Magnetic Thrust Vectoring of Plasma Thrusters

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Abstract. The project aims to create a contactless magnetic steering system that can be employed for vectoring plasma thrusters of small satellites (e.g. 6U CubeSat). Such a thrust vectoring system (TVS) could be used to control the trajectory and attitude of a satellite without the need of moving steering mechanisms, such as gimbals or reaction wheels. Additional benefits of such system are: 1) the increase in the attainable applied magnetic field magnitude in the source, thus increasing ion magnetisation and 2) the improved radial confinement of the plasma in the source. The research work includes the physical realisation of a 3D magnetic thrust vectoring system and focuses on studying the effect of a deflecting magnetic nozzle on the plasma beam produced by a helicon plasma thruster.

The experimental set up will comprise a pair of copper coils surrounding the plasma source which will generate a converging-diverging magnetic nozzle (MN). The thrust vectoring system will be formed by three skewed, concentric coils placed at the plasma source exit. The steering of the MN, thus of the plasma beam (for a fully or partially magnetised ion population) is obtained by choosing different ampere-turn values for each coil of the TVS system; the three inclined coils are connected to an independent and controllable current source, and thus can generate a asymmetric magnetic nozzle and hence control its deflection. A similar system was first presented by [1]. Their idea included three concentric coils of identical dimensions - as shown in fig. 1
The design of the coils employed for the magnetic steering of the plasma beam is currently being undertaken with the aid of 3D electromagnetic simulations. Some results from the simulations of the magnetic field generated by the magnetic vectoring system are shown in fig. 2. The plasma source tube is assumed to end at x = 0.25 m.

The experimental set up will also include a diffusion vacuum chamber having a diameter of 50 cm. This, coupled with proper plasma diagnostic probes, will allow for a complete 3D mapping of the HPT plume. As well as studying the coupling between the ion beam and the magnetic nozzle, an investigation of currently unknown plasma physics mechanisms in helicon plasma thrusters can be carried out, such as:

- ion beam divergence from the magnetic field lines
- plasma asymmetries in the magnetic nozzle
- influence of TVS coils polarity on the plasma beam behaviour

For efficient thrust production, high magnetic fields are necessary to increase the magnitude of the magnetic thrust and to drastically decrease radial losses in the plasma source. Thus, High Temperature Superconducting (HTS) coils could reduce the propulsion mass, size and power requirements. Two double-pancake HTS coils will be implemented in the HPT apparatus to create the primary magnetic field in the source of the plasma thruster and replace the copper coils for the generation of the converging-diverging magnetic nozzle. The implementation of the HTS magnetic system will allow for the determination of a scaling law for plasma thrusters employing superconductive coils, as well as exploring the performance of the HPT at higher magnetic fields without the penalty of high current requirements.

REFERENCES

[1] Merino, M., Ahedo, E. (2017). Contactless steering of a plasma jet with a 3d magnetic nozzle. *Plasma Sources Science and Technology*, 26