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ELECTRIC, FUEL CELL, AND HYBRID VEHICLE, ENGINE AND EMISSIONS, HEAT TRANSFER, FLUID AND THERMAL ENGINEERING

Study on Performance of Airfoil-Bearing Air Compressors for Fuel-Cell Vehicles Considering Hollow-Shaft Recirculating Flow

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Abstract
Air compressor systems for fuel-cell vehicles typically require downsizing, high-performance, and cost reduction. With increasing air compressor performance requirements, attention must be paid to the cooling methods that combine a coolant and air cooling. To reduce the number of system packages and parts, a study was conducted on internal self-air cooling by applying a hollow shaft to an air compressor using an airfoil bearing. The results indicated that although the aerodynamic performance was degraded owing to impeller leakage and recirculating flow, the axial force was reduced; thus, the overall compressor efficiency was not reduced significantly. Several advantages were confirmed numerically and experimentally. The obtained configuration does not require an air-cooling supply unit for the motor and bearing, which simplifies the product configuration. This system can also reduce the thrust bearing size by reducing the axial force. Furthermore, the recirculating flow through the hollow shaft can increase the surge margin, which is an indicator of the operating range of the compressor.

Keywords Airfoil bearing · Air compressor · Hollow shaft · Axial force · Fuel-cell electric vehicle · Computational fluid dynamics

List of Symbols

A	Area m^2
AF	Axial force, N
CFD	Computational fluid dynamics
C_p	Specific heat at constant pressure, J/kg·K.
LC	Load capacity, N
P_{avg}	Average pressure, Pa.
PR	Pressure ratio
Rs	Radius scale of base thrust bearing
SM	Surge margin
T	Temperature, K.
$\dot{m}$	Mass flow rate, kg/s
η	Aerodynamic efficiency
η_c	Compressor total efficiency
ω	Angular velocity, rad/s
τ	Drag torque, Nm

Subscripts

1	Inlet, inner
2	Outlet, outer
S	Stall

1 Introduction

The air compressor for fuel-cell vehicles compresses atmospheric air through high-speed rotation and delivers the compressed air to the stack system. Research on air compressors for fuel-cell vehicles has focused on addressing system requirements. Thus, various compressor types have been investigated. As noted by Yang et al. (2014), studies generally target a pressure ratio between 1.5 and 3.0. Experimental investigations on the aero-acoustic characteristics of centrifugal compressors have also been conducted (Ha et al., 2013). Additionally, to ensure stack durability by limiting oil ingress, the development of oil-free high-speed compressors with airfoil bearings is ongoing.

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