Direct Methanol Fuel Cell Flow Field

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Abstract

Direct Methanol Fuel Cells (DMFC) are being explored as an alternative energy source over traditional lithium ion batteries used in portable electronics by the Army. The driving reaction in the DMFC occurs in an area known as the flow field, which is the area through which fuel flows. This fuel mixture is reacted with an oxidant gas (air) to achieve the chemical reaction producing electricity. Optimization of the fuel cell stack, which is an assembly of several flow field plates stacked on top of one another, can be achieved through development of new, flow field patterns, new flow field types, semi-permeable materials, and cost reduction methods. Machined flow fields, metal foam flow fields, and corrugated sheet metal flow fields are being considered as possibilities.

The final design goal of this phase of the project has been narrowed down to creating a more efficient flow field assembly. In order to design an effective flow field, a modular flow field test fixture was designed for experimental exploration. The fixture can be adjusted to accommodate any design configuration, and is compatible with any flow field design. The fixture will serve as an analysis tool to aid in the design of future flow field prototypes. Preliminary analysis of designs will be done using Fluent, which will help the team understand if a design is worth experimentally testing with the modular flow field test fixture. The flow field test fixture was designed to allow future project phases to continue to develop new flow field configurations, should further development prove necessary.
The Need for Project

Discovering the best flow field design for a particular type of Fuel Cell is integral to achieving peak operating conditions. In order to have a reliable direct methanol fuel cell, it is crucial to have an efficient flow field design. The flow field is important because it is the path the fuel takes inside the fuel cell. If the flow field creates a poor fluid flow, the chemical reactions that produce energy will not occur efficiently and completely. This project will help in developing and testing flow field configurations, which can then be incorporated to the design of a fuel cell stack. With this test setup, the fluid flow across a flow field can be analyzed, providing vital information that can be incorporated into the next flow field design concept.

The Design Project Objectives and Requirements

The objective of this project is to develop a test fixture for Direct Methanol Fuel Cell flow fields, which allows for maximum flexibility in flow field design.

Design Objectives

The objective of this project is to provide the sponsor company with an efficient way of testing new flow field designs for DMFC’s. This meant designing and fabricating a testing fixture to be used in the test setup. It is important for the design to be adaptable to several types of flow field configurations. The design must allow for designers to analyze different flow field configurations to determine the viability of a given design.

Design Requirements

The design must be easy to maintain so it can withstand repeated testing over time and not have to endure costly repairs. The design also needs to adequately simulate the fluid flow that occurs within a fuel cell stack, specifically the flow velocity. It is important the design be built so that the tester can clearly see the flow across a flow field design. Lastly, the design must provide the tester with reliable data that can then be incorporated into the next flow field design to be tested.

Design Concepts considered

Two separate design concepts for the Flow Field Test Fixture were developed. Design 1 was designed so the housing was one solid piece of delrin. Design 2 was designed as three separate pieces, allowing for more testing.

During the design process, two design concepts were developed. Both designs incorporate the same basic layout and functionality. The basic function of the test fixture is to test a flow field and its related inlet and outlet sections under equilibrium flow conditions identical to those found in a fuel cell stack. The latest design concept is a further development of the original. It incorporates greater versatility in testing and a simpler machining process, despite being comprised of more
flexibility and easier machining.

Design 1 – Triangular Inlet Flow Field Test Fixture

This was the first design iteration of the Flow Field Test Fixture. It features a one piece housing made of black delrin, an interchangeable pin field insert assembly at the inlet side, a cavity for machined flow fields to be inserted, and a plexiglass cover. The idea behind this design was to allow several different pin field configurations to be fabricated and tested within the fixture, while also allowing for any flow field configuration to be easily introduced. For initial testing, a blank flow field, which is essentially a flat plate made of white delrin, will be used to evaluate the effects of the pin field at the inlet side.

This design had several flaws that were discovered upon review. First of all, it offered limited testing flexibility. Although there is plenty of testing that could be achieved using this design, the inability of this design to adapt to alternative pin-field shapes, outlet pin fields and so on would limit its effective life-span. These issues were resolved in the second design iteration.

Design 2 – Modular Flow Field Test Fixture

The second design iteration built upon the strengths of the original design, and dealt with the weaknesses by adding features and adaptability. Rather than use a one-piece housing, it employs a three-piece housing. The idea behind this is to allow for any configuration or shape at the inlet and outlet ends of the fixture. It also makes for a simpler machining process, despite the increased number of individual parts. Currently, there are parts which allow for either square or triangular inlet/outlet shapes, and either a square or diamond shaped pin arrangement. These components will be detailed further in the following section.
Recommended Design Concept

The Modular Flow Field Test Fixture allows for an unlimited number of flow field shapes and configurations to be tested, thanks to its great versatility. It provides a clear and simple method to test the flow characteristics of a particular flow field design.

The recommended design for this project is the second design iteration, the Modular Flow Field Test Fixture. This is by far the stronger of the two design considerations, for many reasons.

Design Description – Modular Flow Field Test Fixture

The main goal of this design was to allow for maximum testing versatility, by allowing the test fixture to be modified in any way desired by the flow field designers. In order to do this, a three-piece housing was used. The housing consists of a central Flow Field Housing, and two Peg Board Housings at each end. Currently, a triangular shaped Peg Board Housing and a Square End Housing have been fabricated, but additional shapes are in progress. The figures on the left showcase the two housing end shapes. These pieces can be quickly and easily removed with a set of hex screws. These pieces are each made of black delrin. Delrin was chosen for ease of machinability, compatibility with chemical agents and durability. They are separated by closed-cell-neoprene gaskets for a tight, waterproof seal.

The central Flow Field Housing currently contains a blank flow field insert. It was decided that for the initial round of testing, a simple flat plate flow field would be employed. This is to focus on the effects of the Peg Fields at the inlet and/or outlet on fuel flow. These Peg Fields are assemblies in which round pegs are inserted into an array of holes. The purpose of these pegs is to manipulate fluid flow into and/or out of the flow field. A key feature of the Modular Flow Field Test Fixture is that it allows for just about any configuration/shape of pegs to be employed to manipulate fluid flow. The Peg Fields are also interchangeable pieces which insert into the Peg Board Housings. The Peg Fields consist of two parts, a Lower Peg Field and a Peg Field Cover. The purpose of a two piece assembly is to allow for pegs to be inserted in such a way that they either protrude completely into the fluid flow, or to simply plug a hole and have their top edge be coincident with the base of the test rig. The two piece design allows for easy removal of the pegs that are installed flush with the base.

All of the insert pieces; the blank flow field, the Lower Peg Field,
and the Peg Field Cover are fabricated from white delrin. This is because during the testing process, a red dye will be introduced to the fluid flow to allow for visual flow analysis. The white delrin will provide a good backdrop for visibility of the dye.

The whole assembly is covered by a ¼” thick plexiglass cover, sealed by another gasket made of closed-cell-neoprene. This material was chosen for all the gaskets for its good sealing properties, resistance to solvents, and low cost. The purpose of the clear cover is to allow for easy viewing and photographing of the fluid flow within the fixture.

The Modular Flow Field Test Rig will have several attachments to complete its functionality. First, a precision syringe pump with a prescribed methanol/water mixture will be pumping this mixture to the inlet end via ¼”ID hose. In between the syringe pump and the Test Fixture inlet will be a hose tee, connected to a check valve and another syringe. This second syringe will contain a red dye. Once fluid flow through the test fixture has been achieved, the red dye will be introduced to the system. Once this has been done, a tripod-mounted digital camera will take photographs of the dye as it travels through the test rig. The path the dye takes through the test rig will give an accurate representation of flow distribution and velocity throughout the fixture.

Analytical Investigations– Modular Flow Field Test Fixture

In order to analyze the fluid flow seen on the Modular Flow Field Test Fixture, pictures will be taken of the test area using a digital camera. These pictures will then be imported into SIGMAscan, where the tester can analyze the image and find where the flow field design is flawed. Fluent analysis will also be done to simulate the different possible peg configurations before they are physically tested. With Fluent, the tester will be able to get a preview of how the fluid flow will behave with a given peg configuration. Using this analysis, the tester can determine of the peg configuration chosen worth setting up in the test fixture.

Key Advantages– Modular Flow Field Test Fixture

The key advantages of the Modular Flow Field Test Fixture over its predecessor numerous. Most importantly, it allows for interchangeability of inlet and outlet housing shapes. It allows for
additional inlet and outlet shapes to be fabricated and mated to the existing assembly. It also is much easier to manufacture than the original design.

Financial Issues

The cost of our prototype test rig was around $3000. This was due to the extensive machining required to fabricate it.

Some financial issues arose while coming up with the design concept. First of all, the test fixture was too expensive for Northeastern University to pay for, so the sponsor company, NuVant Systems, provided the necessary funding to get the Modular Flow Field Test Fixture fabricated. Also, machined flow fields are very expensive, so the team was not able to fabricate a flow field design based on the experimental and analytical data gathered. At this point, this is not a major issue, as the first round of testing will involve a blank, flat plate flow field.

Recommended Improvements

The Modular Flow Field Test Fixture allows for continued improvement at any stage. Additional pieces needed include alternate peg board housing inlet and outlet configurations and other peg shapes.

At this stage, it is felt that the basic design of the Modular Flow Field Test Fixture is strong. However, there are several additions to the fixture which are planned. These include new shapes of Peg Board Housings, and the subsequent differently shaped Peg Field Assemblies. This will allow for continued diversity in flow field designs so as to better determine the strongest flow field design candidates. As testing continues with the Modular Flow Field Test Fixture, additional areas of improvement may be identified and acted upon.