# SOLENOIDS AND ELECTROMAGNETIC CAE TOOLS

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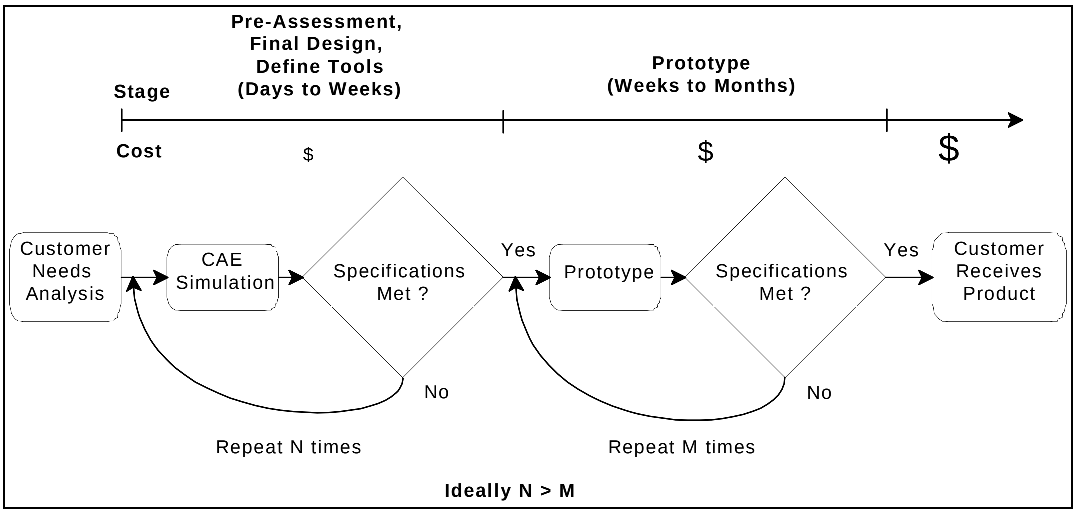


**Figure 1: Time and Cost Benefits of CAE simulation**

For example, solenoid prototyping costs range from $3,000 to as high as $6,000 per prototype and in a non-CAE development environment with a minimum of three prototypes per design costs can multiply. EM-CAE software requires a single initial investment of less then $10,000 to be able to accurately and efficiently simulate solenoid designs.

Integrated Engineering Software (**Integrated**), a Canadian research and development organization, provides the engineering community with electromagnetic CAE software tools. All of Integrated's seven CAE products are based on the innovative Boundary Element Method (BEM) – an excellent alternative to the more common Finite Element Method (FEM). **Integrated**'s two dimensional (2D) and three dimensional (3D) electromagnetic software enables engineers to understand their designs prior to prototyping. The software allows the engineer to test various physical and material configurations, examine new design concepts, and optimize designs for a wide variety of electromagnetic applications.

**BWS** is a German-based engineering firm that develops and manufactures solenoids for various applications including projector shutters, fuel injection systems, door lock systems, mail sorter controls, and automotive brake booster controls. **BWS** engineers use one of **Integrated**'s seven electromagnetic tools called **Magneto** to design solenoids. Magneto is a 2D magnetostatic CAE software tool based on the Boundary Element Method (BEM) technology.

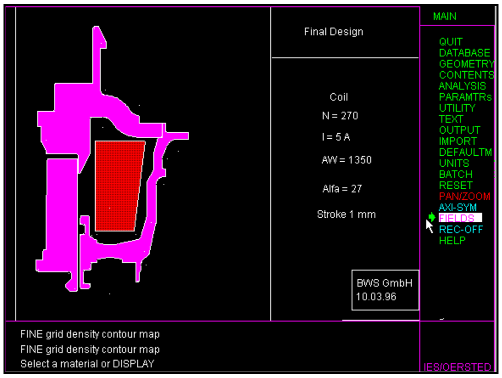


**Figure 2: Magneto - BWS Solenoid (Rotationally Symmetric)**

By using **Magneto**, **BWS** gains various competitive advantages. First, **BWS** is able to develop concepts faster and with more variety. In the past it took 19 days, now with the use of **Magneto** it takes only 4 days per prototype. Second, **BWS** costs are significantly reduced per design. Typical prototype optimization costs per solenoid design were around $12,000 and now solenoid optimization costs are at $2,000. Finally, responsiveness to customer modification requests increases significantly. Customer suggestions can quickly be verified and simulated results transmitted to customers within hours.

One **BWS** solenoid design took advantage of the **Magneto**'s features including, the rotationally symmetric option, parametric analysis and various output configurations. The solenoid was designed for a German automotive supplier to be used in an automotive brake booster with a minimum specified solenoid force of 70 Newtons (Figure 2). The solenoid's geometry is very complex, as many tooled parts (stamped and pressed parts) are specified. Traditional prototyping would have been quite expensive and time-consuming.

First, a CAD model is created using **Magneto**'s built-in CAD system. User's also have the option of reading in IGES or DXF format geometry files from other standard CAD systems. Taking advantage of **Magneto**'s rotationally symmetric option allows **BWS** to greatly simplify the design in terms of modeling and simulation time

Second, the physical properties are defined (e.g. materials and sources). In this example the material used is a non-linear magnetic material (mild steel). The magnetic material is represented by a user defined B-H curve. The solenoid's coil winding is modeled by specifying 1350 Amp Turns in the coil region. The last step before analysis involves placing Boundary Elements only on the surface of material interface in contrast to the Finite Element Method that requires elements in an entire design region (Figure 3 )

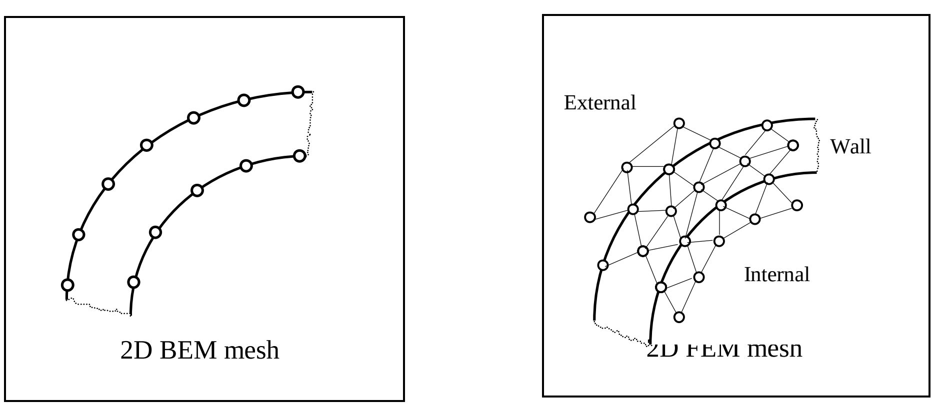


**Figure 3. BEM versus FEM modeling**

Using a Pentium 100 MHz computer, **Magneto** provides various field plots and graphs, torque and force calculations (Figure 4). The results of interest to **BWS** are force vs. stroke characteristic, force at a definite stroke point, and minimum material thickness required. By using **Magneto** to run a parametric simulation a few simple steps are all that is required to generate a plot of Force vs. Stroke (position). As with other BWS designs, the simulated results for this automotive brake booster solenoid are within 3% of measured values.

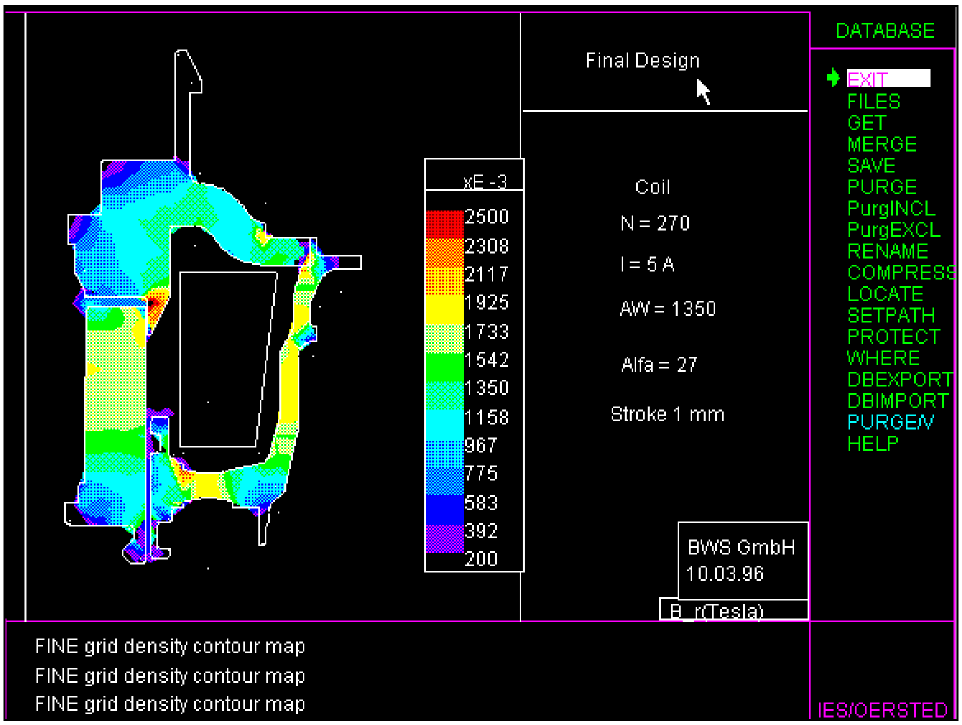


**Figure 4: Magneto - Magnetic Field Color Contour of BWS Solenoid**

Electromagnetic computer-aided engineering software is becoming a standard tool in the solenoid design process, as exemplified by BWS' successful use. In particular, BEM-based electromagnetic software tools from **Integrated Engineering Software** offer engineers a proven and effective method for reducing design costs and optimizing solenoid designs.

**Contributors**

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