Applicant: Declan Brick Capstone: Plasma Jet modeling with SPF-Max

Low temperature plasma and plasma devices have been shown to sterilize bacteria and generate chemically reactive species to treat biological materials without incurring thermal damage[2]. One such low temperature plasma device is the atmospheric-pressure plasma jet (APPJ). APPJs operate at normal atmospheric conditions, so they don't require pressure-regulating equipment such as vacuum chambers. This lack of vacuum equipment makes APPJs cheaper than other plasma devices and thus well suited for commercial and societal applications[2]. However, in order to create effective treatments, the behaviour of APPJs must be characterized across varied operating conditions.

Currently, UAH's Plasma and Electrodynamics Research Laboratory (PERL) has an APPJ that has been developed for biological treatment[1]. Within this device, gas is flowed across a rod electrode, which is powered by a pulsed DC power source that ionizes the gas, turning it into a plasma[1]. Recently, the reactive species produced by the APPJ, namely OH and N_2; the length of the APPJ; the time-resolved propagation of plasma bullets in the APPJ; and the gas flow of the APPJ were characterized at different operating conditions such as voltage, pulse width, pulse frequency, and flow rate[1]. However extensive this characterization is, it is limited by physical measurement techniques. So, other measurement techniques, like modeling, are needed to further characterize PERL's APPJ. That is the goal of this proposal: to use a computational model of the APPJ to further characterize it. The model will use the code SPF-Max which is a smooth particle hydrodynamics code developed at UAH by Dr. Jason Cassibry that is capable of simulating plasmas. Work on learning and augmenting SPF-Max to be able to model the APPJ has already begun and will be completed in the Spring of 2020. This proposed project will take place from May-August of 2020.

The primary parameters we want to characterize are the plasma temperature, plasma density, and internal flow structure of the APPJ. These parameters have not been measured within in APPJ due to the difficultly in physically measuring them. However, within SPF-Max these parameters can be calculated rather simply, allowing us to characterize these parameters across the operating conditions from the experimental characterization. Plasma temperature and density characterize the type of plasma the APPJ is, allowing us to better understand where PERL's APPJ stands relative to other plasmas and other potential applications for the APPJ. Additionally, both the plasma temperature and density give insight into the energy distribution within the plasma and understanding this distribution allows us to determine which portions of the plasma may result in better treatment. As for the internal flow structure, it describes another baseline performance measurement for us to see which sections create more effective treatments. However, we are also interested in turning the APPJ into a plasma sheet, so understanding the internal flow allows us to determine how to manipulate the flow structure to form a sheet. By characterizing these parameters with molding in SPF-Max, we will have achieved the goal of further characterizing the APPJ, allowing us to understand its performance and how to best apply the APPJ for treatment purposes.

Works Cited:

1. Gott, Ryan & Xu, Gabe. (2019). OH Production and Jet Length of an Atmospheric-Pressure Plasma Jet for Soft and Biomaterial Treatment. IEEE Transactions on Plasma Science. PP. 1-12. 10.1109/TPS.2019.2942576.
2. Penkov, O.V., Khadem, M., Lim, WS. et al. J Coat Technol Res (2015) 12: 225. https://doi.org/10.1007/s11998-014-9638-z