How Do I Spot Weld This?

By Nigel Scotchmer

Frequently, people ask how to spot weld two pieces of metal together, and, even more commonly, people wonder "what is the *best way* to weld these parts?" and "what are the *best parameters* to use to weld them?" With the increasing use of advanced high-strength steels (AHSS), especially in the automotive sector, people are also wondering how to ensure that the weld has the desired microstructure, hardness and ductility.

At the same time, the explosion of computing power in ordinary laptops and desktops over the last 10 years has facilitated the growth of finite element analysis (FEA) for everyday applications. Perhaps the best known example of applied FEA has been crash testing of automobiles, where we see a computer-generated three-dimensional simulation of the car before and after a simulated crash, with the strains and stresses of the forces of the crash highlighted in different colours.

This technology is now being applied to spot welding. Companies are simulating welds, optimizing welding parameters, and analyzing the strength characteristics of the simulated welds *prior* to welding.

This advance allows for a quicker turnaround on regular production problems that arise from time to time, a reduced time to market for new products, improved quality, the establishment of wider, more stable and safer "welding lobes" and the introduction of new production methods and innovative technologies.

Let's look at how the simulation of resistance spot welding (RSW) works. RSW itself is accomplished with the application of heat generated by the electrical resistance of the material being welded, which is confined by the application of pressure.

The typical software package that endeavours to simulate this process operates on a normal computer found in any company. The thickness and type of the material being welded, the geometry and material of the electrodes, the current, force and welding time are entered in the computer, which performs numerous mathematical calculations to determine the simulated weld. (Figure 1.)

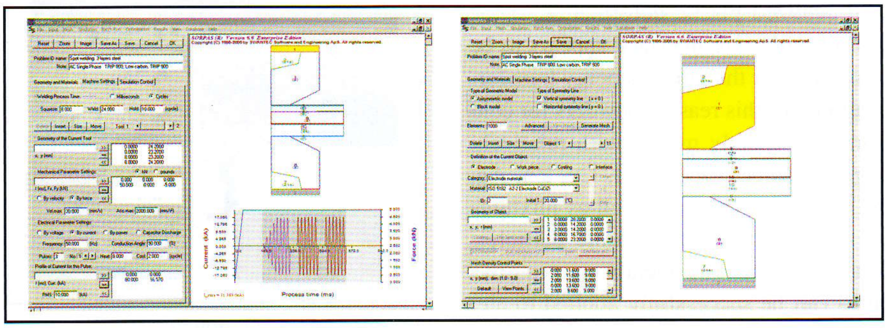

Figure 1: Typical input menus of SORPAS® software.

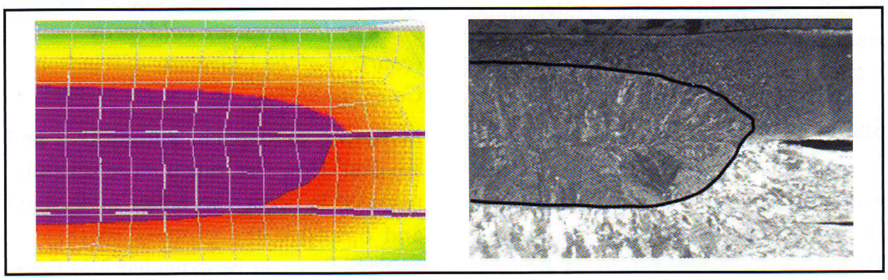

Figure 2: Typical software output with micrograph of actual weld superimposed on the right-hand side for verification purposes. Here we see one sheet of galvanized 1.0-mm USIBOR 1500 high-strength steel being welded to two layers of 0.7-mm mild steel (courtesy of PSA Peugeot Citroën).

As we mentioned earlier, FEA provides a solution to a problem based on the approximation of an array of elements of complex individual geometric parts with complicated boundary conditions. The computer, in effect, takes the large scientific problem of what happens when heat and pressure are applied to metal surfaces for a determined period of time and breaks them down into small, measurable steps, and, in colloquial terms, "crunches" the numbers.

The software takes into account the metallurgical, electrical, mechanical and thermal processes that will occur during the welding process, and calculates the resultant effects. It simulates the heat generated by the current and voltage, the heat transfer across materials, the metallurgical phase transformations caused by temperature change, and the deformation and strain distribution across the contact areas. All of this information is then presented in graphic form useful to the operator. (Figure 2.)

An interesting recent development has been the ability to couple the electrical-heat and mechanical-force mathematical calculations, something the human brain will never be able to do because of the sheer number of calculations required.

At this year's AWS Sheet Metal Welding Conference and SAE World Exposition in Detroit, a number of papers were presented, by companies such as Honda (ref. 1), General Motors (ref. 2), the University of Waterloo (ref. 3), the Edison Welding Institute (ref. 4) and Huys

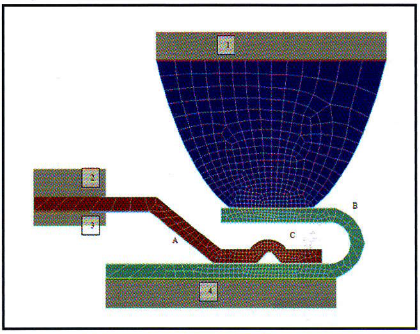

Figure 3: An indirect hem projection weld. Objects 1-4 are machine tools. A, B, and C are work pieces; hem-inner, hem-outer, and hem-projection, respectively.

Industries (ref. 5), showing how simulation can assist the design and choice of materials and geometries, improve process optimization and aid education through improved understanding of the welding process.

For instance, Honda's work explored the complex weld of an indirect hem projection. The edge of an automobile door uses a hem; how it is sealed is often a manufacturing challenge. To explore the design of such a weld in simulation is a novel application and indicative of future possibilities (Figure 3). The simulation work was confirmed and compared with test results.

GM's work explored different electrode geometries. Many opinions are held of electrode design, and this work reviewed truncated, radius and parabolic shapes (see Figure 4) and the type of weld that can be expected from them.

The University of Waterloo's work looked at simulating an unusual projection weld. This is shown in Figure 5. Projection welding is a subset of RSW, and the process, mechanics and welding parameters are very different – and previously considered hard to simulate. In this particular case, the task was complicated by the style, the odd number and type of projections. In the micrograph of the actual weld shown in Figure 5, you can compare the simulation with the actual weld.

The Edison Welding Institute explored ways of measuring electrode life and of evaluating the material characteristics of a simulated weld. This work presages future development, in that the extending and predicting of electrode life is the Holy Grail of resistance welding. These recent

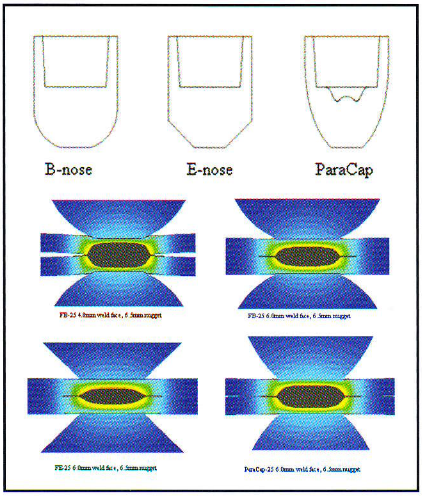

Figure 4: A selection of the electrode styles (B-nose, etc.) used in resistance welding. RSW electrode geometry FEA models simulated for target weld size of 6.5-mm nuggets on 1.6-mm DP800 steel.

articles, all with supporting test verifications, highlight the rapid growth of simulation welding as an established process.

Another application for this type of software is the simulation of predicted material characteristics of welded metal sheets. Since the cooling rate of molten, welded metal can determine its hardness, it has been proved useful to compare the simulated weld nugget with constant-cooling-rate diagrams to assist in determining weld strength. As shown in Figure 6, the cooling rates of points A and B in the simulated weld nugget are graphed by the software; they can be compared with the constant-cooling-transformation (CCT) diagrams commercially published to predict weld performance. This is a significant advance, in that the ability to predict weld strength is a fundamental concern of all welding. Thus, the many calculations a computer can do in a blink of an eye are put to good use!

Other recent work looks at the computer generation of optimized welding parameters and the generation of the complete welding lobe (Figure 7). This use of the simulation software will allow the initial set-up of welding parameters according to the chosen materials and electrode geometry to be determined automatically by the computer, and represents a significant potential saving in time and money.

The rapid advance of simulation RSW suggests that this new procedure to evaluate and assist an established process has

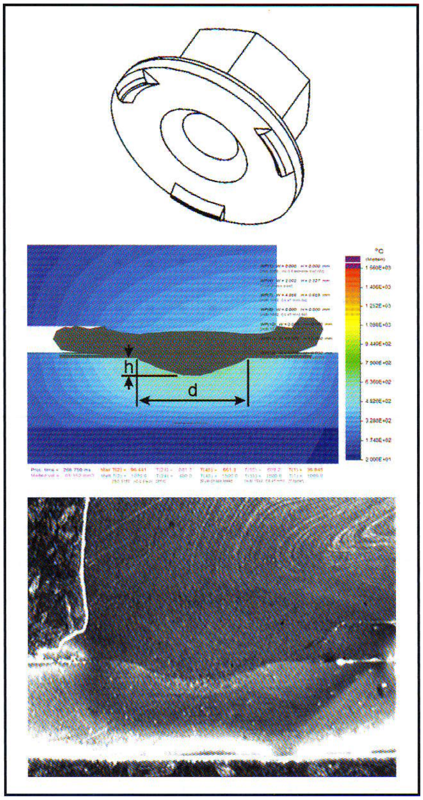

Figure 5: Drawing of a three-projection weld nut, simulation of the one weld and micrograph of the actual weld (courtesy of University of Waterloo).

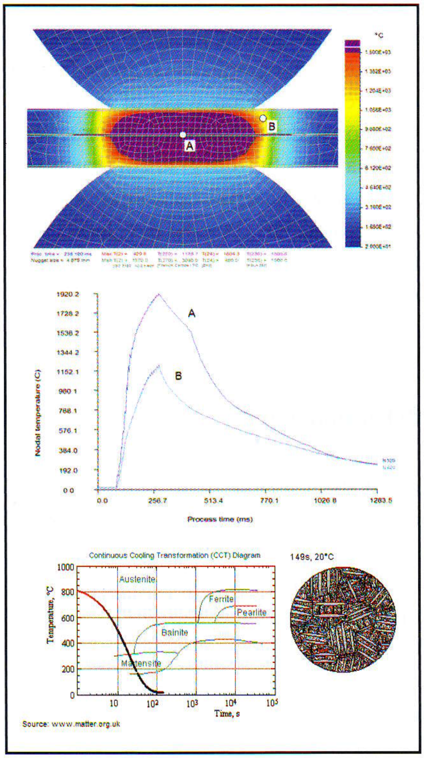

Figure 6: Predicted cooling rates compared with published CCT diagrams, with martensite microstructure on right (courtesy of University of Liverpool).

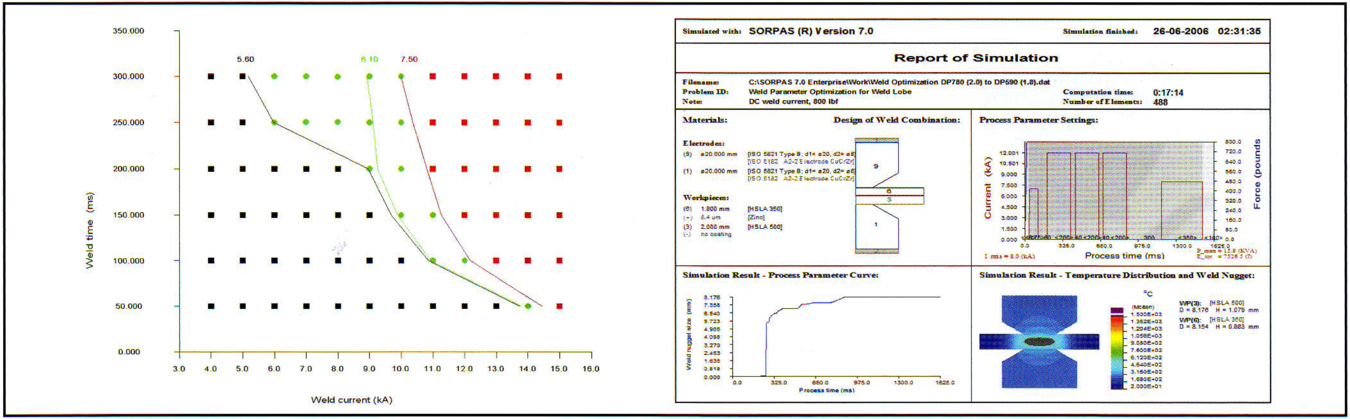

Figure 7: Typical output of SORPAS® software with the welding lobe charting weld current against weld time.

become invaluable. Clearly, it is only a matter of time before stand-alone computer simulations are connected on-line to networks controlling the whole welding process on a complete assembly line. The more we understand the welding process – and can control it in advance – the better the quality and the cheaper the end product will be!

Nigel Scotchmer is President of Huys Industries Limited, Toronto, Canada.

For Further Reading

1. Pete Edwards, Kevin Chan, *Lowering Costs by Simulating Design of Complex Welds*, AWS Sheet Metal Welding Conference XII, Detroit, 2006.

2. Kevin Chan, *et al.*, *Effect of Electrode Geometry on Resistance Spot Welding of AHSS*, AWS Sheet Metal Welding Conference XII, Detroit, 2006.

3. M. Kuntz, J. Bohr, *Modelling Projection Welding Fasteners to AHSS Sheet using Finite-Element Method*, AWS Sheet Metal Welding Conference XII, Detroit, 2006.

4. Jerry Gould, Warren Peterson, *Analytical Modelling of Electrode Wear Occurring During Resistance Spot Welding Galvanized Sheets*, AWS Sheet Metal Welding Conference XII, Detroit, 2006.

5. Kevin Chan, *et al.*, *Weldability Improvement Using Coated electrodes for RSW of HDG Steel*, SAE World Exposition, Detroit, 2006.