Simulation of a Fuel Cell

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Proton Exchange Membrane Fuel Cell(or Proton Electrolyte Membrane Fuel Cell, PEMFC) is one of the energy solutions that does not generate greenhouse gases and any pollutes. The sources that a fuel cell uses are hydrogen gases and oxygen gases and the only product is water. No need to worry about being exhausted of sources and no need to worry about pollutes. Furthermore, a fuel cell has an important advantage compared to an internal combustion engine in terms of efficiency. While the average efficiency of internal combustion engines is around 20%, that of fuel cells is 80%. A fuel cell is still competitive compared to a solar cell which is another promising energy converter; its highest efficiency is 11.1% and 10.6% for the case of an inorganic cell and an organic cell respectively. Additionally no moving part in a fuel cell increases mechanical attraction. Not only no noise is sounded but also the mechanical stability becomes high.

Due to its several advantages shown above, fuel cell would be the most promising energy converter in the future. Since application to vehicles could solve problems, many automotive companies concentrate on developing fuel cell cars. From this year(2014), Hyundai starts to lease fuel cell car(ix35 hydrogen fuel cell car) and the lease price is $499/month with unlimited and free charge of hydrogen gas. Once fully charged of hydrogen gas, this fuel cell car goes 600km and the maximum velocity is 160km/h. The performance of conventional car is not fully reproduced in this car but surely this is not a bad start. Within 5 years, Hyundai plan to sell fuel cell cars. Toyota expects the price of a fuel cell car in 2020 might be competitive with a conventional car. Especially in Europe, there is a high environmental tax, fuel cell car would be more attractive.

Fuel cell car operated in high temperature(120^{o}C) is desired because of high performance, removal of poison and half size of radiator compared to in low temperature(80^{o}C). Several points should be considered if fuel cell is operated in high temperature. First, Nafion(long side-chain perfluorinated sulfonic acid) losses proton conductivity so it should be replaced to Aquivion(short side-chain perfluorinated sulfonic acid). Second, water evaporates and this leads to a serious decrease of proton conductivity. How to manage water in this temperature is one of important problems.

Simulation of a fuel cell will give the answer to this question. Many modeling and simulation exist but most of them are about steady-state condition while dynamic condition commonly happens in automotive condition. Only few researches showed modeling in dynamic condition and all of them concerned in low temperature where H_2O existed as water. Here I consider the condition of high temperature. The equation found by Springer is importantly used in this research.

$$\sigma = (0.005139\lambda - 0.00326)\exp[1268(\frac{1}{303} - \frac{1}{T})]$$

where $\lambda = 0.043 + 17.18a - 39.85a^2 + 36a^3$ and $a = \frac{P_w}{P_{sat}}$,