A Comparison of Biomimetic Design and TRIZ Applied to the Design of a Proton Exchange Membrane Fuel Cell

Jessica Currie, Keith Fung, A.G. Mazza, J.S. Wallace, L.H. Shu*
Dept. of Mechanical and Industrial Engineering, University of Toronto
*shu@mie.utoronto.ca

Abstract

The Proton Exchange Membrane (PEM) fuel cell is an attractive energy conversion device that can provide efficient and clean electrical energy. However, limitations in water management can deleteriously affect its conversion efficiency. Overcoming this technological challenge is essential. In this paper, two design methodologies, biomimetic design and TRIZ, were used to find potential solutions to this water management problem. Each design method produced two potential solutions. We found biomimetic design to have more potential for bias by the designer's prior knowledge of biology. This bias can serve to either hinder or help the design process. A notable finding is that biomimetic design and TRIZ can be considered mutually inclusive in the potential solutions generated in this study. This suggests that either design method could have been used to produce the same solutions.

1 Introduction

A proton exchange membrane (PEM) fuel cell converts the stored chemical energy in a fuel, e.g., hydrogen, into electrical energy. An important and current challenge in PEM fuel cells involves water management, the delicate balance between providing enough water to the membrane for hydration, and removing product water from the cell quickly enough to prevent membrane flooding. Reducing the flooding problem can allow for higher fuel cell operating efficiencies and power densities. To address the water management challenge, biomimetic design and TRIZ (Russian acronym for the theory of inventive problem solving) are applied to identify possible ways to mitigate flooding in the redesign of a PEM fuel cell.

2 Background

This section provides background on the two design techniques used in this work, biomimetic design and TRIZ; and briefly describes PEM fuel cells.

2.1 Biomimetic Design

In biomimetic design, biological phenomena are studied to generate ideas for solving engineering problems. The classic example of biomimetic design is Velcro, which uses hook structures found on burrs that were observed to attach to fur and clothing. Velcro resulted from the designer's own experience with burrs, inspiring a fastening solution. However, many designers may not know of all relevant biological phenomena that could solve a given problem. Thus, Vakili and Shu (2001) developed a systematic method that searches existing biological knowledge in natural-language format to identify relevant biological analogies. The initial corpus, or text, is an undergraduate level biology textbook, *Life, the Science of Biology* (Purves et al. 2001). Search keywords correspond to verbs that describe the desired function of the solution, and identify biological phenomena that can be used either directly for a design solution or as a starting point for further research into useful biological phenomena.

This method was used to solve problems in design for remanufacture (Vakili & Shu, 2001; Hacco & Shu, 2002) and assembly of micro-parts (Shu et al., 2006). To improve the approach, biologically meaningful keywords were generated to bridge different lexicons between engineering and biology (Chiu & Shu, 2005).

2.2 TRIZ (Theory of Inventive Problem Solving)

TRIZ, the Russian acronym for "Theory of Inventive Problem Solving" has been shown to significantly increase the number of unique solutions compared to traditional methods such as brainstorming (Okudan et al., 2006). To develop TRIZ, Genrich Altshuller et al. (Altshuller, 1988) studied over 1.5 million patents to identify 39 engineering parameters as commonly improved attributes in innovative designs. Forty principles were generated based on methods used to solve engineering problems in these patents. Many tools are proposed for TRIZ, but the classical contradiction table remains as one of the more powerful tools (Ross, 2006).

To use the contradiction table, a given problem is expressed in terms of the 39 engineering parameters. Pairs of parameters, one of which is degraded in the process of improving the other, are used to identify principles that have been observed to overcome this contradiction. These principles are examined to generate ideas. The contradiction table, parameters, and descriptions of the principles used in this paper are from the text, *Product Design Techniques in Reverse*