CDA ANNUAL ACTIVITY REPORT
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Cast Copper Motor Rotors:

Project Profile:

This project seeks to develop a new multi-million-pound per year worldwide market for copper in the electric motor rotor by solving the die casting tool material problem. Transferring this technology to the motor manufacturers was the most important track for the year. Copper rotor die-casting demonstrations are resulting in technology transfer to the electric motor manufacturers.

Summary:

Development work was successfully completed this year. Die life was significantly extended through heated nickel alloy dies. Casting demonstrations coupled with motor testing was the principle means of conveying this information. Five motor companies were actively involved in demonstrations. Production of the first motor using die-cast copper rotors should begin this year.

Project Activities:

<u>Die Material Development Efforts:</u>

Testing of the Inconel alloys 617 and 625 die inserts, previously tested for 620 shots, were tested at 650C preheat temperature for an extended run of 950 shots. The new Inconel insert set using Inconel alloys showed minimal additional deterioration in the die set. After 950 shots, there was some minor fatigue cracking due to repeated thermal expansion and contraction. Operating the dies at elevated temperature is absolutely essential toward improving the die life. The dies were operated at elevated temperatures of 600 to 650C to reduce the thermal expansion and contraction associated with casting and subsequent cooling. Limiting the cyclic expansion and contraction is helping decrease the thermal fatigue. This test die-design is an extremely aggressive test due to the large thermal mass of copper that must be cooled through the die walls. Since the test is an extreme, it is an excellent method for quickly comparing and ranking the various die materials.

Die-Casting Copper Rotor Trials:

Five rotors designs for four companies were die-cast with copper at Formcast in Denver. The lamination stack heights and diameters were different for each. The largest rotor was the most difficult to cast for a variety of reasons. Reasons for this are detailed in the "Visual Examination" section below. With the possible exception of these large rotors, all rotors were completely filled and appeared sound.

Metallurgical Results:

Metallurgical analysis concluded that there was no evidence of interaction observed between the copper conductor bars and iron sheets. Copper flashing between the conductor bars and steel sheets was noted on both rotors. The conductor bars showed a characteristic chill zone adjacent to the steel sheet, the core exhibited a coarser equiaxed two-phase structure. Both rotors showed defects at the copper/iron interface and internal defects. Defects were noted at the copper iron interface and within the bulk of the conductor bars. Typical defects are shown below. The interface defects resemble inter-granular cracks and cold folds, the internal defects appear to be micro-shrinkage and entrapped inclusions, possibly slag related. In general these defects were not numerous.

The chemical analysis revealed that small amounts of iron (10 to 11 ppm) and oxygen (0.084 to 0.163 wt.%) were picked up during casting. Electrical conductivity measurements taken from the copper conductor bars indicate that the conductivity slightly dropped (96.8 & 98.7 IACS).

Visual Examination

Visual examination was conducted on the large rotors. In addition, four rotors were sectioned to examine for porosity. The quality of rotor bars was good in all cases. The quality of the end-ring on filling side was also good. The quality of the far end-ring was sufficient in two of the rotors but the quality was bad for the other two rotors (the porosity of the cut surfaces was 25-30%). Possible reasons that may have caused the porosity include: 1. inadequate venting may have caused air to become trapped in the die cavity resulting in higher than expected porosity in the far end ring, 2. this cast rotor required the largest quantity of copper that the induction furnace was capable of melting resulting in a relatively long melting time, which may have allowed for excessive oxygen contamination, and 3. the sensors in the Buhler die-casting machine were not responding properly possibly resulting in too low a pressure and/or plunger speed to adequately fill the die cavity before the copper solidified.

Testing Copper Rotors by Motor Companies:

Six different sizes and types of rotors were die-cast using pure, high-conductivity, copper for motor companies worldwide. Electrical efficiency tests were performed on an assortment of motors using these copper rotors in accordance with IEEE Specification

112 test method B as required by the National Electrical Manufacturers Association (NEMA). The results from these tests exceeded our expectations.

Compared with an identical aluminum rotor, die-cast copper rotors reduced the electric motor's total energy losses by 15% to 23% (1.2% to 1.7% improvement in efficiency over aluminum) depending on the rotor design. Earlier modeling with die-cast copper rotors had indicated a potential range available of 15% to 20% reductions in losses, compared with current die-cast aluminum rotors. The improvement in efficiency was demonstrated consistent irrespective of the variables that were introduced into the die casting process such as pressure, shot speed and cooling rate. Consequently, from these data, it appears that the process of die casting copper rotors can be quite reliable and robust.

Further improvements in process and rotor design such as optimization of the steel laminations should extend copper's lead in efficiency over that for aluminum.

As a consequence in the improvement in efficiency, the copper rotors reduced the operating temperature of motors by as little as 5 degrees C to as much as 32 degrees C. As a general rule, for every 10 degree increase in the motor operating temperature, the insulation life of the motor is cut in half. These data indicate that the life of motors having copper rotors may be extended 50% or more with proper maintenance.

Copper-Motor-Rotor Website:

Due to the growing interest in the Copper Rotor Motor development project, a new website was created that provides a project description and contact information. It also includes all publicly available technical papers and presentations plus periodic updates on the project's progress. A "How-To" manual will be created on this web site to detail the copper die-casting experience for all to follow. This web site can be viewed with the following URL: http://www.copper-motor-rotor.org

Future Activity

An extended die-casting run (500+) of copper rotors using the heated Inconel alloy dies for one of the motor companies was delayed due to complications. Nevertheless, CDA hopes to cast these rotors in the first half of 2001.

Five additional motor companies have asked to be kept informed of the progress of the project and may be interested in casting copper rotors for their own testing purposes. Additional contacts will be pursued throughout 2001. Technology transfer will continue to be the project's emphasis. CDA is looking for appropriate international technical conferences to promote the success. Toward the end of 2001, the project will be transitioned to CDA's Electrical Energy Efficiency Initiative for further promotion.