Simulation Software Helps Automakers

One of the newer developments in resistance spot welding is use of simulation software to predict weld results

BY NIGEL SCOTCHMER

Ten years ago many would have been surprised that an article would be published today describing new developments in resistance welding. After all, resistance spot welding (RSW) is a mature process, having been developed more than 100 years ago, and some would say it lacks the glamour and performance characteristics of the newer technologies emerging today.

Why, then, is the use of resistance welding, and the total number of spot welds in a car, generally increasing around the world in new models? The first reason is that resistance welding is an inexpensive, understandable joining process, with no expensive shielding gases or filler metals employed. In addition, the increased adoption of electronics in the last ten years has made resistance welding easier to measure and control with simulation software and precise weld controllers. Easier to use and more reliable nondestructive examination is also available. Another reason for the increased interest in resistance welding in automotive applications is the increasing use of advanced high-strength steels for improved crash performance and fuel economy. Many of these steels have unique and new microstructures that may perform differently after being welded. Thus the simplest process that is understandable, controllable, and can effectively and inexpensively weld these new, harder-to-weld materials is of immense interest.

An ideal place to start our understanding of RSW is with a discussion of software that simulates the engineering of weld parameters and their predicted results before the weld is performed.

Simulation of RSW

Simulation of resistance welding has taken off in the last ten years with the explosion of powerful laptop and desktop computers. It is now possible not only to simulate and accurately predict weld nugget size, but also to optimize welding parameters and even to predict the hardness and microstructure of completed welds prior to welding. Resistance welding itself is accomplished with the application of heat generated by the electrical resistance of the material being welded confined by the application of pressure.

The typical software package that endeavors to simulate this process operates on a normal desktop computer found at 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 and the software performs numerous mathematical calculations to determine the simulated weld — Fig. 1.

The branch of mathematics generally used in resistance welding software is called finite element modelling (FEM). FEM allows for a solution of a problem to be determined based upon 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 it down into small, measurable steps. In colloquial terms, it "crunches the numbers."

This means that the software takes into account the metallurgical, electrical, mechanical, and thermal processes that will occur during the welding process, and calculates the resultant effects. In effect, the computer 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 this information is then presented in a graphic form useful to the user — Fig. 2.

At the AWS Detroit Section's Sheet Metal Welding Conference, which was held in Livonia, Mich., in May, and at the SAE 2006 World Congress, held in Detroit in April, papers were presented by organizations such as Honda (Ref. 1), General Motors (Ref. 2), the University of Waterloo (Ref. 3), the Edison Welding Institute (Ref. 4), and Huys Industries (Ref. 5) showing how simulation can assist the design and choice of materials and geometries, improve process optimization, and aid education through the improved understanding of the welding process.

For instance, Honda's work (Ref. 1) explored the complex weld of an indirect hem projection. The edge of an automobile door uses a hem; how that hem is sealed is often a manufacturing challenge. To explore the design of such a weld in

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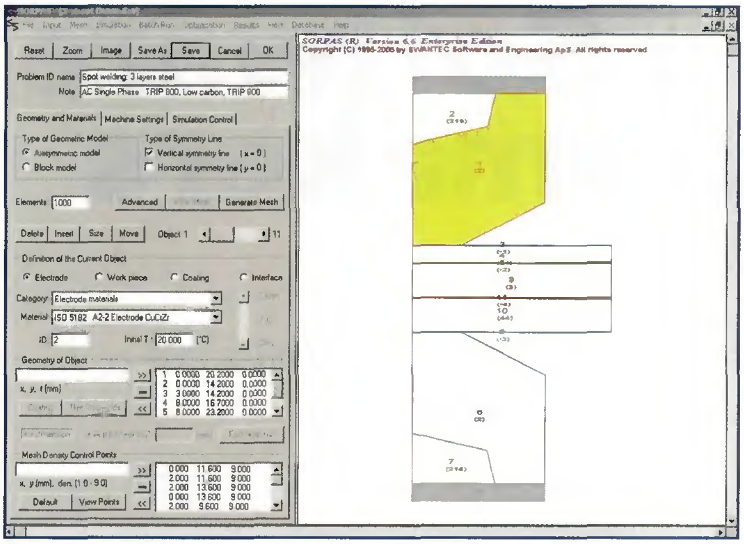


Fig. 1 — A typical input menu using SORPAS® simulation software.

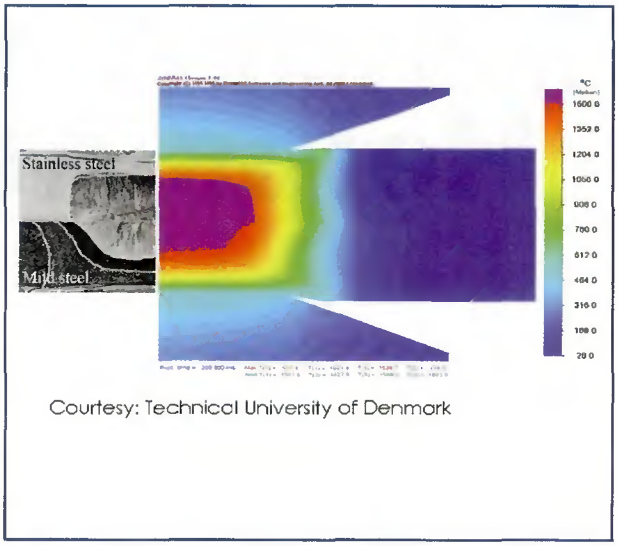


Fig. 2 — Typical software output, with micrograph of actual weld superimposed on left-hand side for verification purposes (courtesy of the Danish Technical University).

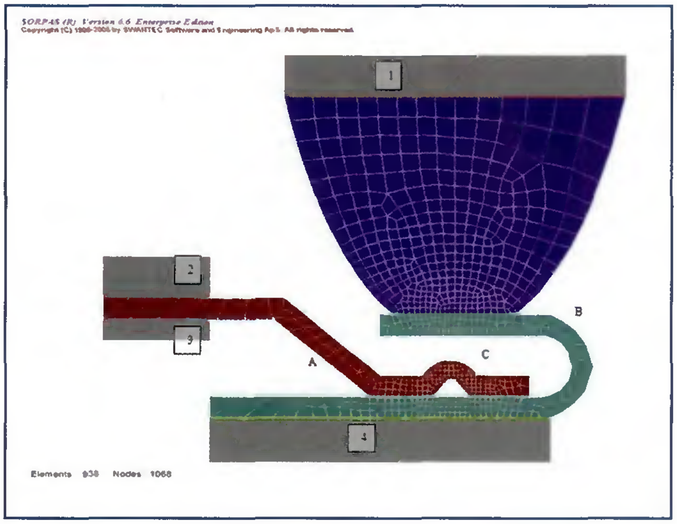
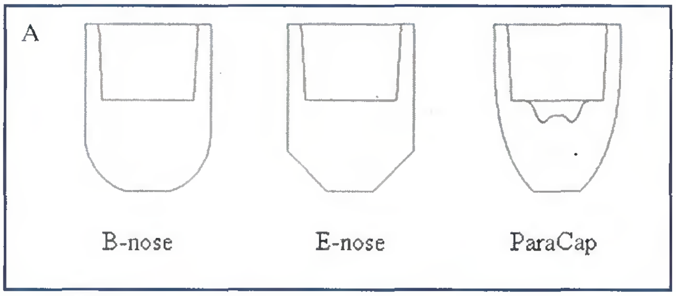


Fig. 3 — An indirect hem projection weld. Objects 1–4 are machine tools; A, B, and C are workpieces — the hem-inner, hem-outer, and hem-projection, respectively.



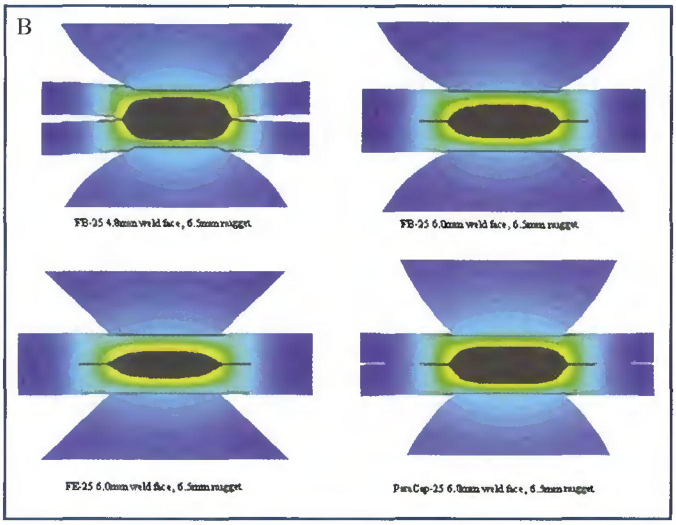


Fig. 4A — A selection of the electrode styles used in resistance welding; B — RSW electrode geometry FEM models simulated for a target weld size of 6.5-mm nuggets on 1.6-mm DP800 steel.

simulation is a novel application and indicative of future possibilities — Fig. 3. The simulation work was confirmed and compared with test results.

General Motors' work (Ref. 2) explored different electrode geometries. Many opinions are held regarding electrode design, and this work reviewed truncated, radius, and parabolic shapes — Fig. 4. The University of Waterloo's work (Ref. 3) looked at simulating an unusual projection weld. The Edison Welding Institute explored ways of measuring electrode life and of evaluating the material characteristics of a simulated weld (Ref. 4). This work presages future development, in that the extending and predicting of electrode life is the Holy Grail of resistance welding. These recent articles, all with supporting test verifications, highlight the rapid growth of weld simulation 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 to constant cooling rate diagrams to assist in determining weld strength. In the charts shown in Fig. 5, the cooling rates of points A and B in the simulated weld nugget are automatically graphed by the software and then can be compared to the constant cooling transformation (CCT) diagrams commercially published, thus predicting weld performance. This is a significant advance, in that the ability to predict weld strength is a fundamental concern of all welding. Thus the

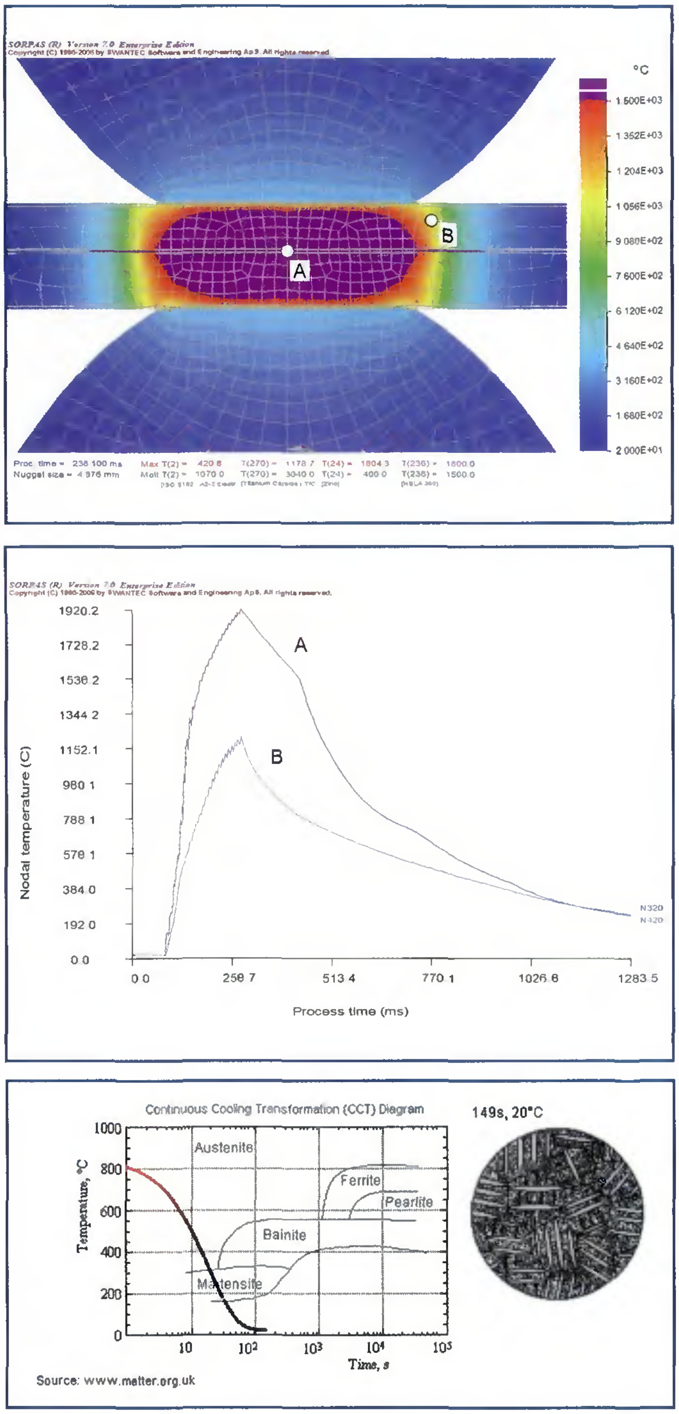


Fig. 5 — The cooling rates of points A and B shown in the top and center figures are automatically graphed by the software. Then, as shown at bottom, predicted cooling rates are compared to published CCT diagrams, with the martensitic microstructure shown above at right (courtesy University of Liverpool).

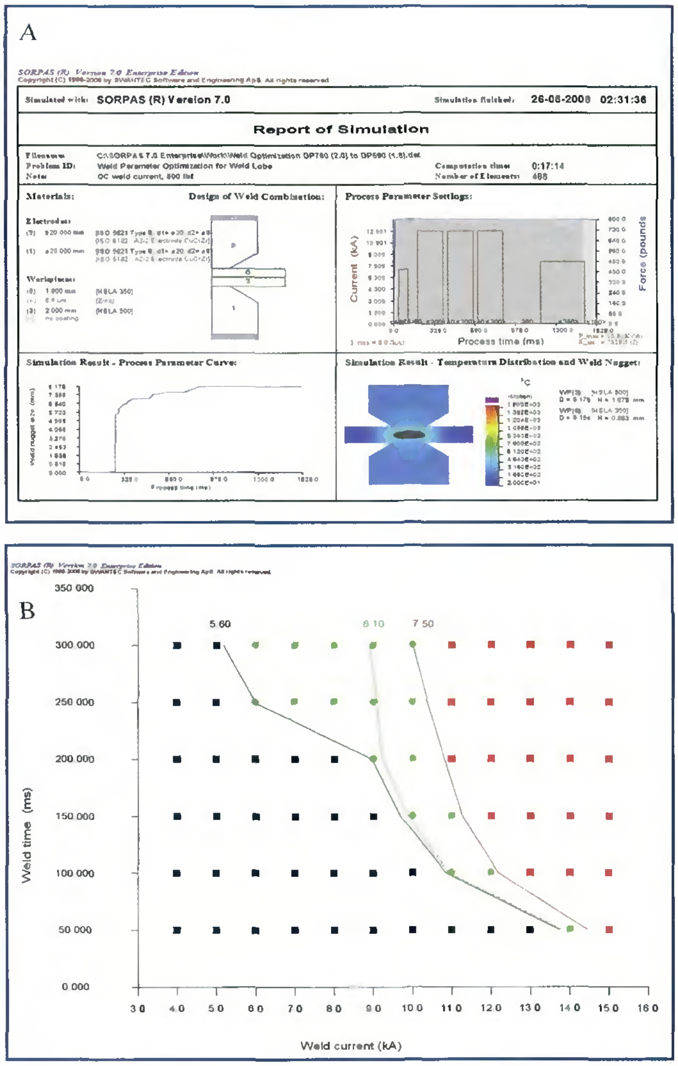


Fig. 6 — A — Weld parameter optimization for the weld lobe; B — typical output and welding lobe charting weld current against weld time.

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 investigation into the generation of the complete welding lobe — Fig. 6. This will allow the initial setup of welding parameters according to the materials and electrode geometry chosen to be determined automatically by the computer, and represents a significant potential savings in time and money.

The rapid advance of simulation RSW suggests that this new procedure to evaluate and assist an established process has arrived. Clearly, it is only a matter of time before standalone 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 part.◆

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