Successful Isothermal Dendritic Growth Experiment (IDGE) Proves Current Theories of Dendritic Solidification are Flawed

The scientific objective of the Isothermal Dendritic Growth Experiment (IDGE) is to test fundamental assumptions about dendritic solidification of molten materials. "Dendrites"--from the ancient Greek word for tree--are tiny branching structures that form inside molten metal alloys when they solidify during manufacturing. The size, shape, and orientation of the dendrites have a major effect on the strength, ductility (ability to be molded or shaped), and usefulness of an alloy. Nearly all of the cast metal alloys used in everyday products (such as automobiles and airplanes) are composed of thousands to millions of tiny dendrites.

Gravity, present on Earth, causes convection currents in molten alloys that disturb dendritic solidification and make its precise study impossible. In space, gravity is negated by the orbiting of the space shuttle. Consequently, IDGE (which was conducted on the space shuttle) gathered the first precise data regarding undisturbed dendritic solidification.

IDGE is a microgravity materials science experiment that uses an apparatus which was designed, built, tested, and operated by people from the NASA Lewis Research Center. This experiment was conceived by the principal investigator, Professor Martin E. Glicksman, from Rensselaer Polytechnic Institute in Troy, New York. The experiment was a team effort of Lewis civil servants, contractors from Aerospace Design & Fabrication Inc. (ADF), and personnel at Rensselaer.

IDGE's first of three planned flights, as part of the United States Microgravity Payload (USMP) series, was highly successful. In fact, by one important measure of the data collected, it was 370-percent successful. This extraordinary success was possible because IDGE is a teleoperable experiment (scientists on the ground can monitor progress and send up commands to alter IDGE programming). During the first flight, dendritic solidification behaved unexpectedly--experiments could be completed more quickly! Teleoperation, involving some 8000 discrete commands over 9 days, permitted the IDGE team operate the experiment far outside its programmed limits, acquiring much more data than was planned.

IDGE had been planned to produce 20 dendritic growths after supercoolings from 0.1 to 1.0 K. Instead, 58 dendrites were solidified at over 20 different supercoolings, ranging from about 0.05 to 1.93 K. Supercooling is the term used to describe the condition in which a dendrite solidifies at a temperature below its normal freezing point. The data consisted of over 400 photographs and over 800 television images of dendrites solidifying in space, along with associated supercooling, pressure, and acceleration data. Photographs were possible because the test material was transparent succinonitrile, which mimics the behavior of iron when it solidifies.

Dendrite tip radii, tip solidification speed, and volumetric solidification rates were determined from the space and Earth data. These were compared with predictions made by theorists over the last 50 years--predictions that are currently used for metal production on Earth. The results indicate that the theories, although sound in some respects, are flawed. Corrected theories based on IDGE data should someday improve industrial metal production here on Earth.

Members of the Lewis-based IDGE team assemble the flight unit. One of the IDGE 35-mm cameras and the Space Acceleration Measurement System (SAMS) sensor head are visible. IDGE is fully operable by remote control from Earth--this feature contributed to its remarkable success on STS-62.

IDGE is scheduled to fly aboard the Space Shuttle Columbia, STS-75, for its second flight. The IDGE apparatus was modified to obtain data that will complement the information obtained during the first flight. Until recently, dendrite tips were believed to be parabolas of revolution. Information gathered by the IDGE apparatus proved this assumption to be incorrect. The goal of the second flight of IDGE is to collect data that will definitively determine the three-dimensional shape of the dendrite tip as a function of supercooling. This will lead to further enhancements of dendritic solidification theories.

To test the universality of advanced solidification theories, a third flight in 1997 will provide solidification data for a different test material. IDGE data will provide a benchmark to test theoretical developments for decades to come.