Saving Time and Money with Resistance Welding Simulation Software

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1. Introduction

Significant time and money can be saved with the use of software that simulates the process of resistance welding. This article provides specific examples of how this has been done with the finite element modelling software called Sorpas®. Sorpas® has been used to assist in the design of resistance welding parts and joints, to determine how welding parameters are to be determined, how the welding parameters can be optimized for various conditions in production, and even of how the microstructure of welded parts has been forecast prior to welding.

This software is currently in use by major automotive and manufacturing companies around the world. Companies such as GM, Ford, Honda, Volkswagen, Chrysler, Mercedes Benz, Volvo, Peugeot, Citroen, Bosch, Siemens, ARO, Roman, Schneider, Danfoss, Magna, Johnson Controls, Bao Steel, Tata, Sumitomo and others use Sorpas® as it helps reduce testing and documents choices and progress made. In addition, it can help free the user to focus his or her time onto those areas where the time is needed.

We will review how a number of world famous companies have used Sorpas® to reduce the time and money they have expended in resistance welding, highlighting examples from the design stage, through testing to production and optimization.

2. Background

Resistance welding is an inexpensive process that requires no shielding gases or filler metals to create a metallurgical fusion bond. An electric current is passed through the metals to be welded after a force is applied, and their innate resistance to the current generates sufficient heat to create the weldment. This is shown in four basic steps in figure 1 below:

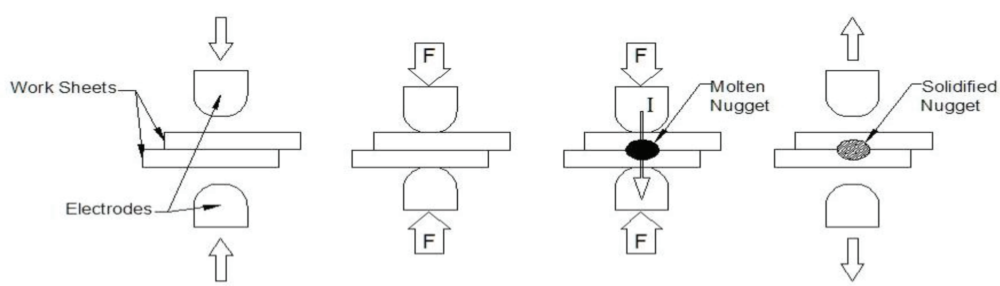


Figure 1, the basic process of resistance welding

Clearly, there is an overriding urge everywhere to reduce costs and the "time to market" in an age of increasing globalization and competition. At the same time, many new steels that are both stronger and lighter are increasingly being employed to raise fuel economy averages and to provide greater crash protection in accidents. Thus, there is a driving force for change and improvement today – with the problems of increasing complexity in designs employing steels that weld differently.

3. How Simulation Works

Sorpas® software uses the power of modern microprocessors in laptops and personal computers to fully articulate all the variables in resistance welding. It does this by considering and calculating all the variables through four separate yet fully coupled models; – the ***electrical model***, with its current/voltage distribution and heat generation; the ***thermal model***, with its heat transfer and temperature distribution; ***the metallurgical model***, with its temperature dependent properties and phase transformation characteristics and the ***mechanical model***, with its deformation, stress and strain distribution, in the contact areas, electrodes and geometry of the work pieces (Ref. 1). Each calculation or iteration involves the use of all four models as shown in Figure 2 below.

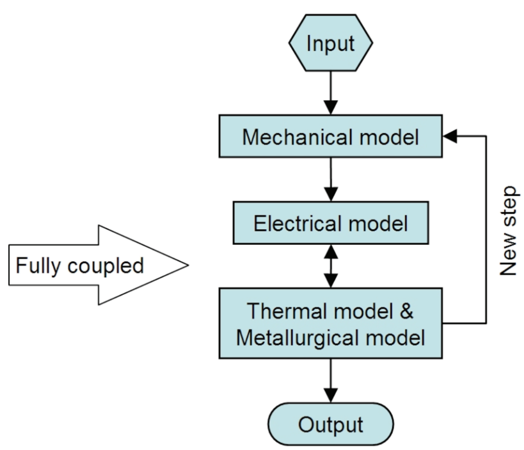


Figure 2, the coupling of numerical models

The user of the software enters into the computer the geometry of the parts, identifying the materials to be welded, the interface conditions and the electrodes employed. In another window, the user enters the welding parameters to be used, such as force, time and current. The user can also ask the computer to generate the required welding parameters, and automatically or manually alter the extent of accuracy sought and the overall simulation controls. When instructed, the computer will then generate welding parameters, welding lobes, and optimizations, based upon the instructions it has received. Figure 3 shows the first two user interface windows of the program. All input variables are kept in common welding parameters and terminology. In figure 4, an example of one of the printouts available which provides a summary of the simulation is shown. Other reports include real time animations of the simulated weld, showing such items as deformation and heat and strain distributions.

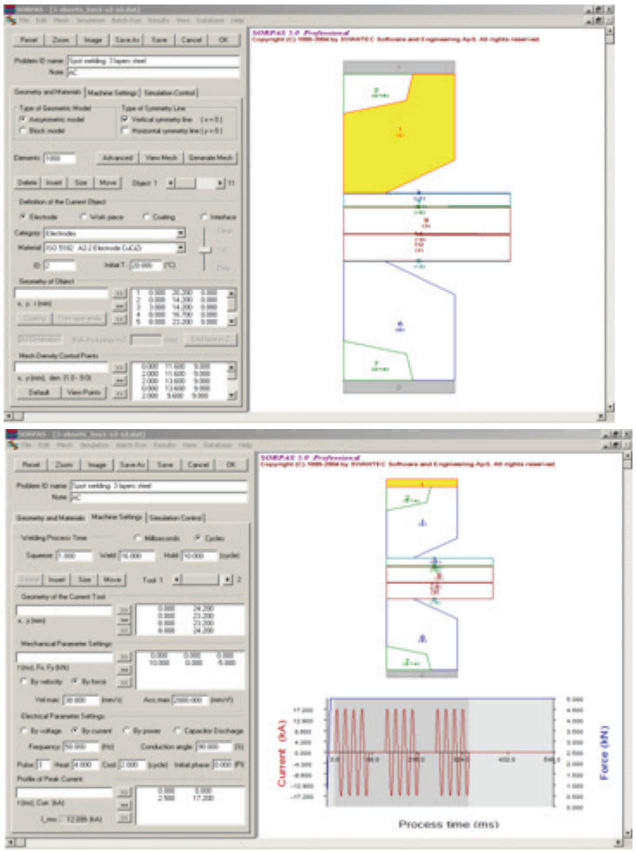


Figure 3, the geometry input page (left) and the welding parameter input page (right)

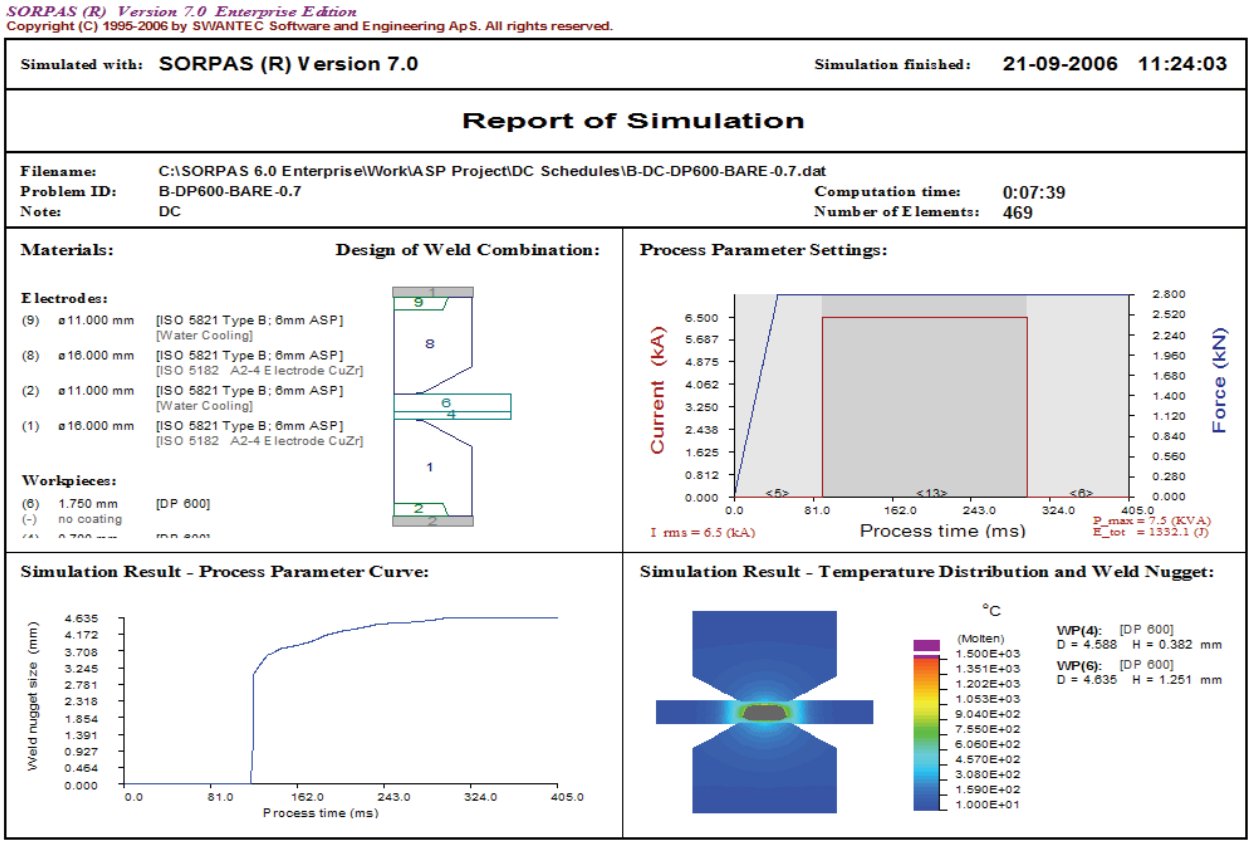


Figure 4, one of the reports of the software summarizing test results

4. Design Stage

In the design phase the characteristics and limitations of various joining processes and materials are weighed and selections made. Engineers consider the parts, their design and how they might fit together. To-day, especially in the automotive sector, with our future oil supplies uncertain, more and more attention is being applied to thinner and stronger alloys to take a larger role in manufacturing. And, generally, all of this analysis has to be done more quickly than in yesteryear. We are going to show here examples of how three manufacturers, Volkswagen, Danfoss and Honda, saved time and money at the design stage by using Sorpas® to visualize the inner workings of the welding process, thereby reducing testing and costs, while at the same time optimizing the welding parameters for long term performance and quality.

Volkswagen's patents governing "resistance welding with additional elements" was achieved with Sorpas® (Ref. 2). These patents can cover welds in dissimilar metals where additional material is inserted at the faying surfaces. Sorpas® was able to reduce the testing of their hypotheses by simulating projection welding that acts in a similar fashion to their "additional elements". Volkswagen believed it would be very time consuming and too expensive to consider the influences of heat, force and current on the myriad of differing materials considered for this innovative process (Ref. 3). Sorpas® was able to significantly reduce and focus the testing window. Volkswagen's drawings below, (figure 5), illustrate how modeling and simulation of projection welding helped achieve production welding parameters for their innovative process.

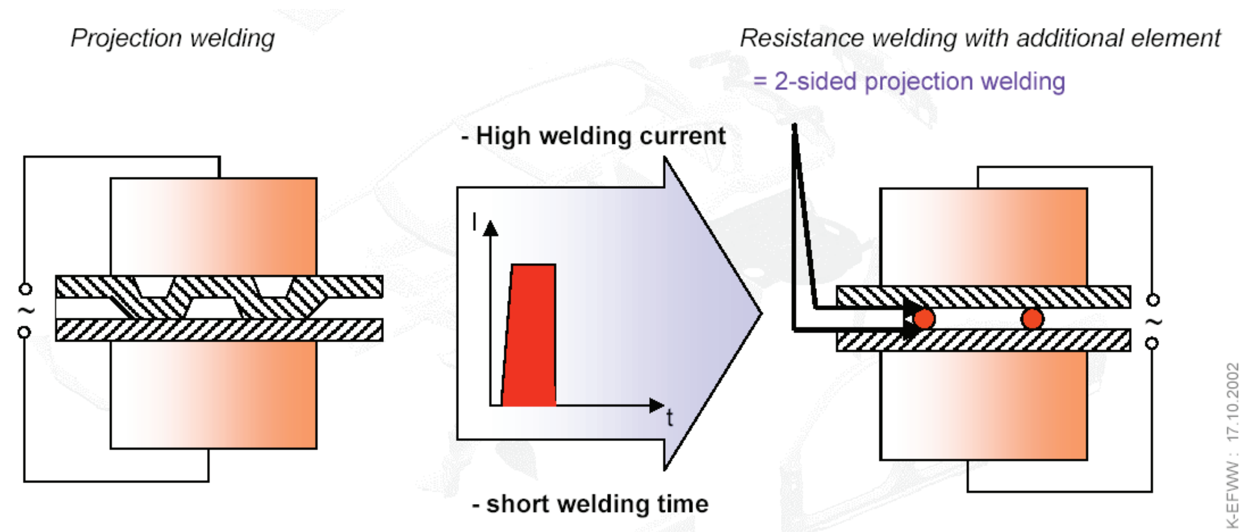


Figure 5, Volkswagen's patents covering "resistance welding with additional elements"

Other manufacturers, such as Danfoss, have used Sorpas® to help design the actual part used in production (Ref. 4). In the drawings below (figure 6), it can be seen how different designs of insulation (blue) in the part (on the left) will generate different weld characteristics after simulation (on the right). Modelling and simulation of the differing part configurations was able to show the differences in how the heat was generated in the parts and, subsequently, how the weld was initiated and grown. Therefore, the engineer can choose which design looks the most promising and pursue it with additional testing. Thus, it can be readily seen how simple simulations can greatly decrease the time to market, while at the same time creating a paper trail where choices made are appropriately documented, with their accompanying result noted. This failure to document is one of the more glaring failures of the traditional "hit and miss" approach to resistance welding design; thankfully, that age is now ending with the adoption of Sorpas® and the ease of its documentation and testing.

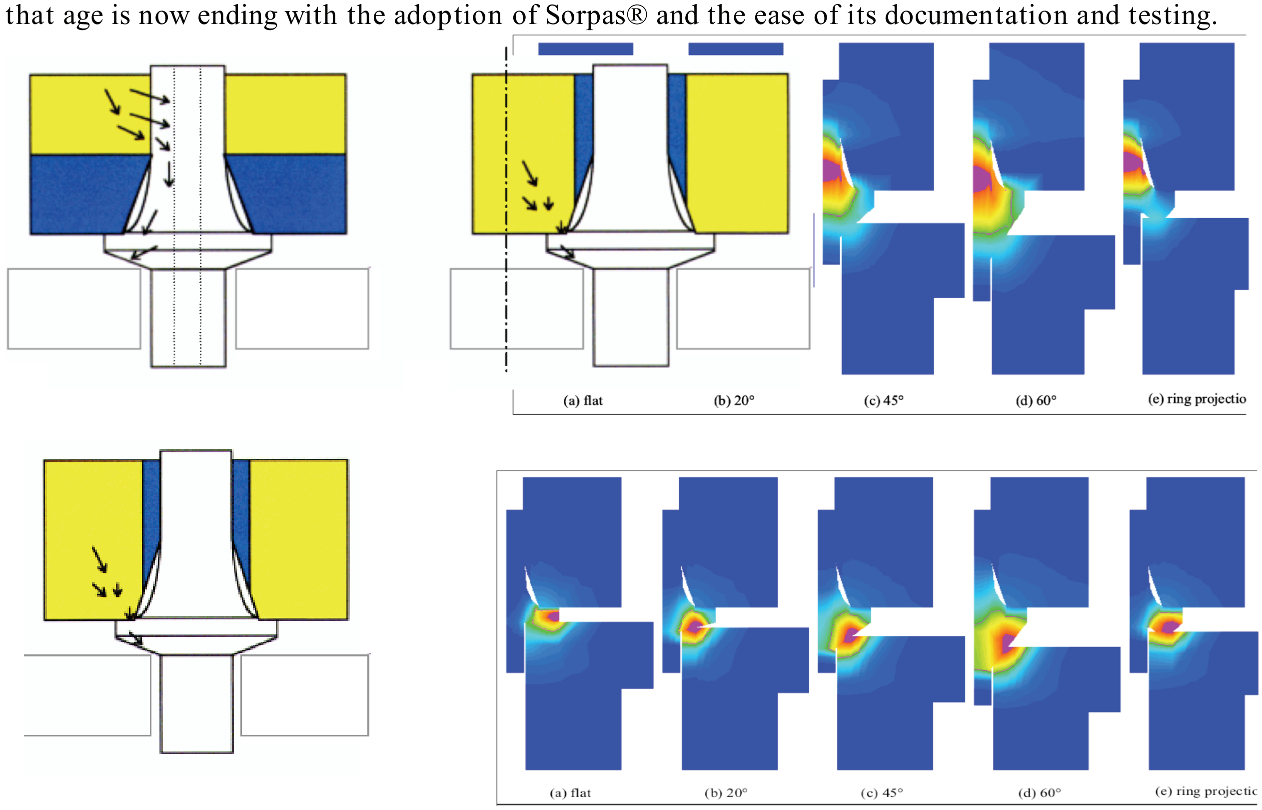


Figure 6, Danfoss' innovative micro welding applications

Honda used Sorpas® to reduce testing for a common automotive conundrum. How do you inexpensively join the hem of an exterior car door and its inner panel without marking the outer surface? Honda's method was to use Sorpas® to aid in the optimization of welding parameters and projection design for an indirect hem projection weld (Ref. 5). In this case, physically prototyping the many different configurations and testing the actual parts was not economically sound. Without simulation, the choices available for possible welding parameters of a hem projection indirect weld are daunting and perhaps unmanageable with the newer emerging coated steel alloys. However, the use of an indirect resistance weld was easily managed by the software as it was able to reconfigure the electrodes and tools to accommodate any resistance heating process while remaining very user friendly. Figure 7 and 8 below show Honda's design. Sorpas® was able to convincingly and accurately estimate the effect of different weld parameters and projection nipple heights that would yield an indent free outer surface.

Sorpas® was able to do this by running a series of simulations where certain variables were altered. Many of these variables could be tested and simulated over night, freeing up the laboratory and engineers to work on more pressing matters and focusing their research where the return was greatest on their time.

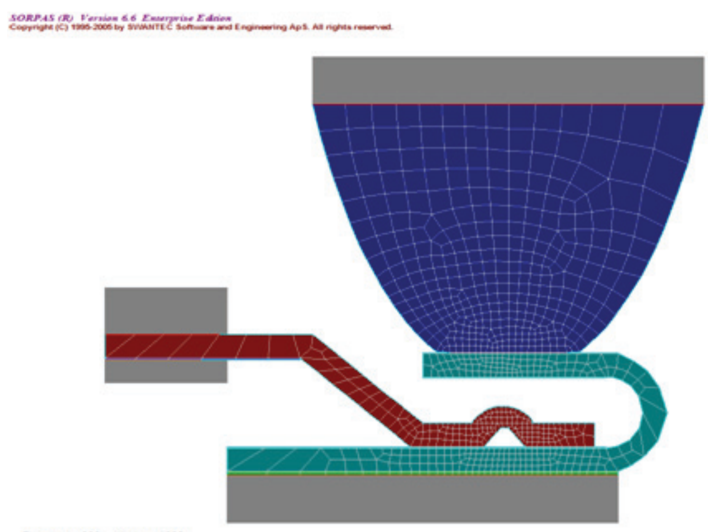


Figure 7, the geometric mesh automatically generated by Sorpas® for the finite element modelling

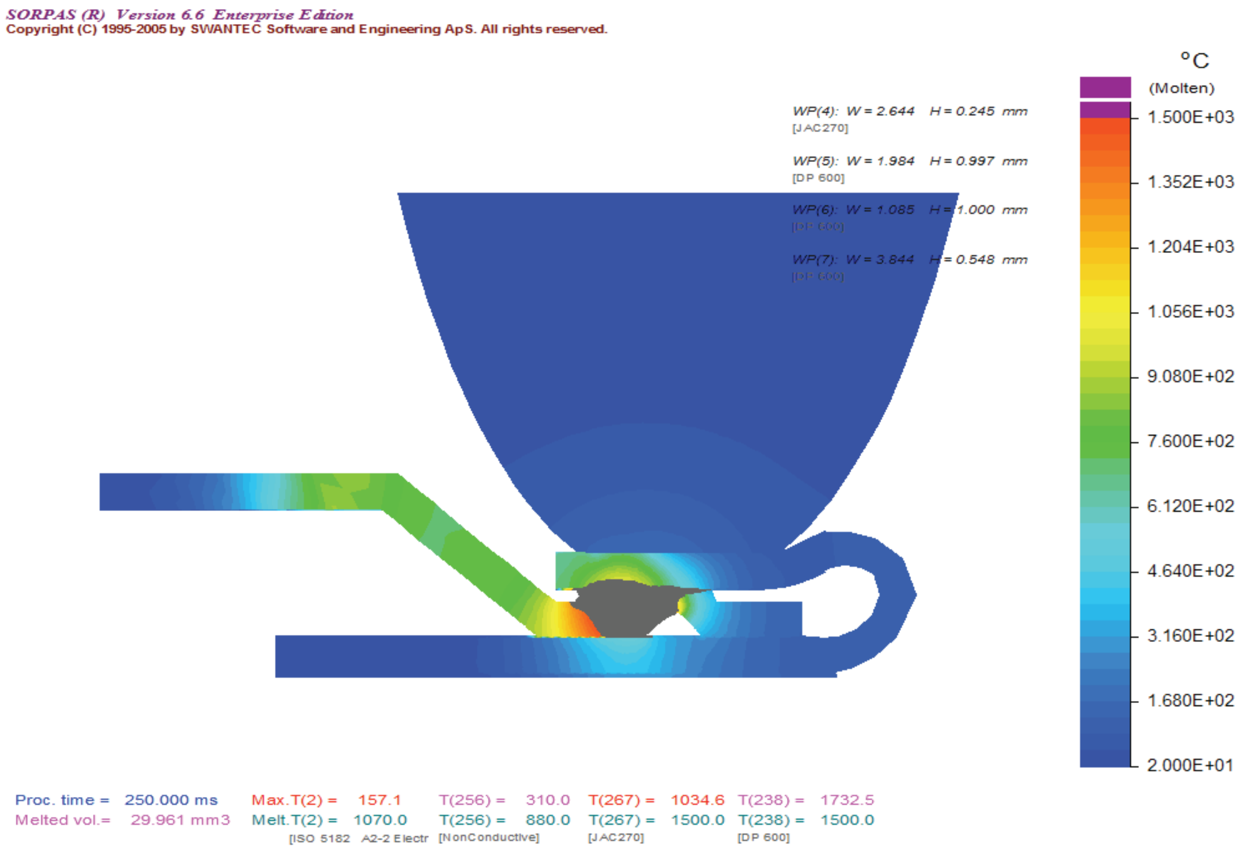
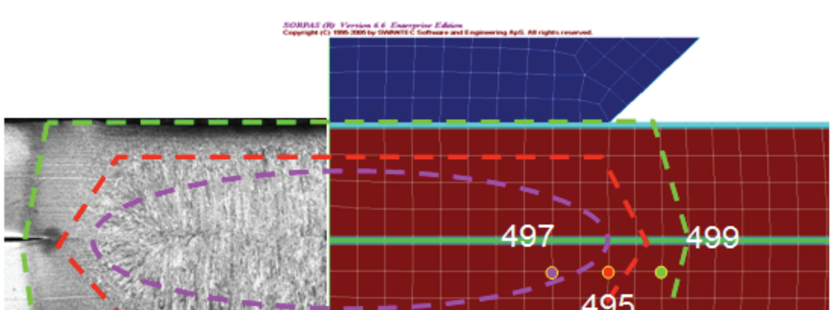


Figure 8, one of the finished simulations, illustrating a specific combination of welding parameters and projection designs.

5. Anticipating New Materials

The perfomrance characteristics of some new TRIP and DP steels alter when they are welded. When these new complex phase steels are made, their strength and character arises from its unique microstructure which has been carefully honed by controlled cooling and heating. After welding, the presence of a fusion nugget and heat affected zone present the entire range of temperature history from melting to only slight warming around the weld area. This heating to form the weldment effectively destroys the carefully created microstructure that gave rise to the steel's character in the first place and can also lead to other problems such as hardening and cracking. The cooling rate of an advanced steel is often critical to its performance and microstructure. Another issue may be that there is a DP steel welded to an HSLA steel, creating a weldment of uncertain provenance with a unknown mixture of two alloys in the weld.

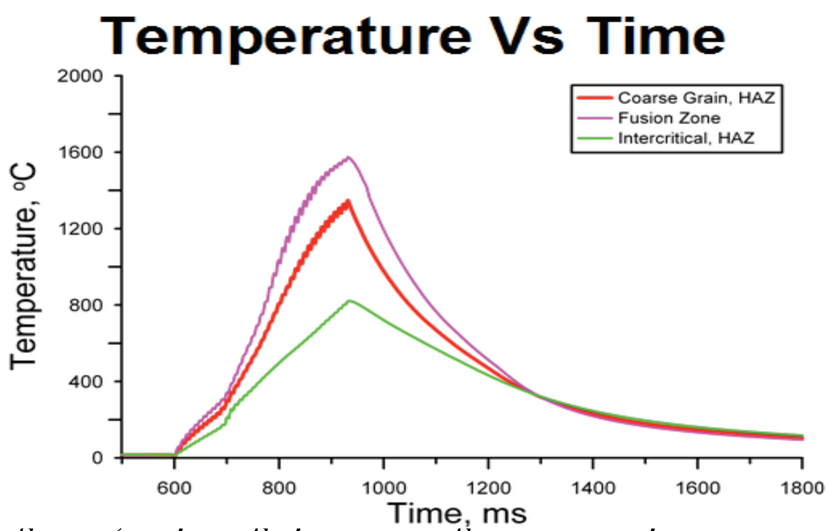
Thus the cooling rate of a weld in an advanced high strength steel may adversely affect the performance of that new fancy steel in a potential crash. With these types of issues in mind, the University of Waterloo is doing some interesting work with Sorpas® in endeavoring to predict the microstructure, and hence the performance, of a weld in simulation (Ref. 6). Figure 9 below is an amalgamation of a metallographic photgograph of a weld perfomed in the univeristy on the left which has then been compared to the earlier Sorpas® simulation on the right to confirm its reliabiltiy. Dotted lines indicate the overall accuracy of the simulation. Certain nodal points in the simulation are indicated on the drawing, and the simulation indicates their peak temperature (far right).



Node	Peak T
497	1605
495	1362
499	880

Figure 9, a metallographic photograph and Sorpas® simulation showing peak temperatures in different regions of the weld and HAZ.

These peak temperatures are then generated as graphs by Sorpas® in figure 10 below, and indicate the coarse zone of the HAZ, the fusion zone and the inter-critical HAZ. Then they are referenced to the published constant cooling diagrams (CCT), a copy of one which is reproduced below in figure 11. Coloured dots on the CCT in figure 11 tie into the colours on figures 9 and 10, indicating the various regions of the weld, based upon peak temperature. It is noteworthy that the simulated peak temperatures of the weld tie into the CCT diagram and the metallographic photographic record of



the welding of specific sites, or nodes, of the weldment (see figure 9).

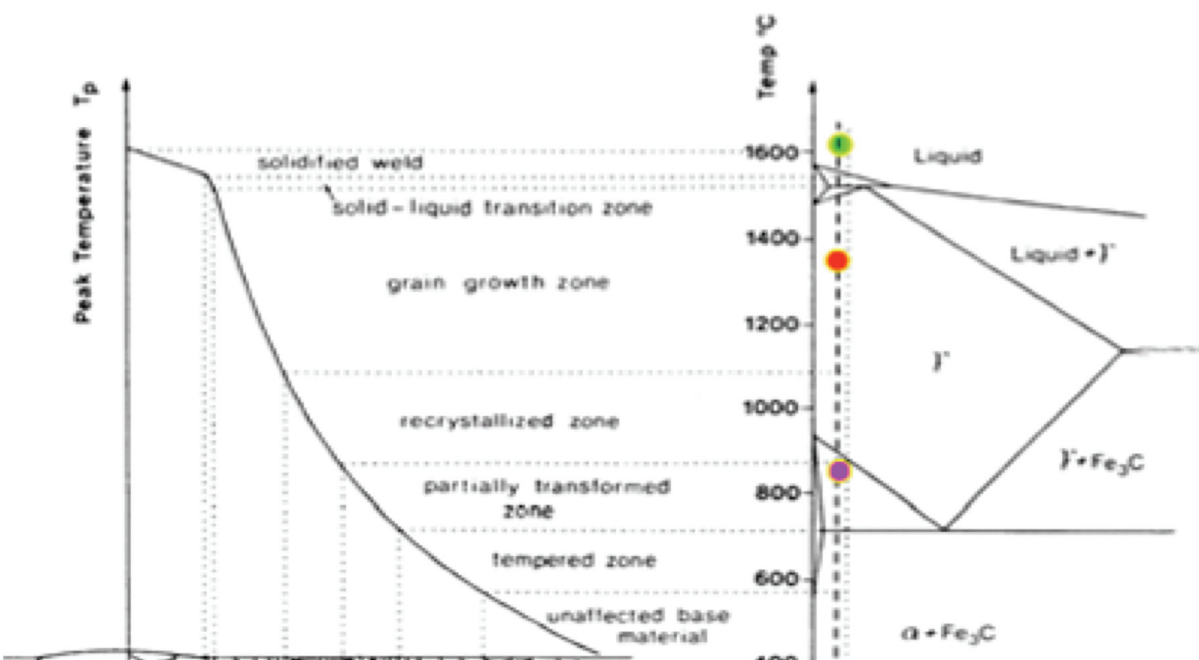
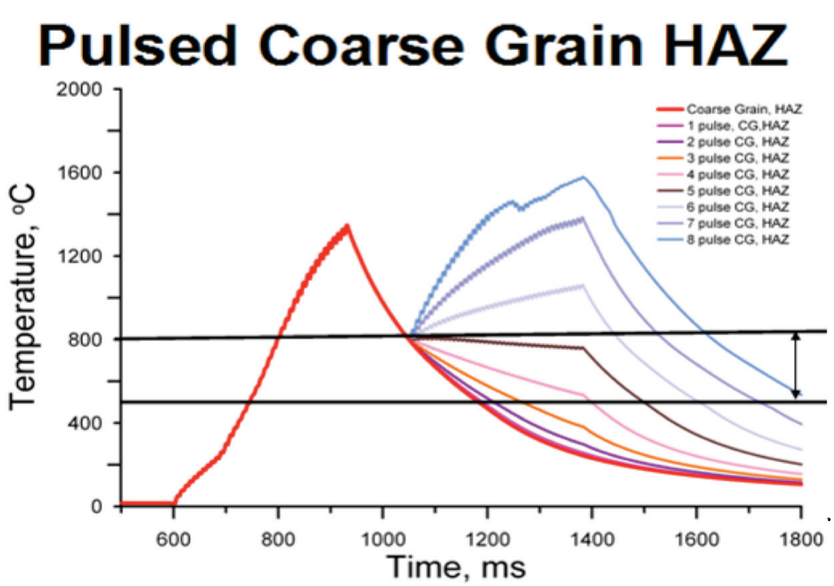


Figure 11, a published constant cooling diagram indicating the peak temperatures from figures 9 & 10.

6. Production Stage

We have shown above how Sorpas® can clearly help reduce time and money spent in the design and prototyping stages of new products and new materials. The greatest use of Sorpas, however, has proved to be in the day to day use of the software as an aid to increasing stable and consistent production and the optimization of welding parameters.

As an example, let us take the parts we were looking at in figures 9, 10 and 11. Let us suppose that we want to change the peak temperature of the weldment and thus control its cooling rate. Sorpas® can readily predict changes in the resultant microstructure (figure 13) with changes in the length of heat or numbers of pulsed heat inputs. Figure 12 below shows results from simulation for the temperature history in the coarse grain HAZ and the resultant changes to peak temperature and cooling rate based upon increments in weld time of a second weld pulse. Thus it becomes easy to adjust and document changes and improvements in a production setting (Ref. 7).



a weld in a Sorpas® simulation

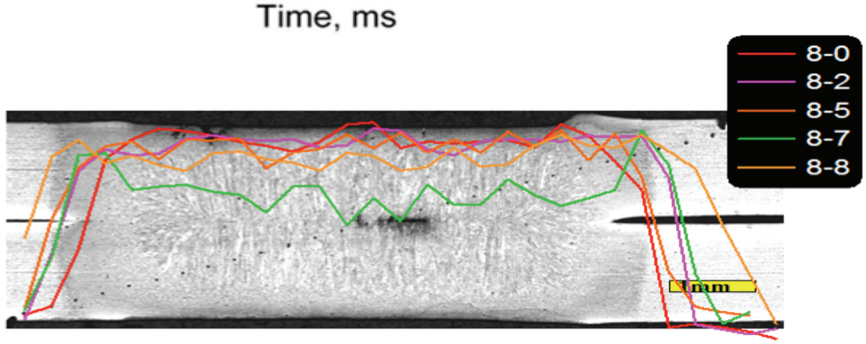


Figure 13, a metallographic image showing various hardness readings based upon welding times chosen for the post weld tempering pulse.

Of course, the production environment is primarily concerned with optimizing welding parameters, to maximize and stabilize production. Optimization is an ongoing process, as parts will have variances in their fit and set-up; and the materials themselves will vary both in their surface preparation, cleanliness and appearance as well as in their material from which they are made (Ref. 8). Therefore, it is every engineer's prayer that he or she can find the best spot in the weldability lobe to gain that overall consistency. It is with this mind that we have chosen our last example of Sorpas® saving time and money for manufacturers.

We have chosen a North American Tier 1 automotive supplier that is currently welding a new line with DP600 steel. They found that their initial welding lobes were very narrow and that the welding heat was too high, which caused not only short electrode life but also transformer duty cycle issues. In addition, the company did not have the physical time and resources to deal with problems of poor quality welds, inspection and repair – a common complaint in these times (Ref. 9).

Sorpas® has a function to automatically generate weld current optimizations based upon a requested size of weld nugget. Complete weldability lobes are calculated in accordance with ISO 14327:2004. The weldability lobe generated by the software has solid colours indicating risk of expulsion while also indicating the nugget size. It also indicates nugget width at the convergence of the weld time and weld current. Purple indicates electrode melting, red shows expulsion at the interface between sheets, green for welds and grey for no welds (please see figure 14).

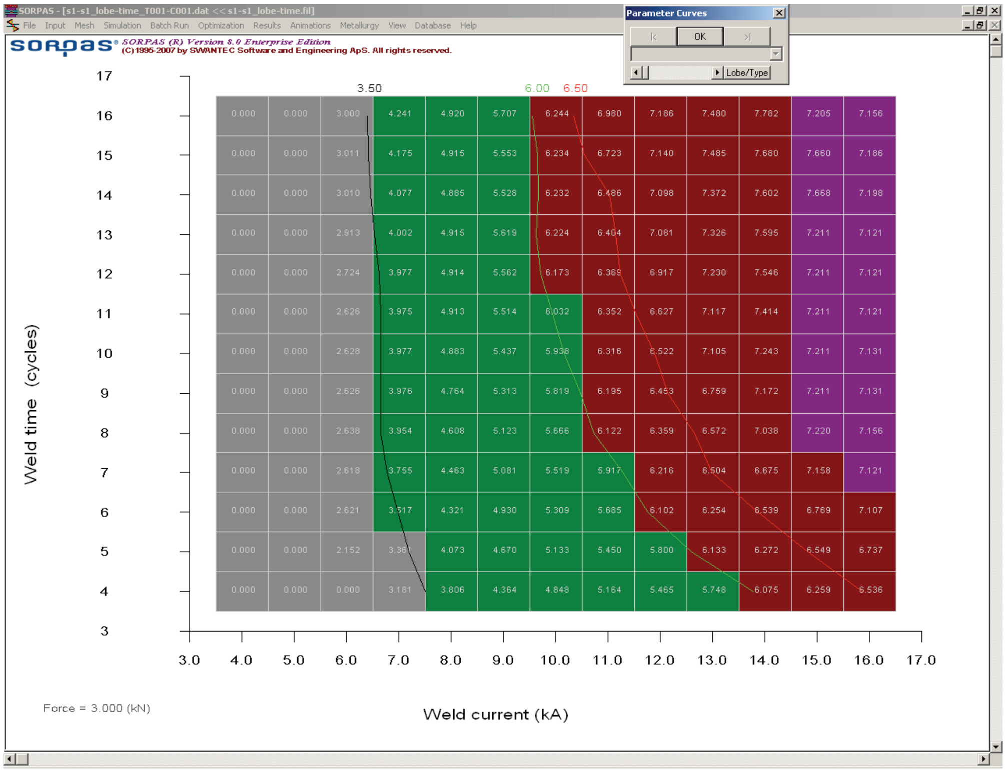


Figure 14, the weldability lobe diagram.

The generation of these weldability lobes was then used by this company as an initial guide to set individual welding machines. It was found that the simulations were, on average, 90% accurate. The company also adopted titanium-carbide metal matrix composite coated electrodes, which were found to have a wider welding lobe than uncoated class 2 electrodes. The company believes that is has saved $100,000 with Sorpas® through:

a. reduced costs with fewer tests,
b. reduced scrap and wasted time,
c. reduced costs for production maintenance problems,
d. reduced time to respond to OEM requirements,
e. reduced time for production running-in, settings determination and optimization,
f. improved weld quality and production stability, and
g. fewer problems and misunderstandings and more accurate and documented procedures.

7. Conclusion

Sorpas® simulation resistance welding software, in the hands of a qualified and diligent engineer, can significantly reduce the time and expenses of developing new designs and materials, establish better process parameter settings, and improve trouble shooting and weld quality.

8. References

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