A Preliminary Study of an Experimental Demo for MHD Accelerator: Activity in UTCC Thailand

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The objectives of current MHD acceleration study at UTCC, Thailand, are to fundamentally design the compact experimental demo of MHD accelerator and to clarify some significant plasma variables along and at the exit of the channel. The mullite ceramic is introduced for constructing a compact channel. The significant challenge of the current study is to provide the 0.4-tesla neodymium magnetic as an MHD source, while the model rocket engine (C6-0, ESTES) is introduced and employed as a gas (plasma) source. Results of the present demonstrations reveal that the gas velocity estimated using the gas pressure measurement through the Pitot tube gave the fastest speed of gas. The value of 117.2 m/s was calculated. The TOF method using two photo diodes showed the slowest speed of 50 m/s.

Key Words: MHD accelerator, MHD Channel, Gas Pressure, Plasma Temperature, and Gas Velocity.

1. Introduction
In recent years, MHD and related works have been studied extensively in many research institutions. The widely known applications of MHD are generator and accelerator. The study of MHD accelerator was primitively as one of the promising candidates for the propulsion systems particularly in a spacecraft or a jet-plane. This is because the MHD acceleration is able to produce amazingly high thrust and generate extremely fast speed of exhaust gas. However, most of the previous works were in numerical analysis studies of both one-dimensional and three-dimensional calculation [1-12]. This might be because the experiments of MHD accelerator require high power and high voltage resulting in high costs of conducting the experiments. In addition, plasma produced using MHD acceleration is generally in high temperature regime. It is somewhat not easy to find the existing materials to construct the channel for the reality experiments.

The objectives of the current study are to fundamentally design the compact experimental demo of MHD accelerator and to clarify some significant plasma variables along and at the exit of the channel. These are extremely essential for the state-of-the-art MHD accelerator field of research if the principle is to be used for reality applications in the near future. Some significant variables have to be clarified and substantially understood, while conducting the inexpensive demonstration.

To conduct the demonstration, designing and constructing a compact MHD channel is considerably a key. Selecting a proper material to be constructed as a channel is also significantly crucial. In this study, the mullite ceramic is ultimately introduced for constructing a compact channel. This is based on the fact that the mullite ceramic is able to endure and resist a relatively high temperature, heat and a shock generated by the heat. Another significant challenge of
the current study is to provide the 0.4-tesla neodymium magnetic to be used as an MHD source. This is because it is considerably strong magnetic power with a compact size, while it is affordably inexpensive. The substantial highlight of the present work is that the model rocket engine (C6-0, ESTES) is introduced and employed as a gas (plasma) source. The advantages of this model rocket engine are that it is economy, compact, and highly reliable. The additional advantage is due mainly to its easiness of electrically ignition.

In the analytical procedures, some measurement methods, namely measuring the gas pressure, TOF using two diodes, employing the lighting detector resistor, and optically measurement system are introduced for investigating the plasma behavior and parameters. Results reveal that the gas velocity estimated using the gas pressure measurement through the Pitot tube gave the fastest speed of gas. The value of 117.2 m/s was calculated. The TOF method using two photo diodes showed the slowest speed of 50 m/s.

The current paper is organized as follows. The explanation of how to construct the experimental setup as well as the materials to be used is presented firstly. Then, results of differing measurement methods and its problem are investigated and discussed. Finally, the conclusion of the current experiment of a compact MHD accelerator is summarized.

3. Results and discussions
In this section, significant parameters and results of the measurements are presented.

3.1 Plasma Temperature and Measurement
In general, plasma temperature is measured in order to investigate how effective the plasma generation process is produced. The higher temperature the plasma is, the more efficient the plasma generates. To measure the temperature, as one may know that gas plasma induced by the MHD acceleration is extremely high (more than 1800 K), researchers at Nob. Harada Plasmadynamics Lab in Nagaoka University of Technology recommended using the Optical Measurement Method. It is shown as in Fig. 2. Is indicates the light intensity of the light source, while Ip indicates the intensity of light radiated by plasma. It is Ip plus Is. This set of Optical Measurement Method is placed at 1000 mm far from the exit of the MHD channel.

Figure 4 shows the waveform of plasma production when it is generated in the MHD channel. The red-fronted line is the plasma temperature. It can be seen that the temperature of about 2000 K is estimated at the stable state of plasma production.

3.2 Plasma Velocity Estimated by Gas Pressure
To observe and measure the gas pressure along the channel and at the exit is significant as it is one of useful parameters to ultimately estimate the gas velocity. The gas pressure is measured using the differential manometer (Okano works Ltd, DMC-203N) and a Pitot tube (Okano works Ltd, LK-00). According to the values shown on the screen of the differential manometer, the dynamic pressure is equal to the total pressure subtracts the static pressure. A maximum value of gas pressure of 0.7 kPa is observed and measured. As can be seen in fig. 2, the Pitot tube is melted and bended after the measurement. This is because the temperature of the gas is
considerably high, so the material made of the Pitot tube is not able to resist and endure (it may exceed 1800 K). To estimate the gas velocity at the exit of the channel, this following expression is used.

\[ V = C \sqrt{\frac{2P_d}{\rho}} \]

where \( v \) is gas velocity, \( P_d \) is dynamic pressure, \( C \) is Pitot tube coefficient (1.0), while \( \rho \) is fluid density. Using this estimation, the gas velocity of 117.2 m/s is calculated.

3.3 Plasma Velocity Estimated using a Photo Diode

In this section, the result of estimated gas velocity is presented. In the measuring process, the TOF using 2 Photo Diodes is used.

The velocity is calculated using the distance between the two diodes over the recorded time when the gas (plasma) reaches the diode. When the distance between two diodes is 0.02 m, while the gas (plasma) takes 0.0004 s drifting from the first diode to another, the velocity of 50 m/s is calculated.

3.4 Plasma Velocity Estimated using Lighting Detector Resistor

The LDR at the darkroom is used to calculate the plasma velocity. This is based on the assumption that there might have the sparkle in the MHD channel when the gas is ionized producing plasma. Therefore, two set of LDR are placed at the exit of the channel. However, to calculate the velocity, the distance of each LDR is needed to be set. The distance of 20 cm is designated. The micro controller circuit board is introduced in order to record the trigged time of each LDR. The distance from the edge of the channel where the plasma flows out is also needed to be designed. In the current experiments, 2 values and positions, namely 3 cm and 1.5 cm from the edge of the channel, are experimented and investigated. To prevent from the under-or-over estimated velocity, each position is conducted twice. The results of velocity are shown in Table 1.

Table 1 shows gas velocity at differing measurement positions.

<table>
<thead>
<tr>
<th>Distance from the channel to measuring system</th>
<th>Gas velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 cm (1st)</td>
<td>112.71 m/s</td>
</tr>
<tr>
<td>1.5 cm (2nd)</td>
<td>116.50 m/s</td>
</tr>
<tr>
<td>3 cm (1st)</td>
<td>92.63 m/s</td>
</tr>
<tr>
<td>3 cm (2nd)</td>
<td>93.04 m/s</td>
</tr>
</tbody>
</table>

In addition, the photo of gas plasma while flowing out of the MHD channel is recorded and is shown as in Fig. 3.

It can be seen that the gas plasma disperses un-directionally. This may be one of the reasons why the first recorded plasma velocity is not equal to that of the second recorded. However, the recorded velocity at two different positions seems to be acceptable as it does not show significant difference. Another factor may be because the experiments are conducted at the room where the light intensity is not controlled. So, the light or flashing lamp may cause the errors.

4. Conclusions

The current study has presented the experimental concept for MHD acceleration and its fundamental results. With the collaboration with Nagaoka University of Technology, the mullite ceramic was recommended to construct the channel.
attached with the neodymium magnetic of 0.4 Tesla. To observe the plasma temperature generated in the MHD channel, the optical measurement method was used. Result revealed that the plasma temperature was approximately 2000 K. The gas velocity at the exit of the MHD channel was also investigated. Results showed that the gas velocity estimated using the gas pressure measurement through the Pitot tube gave the fastest speed of gas. The value of 117.2 m/s was calculated. The TOF method using two photo diodes showed the slowest speed of 50 m/s. Estimating the gas velocity using the LDR which is controller by the micro controller circuit also showed the acceptable results. The difference from the value observed by the gas pressure measurement and estimation was not so significant. This experimental demo could investigate the fundamental parameters of MHD acceleration.

References