ABSTRACT

Fuel Cell is an electrochemical device that continually converts chemical energy of fuel into electric energy as long as fuel and oxidant are provided. Proton Exchange Membrane Fuel Cell (PEMFC) among various types of fuel cells is of great research interest due its versatility and ability to operate at room temperature. In case of PEMFC, the fuel (hydrogen) is supplied at anode and either oxygen or air is supplied at cathode. Heat and water are produced as by-products apart from electricity due to oxidation at anode and reduction at cathode. The removal of the by-products needs to be optimised to avoid the problem of flooding and dehydration of membrane. Excess quantity of water in liquid phase would certainly lead to obstructing the pores in the Gas Diffusion Layer (GDL) and Catalyst Layer (CL) while inadequate quantity of water would lead to membrane dehydration, thus resulting in bad performance of the PEMFC. For this reason, the water management is among the essential issues influencing efficiency of PEMFC system. Different flow field layouts have been developed for efficient elimination of water from PEMFC flow channels. The water which is accumulated on the cathode side of the flow channel is removed by the reactants whereas the water accumulation in the interfacial of cathode flow field landing and GDL is really tough to eliminate. This gathered water obstructs the flow of catalyst from GDL to the catalyst layer, thus decreasing the performance of PEMFC. In this concern, a permeable landing might facilitate easy water removal in the cathode side and also substantially improve PEMFCs efficiency. There is a requirement for a new basic and cost-effective method of water elimination in the landing region of the cathode flow field. The objective of this work is to manage the water flooding on the landing through the modification of serpentine flow field on cathode by

inserting porous inserts on grooves machined on the landing surface of ribs. Also, the effect of increasing the size of the porous inserts are analysed and their relative performances are compared.

For this purpose PEMFC with an active area of 25 cm^2 with different flow field designs namely serpentine, modified serpentine with inline arrangement of porous inserts (MSI) and modified serpentine with staggered arrangement of porous inserts (MSS); and porous inserts made of Vulcan carbon (PCI) and carbon sponge (PSI) were studied. The influence of increasing the size of the porous inserts was studied by comparing the performance PEMFC employing inserts of size 2 mm, 3 mm, 4 mm and 5 mm. Initially numerical analysis was carried out to find the best combination, followed by experimental validation. The results showed that the MSS flow field with 4 mm PSI performed better compared to other flow fields under study. The reliability of the results was verified by using Electrochemical Impedance Spectroscopy for serpentine flow field and MSS flow field with 4 mm PSI.

The MSS flow field with 4 mm PSI was found to perform 42.38 % more than the serpentine flow field at 25 cm^2. Hence, the same was scaled up, to assess its performance at larger active areas.

However, increasing the active area of the fuel cell reduces the ability of reactants to remove the water accumulated in the flow channel due to pressure drop over long path owing to increased size. Hence, It is essential to better flow distribution to reduce the accumulation of water on PEMFC with larger active area. The present research study focuses on preventing water flooding in PEMFC scaled up from 25 cm^2 to 36 cm^2, 49 cm^2 and 100 cm^2. As the approach of incorporating porous inserts on grooves machined on landing of ribs of cathode flow field improved PEMFC performance with 25 cm^2 active area, the same approach is utilized to address the flooding issue during to scaling up studies. Hence, MSS flow field with 4 mm PSI were used during scaling up studies for various active areas (36 cm^2, 49 cm^2 and 100 cm^2). The results are compared with serpentine flow fields of respective active areas.

The MSS flow field with 4 mm PSI outperformed the serpentine flow field by 89.16 %, 42.85 % and 38.88 % at 36 cm^2, 49 cm^2 and 100 cm^2 active areas respectively. The PSI kept on the grooves machined on the landing of ribs of cathode flow field removes the water accumulated in between GDL and landing by virtue of capillarity of its permeable framework, thereby enhancing the efficiency of PEMFC in scaling up studies compared to the conventional serpentine flow field. This modification is recommended for enhancing the performance of PEMFC as it is economically viable.