Computational modelling of thermal plasmas for industrial applications

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Thermal plasmas are widely applied industrially, for example, in arc welding, plasma spraying, plasma cutting, plasma waste treatment and gasification, and circuit breakers. Computational modelling is increasingly used to develop and optimise such applications. Modelling thermal plasmas requires solving a set of coupled fluid dynamic and electromagnetic equations. I will present three examples demonstrating the value of computational modelling based on collaborative projects with companies developing or using thermal plasma processes.

The first demonstrates the importance of calculating plasma thermophysical properties, which are required in computational models. The standard gas used in high-voltage circuit breakers, SF_6, has a very high global warming potential (GWP) of 23 900. An attractive replacement gas is Novec™ 4710, or C_3F_7CN, which is typically mixed with CO_2 to give a reduction in GWP of >99%. However, using the mixture requires a thorough redesign of the circuit breaker, in which computational modelling plays an important role. CSIRO provided a leading manufacturer, LS Industrial Systems (LSIS), with thermophysical properties of mixtures of C_3F_7CN with other gases. Adopting these data in their models, LSIS developed the world's first 170 kV 50 kA circuit breakers using Novec 4710.

The second example is the application of the PLASCON plasma waste treatment process to destroy ozone-depleting substances (ODSs) such as chlorofluorocarbons and halons. Experiments found that a significant proportion of the input ODS was converted to other ODSs. The problem was analysed with a plasma model incorporating chemical kinetics, resulting in the prediction that adding steam to the gas feed would solve the problem [1]. PLASCON (now PyroPlas®, owned by A-Gas) has since been used in Australia, UK, USA and Mexico to destroy ODSs and fluorocarbon greenhouse gases.

The final example is arc welding. Optimising parameters such as current, travel speed and electrode angle for a particular weld requires repeated experimental trials, which are time-consuming and expensive. CSIRO's ArcWeld software [2] explicitly incorporates the arc plasma in the computational model, improving accuracy and reducing the number of experimental trials required. The software was developed in collaboration with General Motors and CRRC Qishuyan Institute.

[1] Murphy A B, Farmer A J D, Horrigan E C, McAllister T 2002 Plasma destruction of ozone-depleting substances, *Plasma Chem. Plasma Process.* **22** 371-385.

[2] Chen F F, Xiang J, Thomas D G, Murphy A B 2020 Model-based parameter optimisation for arc welding process simulation, *Appl. Math. Modell.* **81** 386–400.