A Bibliometrics on Hall Thruster Control Systems

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Introduction

- Hall thrusters are electric thrusters used in the correction orbit and atitude of artificial satélites and in the propulsion of space probe.
- Hall thrusters had their in-flight tests in the 1960s in the US and Russia (Goebel et al,2008).
- The main is the production of thrust through plasma (from the ionization of neutral gas and its acceleration).
- The Plasma Physics Laboratory at the University of Brasilia has been developing Hall thrusters since 2004 (Ferreira et al,2019). The current version is called PHALL II-C.
- The work developed for XXI CBDO consists of a study on control systems for subsystems of Hall thrusters found in the literature, performing, therefore, a bibliometrics on the theme.

Methodology

- Articles were searched on the Web of Science website, accessing it from the Capes database website;
- as input, the expression “Hall Thruster Control” was used. Aiming to select articles that are about development of control systems for subsystems of Hall thrusters;
- articles from 2008 to 2022 (15-year interval) were selected;
- A total of 74 articles were considered that, initially, had chances of covering the research topic;
- These articles were studied and those that really are about proposed theme were filtered.

Synthesis

A total of 6 articles covering the theme were found. A synthesis of each control system carried out in the articles is found in Tables 1 to 7.

Table 1 – Hollow Cathode Control System (FU et al,2017), Impact Factor of the journal: 5.967.

Goal	Main Characteristics	Main Conclusions
Carry out heating and ignition of the hollow cathode and keep it on.	Union of the three energy sources in a single source and use of PID controllers with three loops.	Improved power density, efficiency and dynamic response.

Table 2 – Magnetic Field Control System (LIQIU et al,2012), Impact Factor of the journal: 3.234.

Goal	Main Characteristics	Main Conclusions
Perform Suppression of breathing mode oscillation.	The discharge circuit is placed in series with the electromagnetic coils.	Reduces oscillation amplitude.

Synthesis

Table 3 – Discharge Voltage Control System (Reza et al,2021), Impact Factor of the journal: 2.954.

Goal	Main Characteristics	Main Conclusions
Keep the discharge voltage at a fixed value.	Modifying the rate of mass flow of the propellant gas through the anode until the target voltage is reached.	Successful change of operating point, and no major problems were encountered regarding thruster stability or system regulation.

Table 4 – Solar Panel Peak Point Control System, (Reza et al,2021), Impact Factor of the journal: 2.954.

Goal	Main Characteristics	Main Conclusions
Keep the solar array simulator at the maximum power point.	The system performs a variation in the propellant mass flow rate by evaluating the derivative of the power in relation to the discharge voltage.	This type of control makes it possible to control the thruster even in the most severe condition of a sudden change in the performance of the solar arrays.

Synthesis

Table 5 – Low Frequency Discharge Current Oscillation Control System (BARRAL & MIEDZIK,2011), Impact Fator of the journal: 2.877.

Goal	Main Characteristics	Main Conclusions
Damp low-Frequency discharge current oscillations.	Simulation of PID controllers: one on the voltage output and the other on the magnetic field output.	The PID controller over the voltage output proved to be the best option.

Table 6 – Ionization Oscillation Control System (BARRAL & KACZMARCZYKI et al,2011), Impact Factor of the journal: 2.357.

Goal	Main Characteristics	Main Conclusions
Damp discharge current oscillations.	PID controller that acts on the discharge voltage.	Pure proportional control is more effective.

Table 7 – Mass Flow Control System (HOPKINS et al,2014), Impact Factor of the journal: 2.005.

Goal	Main Characteristics	Main Conclusions
Prevent thermal escape in a direct evaporating feed system and stabilize discharge current.	An algorithm was used to implement a PID controller.	Low total system power consumption during steady-state operation.

Discussion

- Of the 74 articles considered, only 6 articles (8.1%) actually covered the theme considered. This shows that there is little research in this area and that, therefore, there is a gap to be filled in it.
- The 3 articles with the most citations deal with the same topic: current oscillations. Indicating that this is the biggest trending topic in the area. In (LIQIU et al, 2012), the importance of this topic is mentioned and it is due to the fact that these oscillations can affect the power processing unit, make a reduction in the specific impulse, in the efficiency and in the life time of the Hall thruters, in addition to controlling electromagnetic compatibility with other equipment installed on satellites.
- In 3 works, PID controllers were used. It's a basic controller. Which shows the possibility of searching for more robust controllers or with optimized response.

Discussion

- It appears that the review presented a different journal for each work and showed IEEE Transactions on Power Electronics as the main journal in the area, due to the fact that it has the highest impact factor (5.967).
- It can be seen that Barral is the author with the highest number of publications (2 publications) and that he was the most cited author (24 citations). Therefore, Barral appears as the main author in the field of Hall thruster control.
- Although they are Engineering problems, most of the works were presented in journals from other areas such as Physics.
- It is also verified that the main institutions are the Harbin Institute of Technology and the Institute of Plasma Physics Laser Microfusion with 2 works each.

Conclusions

The present work proposed to carry out a review in relation to control systems for Hall thrusters subsystems in the 15-year interval from 2008 to 2022. We considered 74 articles that could cover the subject and, after studying these articles, only six articles (8.1%) actually cover the topic. Which shows that there is a big gap for research in the field of Hall thruster control. In addition, the control of current oscillations is the biggest trend in the area. And Barral shows himself as the main author.

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