Improving Powertrain Components by Intelligent Induction-Hardening

ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF TRANSPORTATION TECHNOLOGIES

Transportation

FOR THE 21ST CENTURY

Background

Automotive powertrain components need to have the highest possible power density throughput and surface strength at the lowest possible cost. The bearings, shafts, and gears that transmit power from the engine to the axle must be tough, durable, and corrosion-resistant to perform successfully. The automotive industry has sought ways to optimize the quality and performance of powertrain components while avoiding long design cycles and lowering manufacturing energy use and costs. New methods for improving and optimizing the heat-treating processes for induction hardening steel surfaces will help industry accomplish those goals.

The Department of Energy's Office of Transportation Technologies has supported this research, which was conducted through cooperative research partnerships among DaimlerChrysler Corporation, Ford Motor Company, General Motors Corporation, AISI Bar Applications Group, Delphi Saginaw Steering Systems, and the Sandia National Laboratories. Work was carried out in three areas: development of a computational model of the induction hardening process; development of science-based sensors and closed-loop control algorithms that apply to different types of steel and components; and the manufacture of components with optimal strength-to-weight ratios, using the foregoing tools.

The Technology

Induction hardening is a case-hardening process that heats parts by inducing alternating eddy currents in the part that cause the surfaces to be resistively heated. An austenized layer of appropriate thickness is developed, then quenched to produce a hardened surface. The process is very non-linear and requires long lead times and significant experience to correctly deploy. Researchers have developed simulation codes to predict the thermal cycle and structural changes induced by the induction-heating/hardening process. Other innovations are science-based electromagnetic sensors to measure the depth of heating and to monitor and control changes to the metal over time. An adaptive-control algorithm is available that can update the heating parameters and provide closed-loop control.

Commercialization

Delphi Saginaw Steering Systems has produced intermediate axial shafts for the General Motors Saturn vehicle using a prior version of the control algorithm. Discussions are underway to license the simulation codes and the sub-routines for electromagnetic and on-heating transformation kinetics. Demonstrations have been conducted of the science-based sensors and adaptive control algorithms. Plans are underway to commercialize all these technologies following additional tests and validation.

Benefits

- **Achieves energy savings of up to 95 percent compared to furnace heat-treating operations**
- **Uses available materials and infrastructure to manufacture lighter, improved components; improves fuel economy 5 percent for every 10 percent reduction in vehicular weight**
- **Substitutes low-cost, on-line, closed-loop monitoring of hardened parts for higher-cost, open-loop, destructive testing**
- **Improves reliability of the heating process**
- **Avoids the toxic chemicals used during furnace heat-treating processes**

Examples of induction-hardened vehicle components including axle shaft components, a steering rack, and miscellaneous pump shafts (photo: Delphi Saginaw Steering Systems).

Contacts:

Joseph Carpenter
Office of Transportation Technologies
(202) 586-1022
joseph.carpenter@ee.doe.gov

J. Bruce Kelly
Sandia National Laboratories
(505) 845-3384
jbkelle@sandia.gov