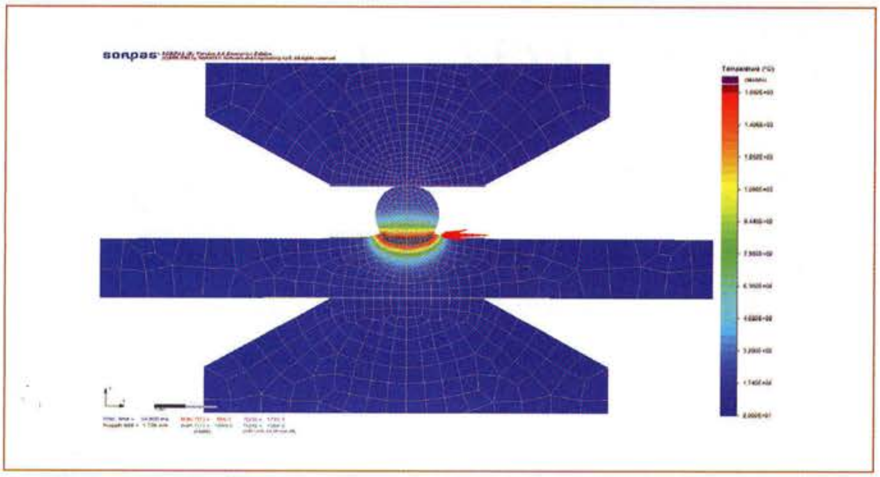

Fig. 10 — A simulation output of a cross wire weld, showing expulsion as a red flame.

Table 2 — Welding Parameters for Reinforcing Steel (60 Hz AC)

d (mm)	F_E (kN)	tx_up (cycle)	tx (cycle)	Cold Drawn I_{2x} (kA)	Cold Ripped I_{2x} (kA)	Hot Rolled I_{2x} (kA)
5	1.5	1	4	4.5	5.0	6.3
6	2	2	6	5.4	6.0	7.4
7	2.5	2	7	6.6	7.3	9.1
8	3	2	9	7.6	8.4	10.5
9	3.5	3	11	8.6	9.6	11.9
10	4	3	13	9.7	10.8	13.4
12	5	5	18	11.2	13.1	16.3
14	6	6	25	13.7	15.2	18.9
16	7	8	32	15.8	17.5	21.7

jection welding would improve the overall quality of cross wire welding. Figure 6 further illustrates this by showing differences in the typical weld nugget hardness between three common steels.

Marc Mueller of H. A. Schlatter AG, a maker of a wide range of cross wire welding machines from Switzerland, has provided some interesting graphs that illustrate some critically important values for projection welding that illustrate the need of a standardized procedure for determining the weldability for reinforcing steels. Today's standards define reinforcing steel with CE up to 0.50 as 'weldable' (Fig. 6) without any restrictions, even if there is a high tendency to harden. Figures 7–9 illustrate the challenge of achieving the shear test requirements of DIN 488-5 using the parameters of Table 2. These figures illustrate that a high current level is required to achieve the deep penetration required, especially in hot-rolled reinforcement mesh, and are the result of years of experience from Mueller and his customers.

The thinner lines in the diagrams show the 95% area (using duplex standard deviation) of shear test force results. For a comparison, the mean of cold- and hot-drawn material is also given in Figs. 8 and 9. These graphs show the necessity of controlling the welding parameters to achieve the required strength. Established international standards would improve quality by mandating acceptable strength. To decrease the amount of expulsion during welding, an upslope is necessary to reduce the current concentration at the start of the current flow when welding hot rolled reinforcing steel of types shown in Fig. 9.

Another way of improving the quality of resistance cross wire welding is the emerging use of simulation software, which attempts to predict the performance of cross wire welding based upon the finite element modeling of input parameters of the material, time, current, and force. An example of the output of this process is given in Fig. 10. Peak temperature achieved in the simulation is cross referenced to the bar at the right.

Michael Kuntz of the University of Waterloo has taken this a step further with the small-scale microwelding simulation of cross wire welding of fine stainless steel wires for biocompatible material applications such as medical implants. Figure 11 shows how he has used a simulation software program to predict the outcome of DC welding under differing scenarios to see the peak temperature distribution, which would assist him in evaluating the size of the heat-affected zone, and understanding how the mechanical properties might be affected. Three weld currents of 100, 120, and 150 A are illustrated, respectively. The simulations are paired with a microphotograph of the actual resultant weld for comparison.

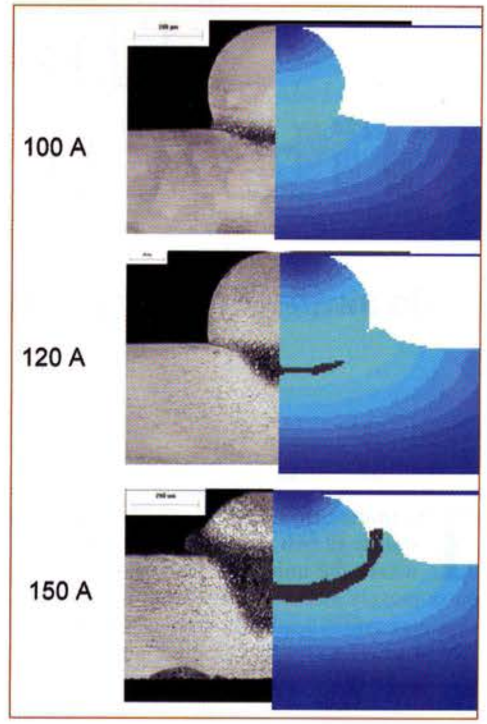

Fig. 11 — Metallographic results of microweld with superimposed simulation.

Final Thoughts

This article has looked at some applications of cross wire welding, has highlighted the need for the industry to create tensile shear strength standards for projection welding with the increasing use of advanced high-strength steels and ultrahigh-strength steels, and the emerging trend toward the adoption of simulation resistance welding to reduce weld verification testing and preproduction scrap and labor. In projection welding, it is not possible to weld without expulsion. The problem is controlling the amount of expulsion and obtaining the required strength. Standardized procedures are needed for determining the weldability of materials for cross wire welding. ♦