MELT IT IN MID-AIR

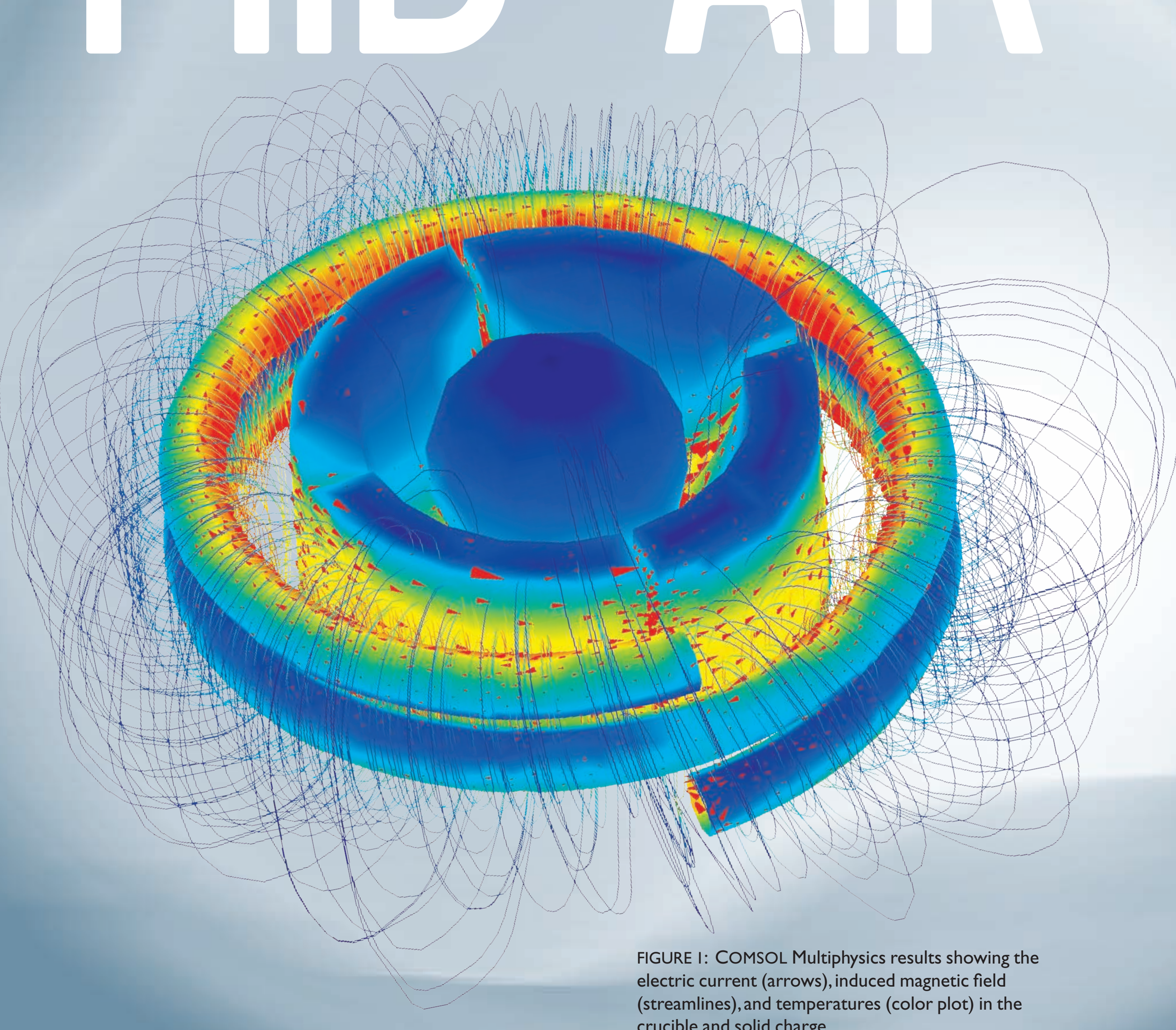

FIGURE 1: COMSOL Multiphysics results showing the electric current (arrows), induced magnetic field (streamlines), and temperatures (color plot) in the crucible and solid charge.

Have you ever noticed how difficult it is to align two permanent magnets end to end, almost together but without touching? Research engineer Dr. Roland Ernst puts troublesome magnetic properties such as these to work in his research work.

BY JEAN-MARC PETIT

Dr. Ernst develops cold crucibles that melt incredibly hot metals and other materials without letting the melt touch the container walls. With these methods he can refine ultra-pure titanium and other materials. His approach combines electric currents, induction, heat transfer, and magnetic levitation.

EPM-Madylam Laboratory specializes in designing strategies for the electromagnetic processing of materials for a wide range of uses. Aeronautics and other industries, such as the biomedical industry, require highly pure materials including titanium alloys, silicon, or pure glass. Simply heating a raw material in a container has obvious limitations, most notably that containers made of fireproof graphite or ceramic leave impurities when the melted raw material comes in contact with the container wall. Wouldn't it be ideal to both levitate the contents and use electromagnetic fields to melt the raw materials in mid-air (Figure 1)?

Dr. Ernst successfully developed setups of this nature. His cold crucibles consist of a cylindrical insulator with an electrically conductive coil wrapped around it (Figure 2). Inside the insulator is a circle of evenly spaced sections made up of conductive materials such as copper. The raw material to be heated, known as the "charge," is placed within this circle of sections (Figure 3). Sending a high current through the coil induces a current within each of the sections. This in turn induces a current in the charge to incur Joule heating and a melting of the charge.

A skewed magnetic field arise from the fields coming from the coil and the sections, concentrating the total field into the charge. This leads to the levitation of the charge.

Dr. Roland Ernst

A trick in getting the cold crucible to work lies in determining the best size and spacing of the sections. Regarding the electromagnetic component, Dr. Ernst explains, "The models are easy to set up and especially efficient with COMSOL Multiphysics' impedance boundary condition, even with the low-skin-depth high-frequency conditions we use. The results show me how the electromagnetic fields behave over whatever full 3D geometry I need."

With the coupling of the electromagnetic fields to heat transport in the charge, temperatures in the charge rise (Figure 1). Dr. Ernst comments, "Now I'm adding the solid-to-liquid phase change plus the fluid flow and deformation that comes with the melting." He adds, "COMSOL Multiphysics allows me to efficiently model the full 3D problem, and that's especially important for the melting part. We must understand the asymmetries inside the melted charge to avoid the risk of contact with the crucible wall." ■

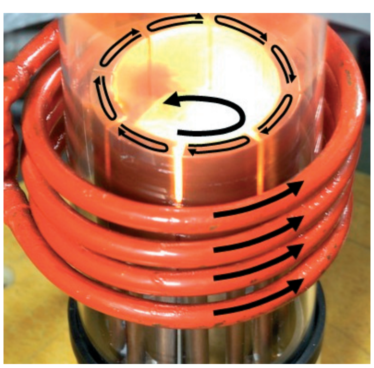

FIGURE 2: A photograph of the cold crucible with labels that indicate the direction of current in the external coil and sections.

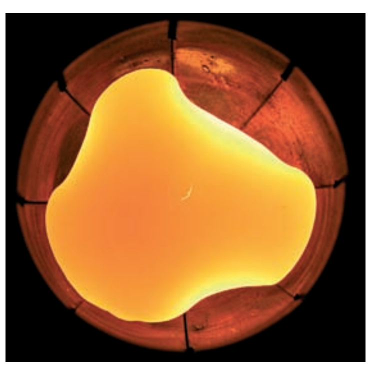

FIGURE 3: This photograph illustrates the asymmetry in the melted charge held in place with magnetic fields.