IV.E.4 Foil-Bearing Supported High-Speed Centrifugal Cathode Air Blower

Giri Agrawal (Primary Contact), Bill Buckley, Dennis Burr, Sam Rajendran
R&D Dynamics Corporation
15 Barber Pond Road
Bloomfield, CT 06602
Phone: (860) 726-1204; Fax: (860) 726-1206
E-mail: agragiri@rddynamics.com
Website: www.rddynamics.com

DOE Project Manager: Charles Alsup
Phone: (304) 285-5432
E-mail: Charles.Alsup@netl.doe.gov

Objective

Design a foil-bearing supported high-speed centrifugal cathode air blower (CAB) meeting all the technical requirements of the Solid State Energy Conversion Alliance (SECA) members and develop a process to reduce manufacturing cost of CABs to $100 per unit based upon a production volume of 50,000 units/year.

Accomplishments

- Preliminary design for a low cost high efficiency cathode air blower was completed.
- A cost model targeting $100 was developed.
- Breadboard testing was conducted to prove structural integrity of plastic impellers.
- Feasibility of program was shown.

Introduction

The goal of SECA is to develop commercially-viable ($400/kW) 3 to 10 kW solid oxide fuel cell (SOFC) systems by year 2010. SOFC power generation systems are attractive alternatives to current technologies in diverse stationary, mobile, and military applications. SOFC systems are very efficient, from 40 to 60 percent in small systems and up to 85 percent in larger co-generation applications. The electrochemical conversion in a SOFC takes place at a lower temperature (650 to 850ºC) than combustion-based technologies, resulting in decreased emissions – particularly nitrogen oxides, sulfur oxides, and particulate matter. These systems all offer fuel flexibility, as they are compatible with conventional fuels such as hydrogen, coal, natural gas, gasoline, or diesel. Despite these advantages, advances in balance of plant (BOP) component design must be developed before the SECA program goals can be realized.

SOFC systems require blowers to provide motive force to incoming atmospheric air, in order to overcome the pressure drop in the various valves and heat exchangers, and in the fuel cell stack. The energy required to drive this component is typically one of the largest parasitic loads for the SOFC system; consequently, high blower efficiency is paramount to high system efficiency. Furthermore, blower reliability is critical to ensure safe long-term system operation.

Approach

- In Phase I, a CAB was conceptualized and designed. A process using DFMA (Design for Manufacturing and Assembly) techniques was developed for reducing manufactured cost of CABs to $100 per unit, based upon a production volume of 50,000 units per year.
- In Phase II, a detailed design of CABs will be completed and a prototype manufactured and tested using cost reduction techniques identified in Phase I.
- Phase III will start the commercialization phase of the project. CAB field demonstrations will be initiated with SECA members and other potential OEM manufacturers. Distributors will be identified and contacted.

Results

A preliminary design has been performed. The CAB has been designed as a centrifugal compressor running at 80,500 rpm. In order to meet high reliability, the rotating assembly will be supported on foil air bearings.

The CAB is driven by a brushless permanent magnet DC motor and controlled by a sensorless controller. Such motors have shown high efficiency and high reliability for the power range required for the CAB.

An existing fuel processor blower (FPS) developed at R&D Dynamics Corporation was used as a baseline to develop and reduce the cost of the CAB. The existing FPS blower was previously designed, manufactured and successfully tested for a proton exchange membrane (PEM) fuel processor and was built by R&D Dynamics for UTC Fuel Cells under a DOE funded project. A cross-section of the CAB is shown in Figure 1. An innovative low cost split housing was designed to reduce manufacturing and assembly cost of the CAB. Figure 2 shows the split housing design. Plastic impellers were tested for structural integrity to be used in CABs which will reduce blower cost. Figure 3 shows the

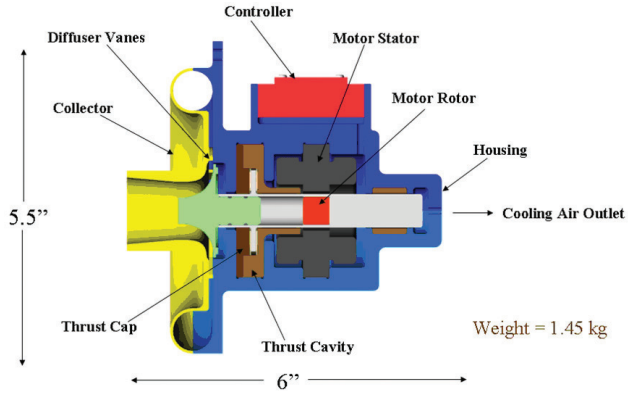

FIGURE 1. Cross-Section of CAB

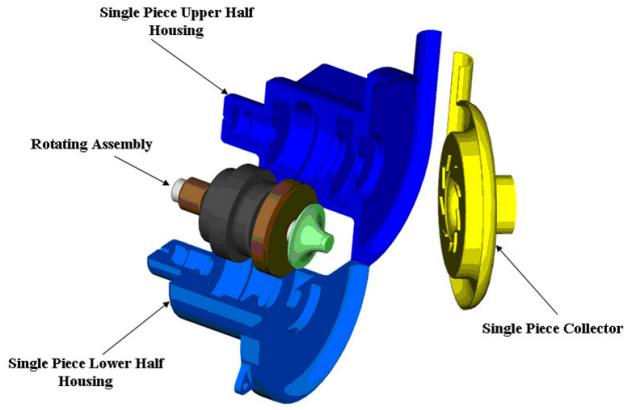

FIGURE 2. Split Housing Design of CAB

plastic impeller installed in the high speed test rig ready for testing.

The CAB is affordable, efficient, reliable, small, light weight, and meets turndown requirements.

The FPS blower was used to develop the first cost model using DFMA tools. From the first cost model of the FPS blower, cost components were identified. From the cost components and lessons learned, the CAB was designed. A final cost model was developed for the CAB. Part count was reduced from a total number of 113 parts for the existing FPS blower to a part count of 16 for the CAB. The CAB estimated cost is $105.11, which is close to the DOE target of $100 at a production rate of 50,000 units/year. Additional DFMA analysis could further reduce the cost.

Technical Requirements

A blower specification was selected from the requirements provided by DOE and discussions with SECA members. It was understood that once this blower is developed, it can be scaled to meet specific requirements of various SECA members. The specific

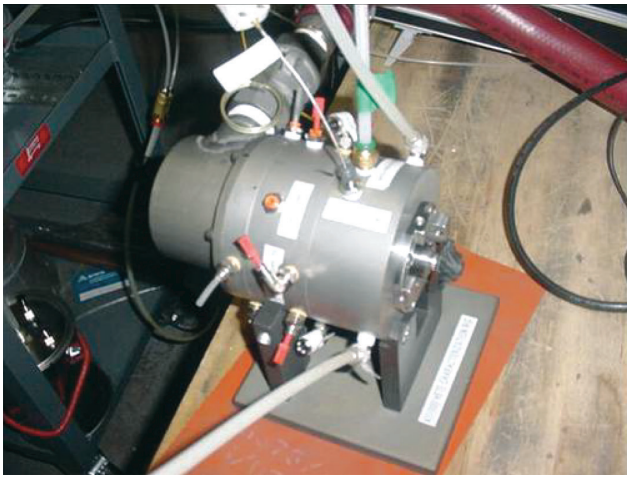

FIGURE 3. Plastic Impeller Installed in Test Rig

blower requirements selected to design the CAB are as follows:

- Process Gas Air
- Inlet Pressure 1.01 Bar (14.7 psia)
- Outlet Pressure 1.22 Bar (17.64 psia)
- Pressure Ratio 1.2
- Inlet Temperature 20°C (68 °F)
- Outlet Temperature 40.7°C (105.4 °F)
- Volume Flow Rate 1500 slpm
- Mass Flow Rate 1.8 kg/min (3.98 lbm/min)
- Turn Down Ratio 5:1
- Isentropic Power 474 watt

Technical Summary of CAB (Design Point)

The technical summary of the blower design is as follows:

- Blower Type Centrifugal
- Mechanical Speed 80,500 rpm
- Weight 1.45 kg (3.2 lbm)
- Bearings Foil Gas Bearings
- Motor Type Permanent Magnet Motor
- Controller Type Sensorless Controller
- Input Electric Power 769 watt
- Isentropic Efficiency 75%
- Total Blower Cost $105.11 [@ 50,000 units/year]
- Life >40,000 hrs

Conclusions and Future Directions

Phase I research work was highly successful in meeting all the requirement of SECA members and proved the feasibility of the project. Phase I work opened venues for further development to

manufacture the designed blower and test successfully to commercialize the technology for SOFC system applications to meet the goals of SECA members, which will be done in Phase II of this project.

FY 2007 Publications/Presentations

1. "Project Review Presentation" March 5, 2007, DOE NETL- Morgantown,WV 26507.