VERIFICATION OF THE THRUST SIGNATURE OF A MACH EFFECT DEVICE

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A Mach Effect Thruster is an apparatus based on piezoelectric material, which is supposed to produce thrust via an interaction of its components with, chiefly, the distant mass of the universe. A device of this sort, built and tested by Woodward, has been tested on a thrust balance in high vacuum at FOTEC (Austria). The results confirm qualitatively the presence of the same effect observed by Woodward.

1. INTRODUCTION

Being able to reach another planetary system in a reasonable amount time would only be possible if some kind of propellantless propulsion were developed. Propellantless systems like laser sails are an option, but they come with the drawback of relying on an external and distant source of power. The alternative of a self-contained propellantless system, capable of producing movement with seemingly no interaction with its surroundings, is considered to be the ultimate space propulsion scheme.

Since 1990, James F. Woodward and collaborators have shown that it should be possible, via Mach's Principle, to achieve such a scheme [1,2]. If the theory developed by Woodward were verified and validated experimentally, it would not only have practical consequences for space flight, but would also tell us more about the structure of our universe, as it would shed light on the origin of a fundamental property of mass, inertia. The last experimental embodiment of this theory is a device named MET, Mach Effect Thruster. The same device is also known as MEGA, Mach Effect Gravity Assist, an acronym which better describes the underlying working principle.

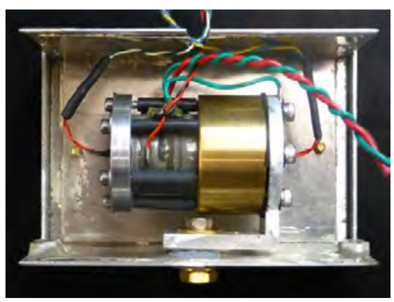

FIG. 1: The MET tested at FOTEC (lid of the Faraday cage removed)

A device of this sort has been sent to the author by Woodward in 2014. The device (Figure 1) is constituted by a stack of piezoelectric discs (material: lead zirconium titanate) clamped between an aluminium cap (left in the figure) and a brass reaction mass, and mounted inside an aluminium Faraday cage lined with mu-metal foil.

Applying a sinusoidal voltage to the piezoelectric stack causes it to change in size and shape, according to its piezoelectric and electrostrictive properties. The combined effect of these deformations is thought to produce thrust by an exchange of momentum via gravitational interactions with the distant cosmic masses [1,2].

What follows is a description of the tests this device underwent at FOTEC during the spring of 2014.

2. EXPERIMENTAL SETUP

The device has been installed on a thrust balance which has been developed to measure the thrust produced by liquid metal ion thrusters, usually ranging from some μN to more than 1 mN. The balance is of the torsion type, with vertical rotation axis, and the pivot consisting of two flexural bearings. The deflection of the balance is detected by a fiber optic displacement sensor. More details on the balance construction and verification can be found in [3].

The electrical connections to the device are implemented via a stack of liquid metal (Galinstan) contacts placed at the pivot: this method assures virtually no friction and no spurious forces produced when power is fed through the contacts (at reasonably low current/voltage values).

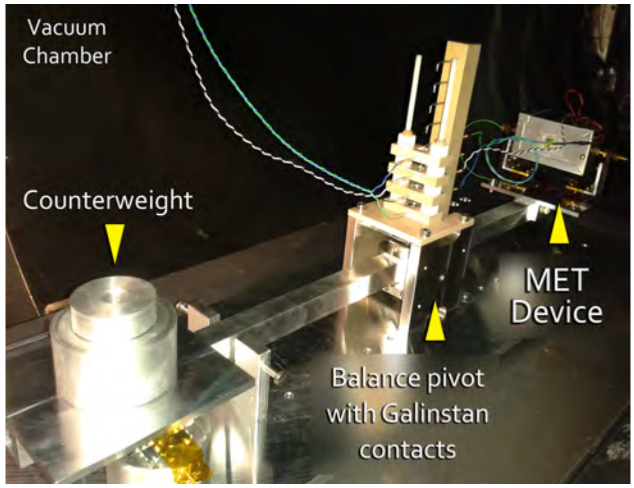

FIG. 2: The MET device mounted on the thrust balance inside the vacuum chamber

The device, mounted on the thrust balance, has been tested inside a vacuum chamber (Figure 2). The vacuum chamber is a cylindrical steel chamber of about 800 mm in diameter and 1750 mm in length; it is equipped with a roughing pump and a turbo pump, and pressures as low as $10^{-6} - 10^{-7}$ mbar ($10^{-4} - 10^{-5}$ Pa) can be customarily achieved.

Preliminary testing has been performed with only two electric lines to the device: the power line, which provided power to the stack of piezoelectric disks, and the temperature measurement line, for the measurement of the temperature on the aluminium cap end. Between the two available temperature measurement sensors, located respectively at the aluminium cap end and at brass reaction mass end, the first one has been chosen because of the faster response due to the lower thermal mass.

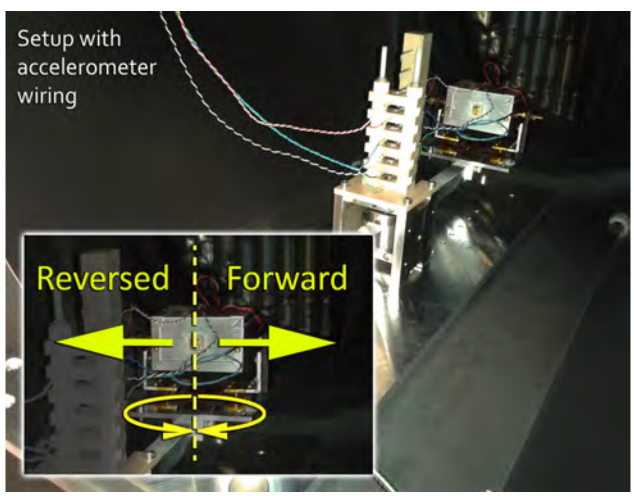

FIG. 3: Setup with added accelerometer wiring and explanation of the thrust vector direction. When going from forward to reversed thrust, the device is rotated around the axis represented by the dashed yellow line.

In subsequent testing, a third line has been added for measuring the voltage across a thin piezoelectric disk, part of the stack, which is passively used as an accelerometer (Figure 3). This enabled better monitoring of the operating conditions of the device. If fact, in order for Mach effects to be produced, both piezoelectric and electrostrictive force components must be present, and this can be confirmed by the presence of second harmonic content in the accelerometer signal (Figure 4).

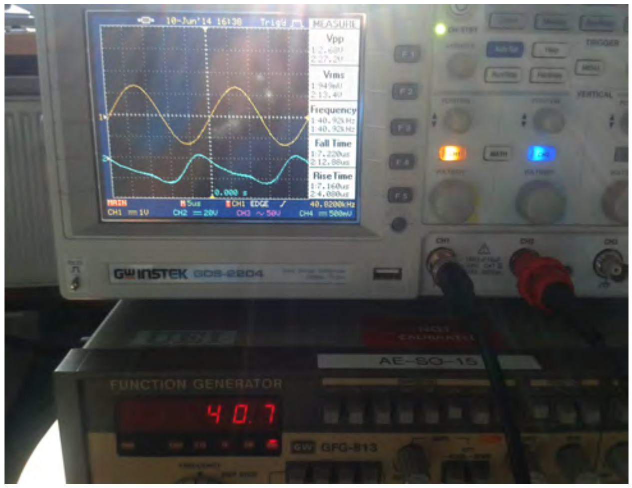

FIG. 4: Oscilloscope showing the driving signal (yellow) and the accelerometer signal (blue). The latter shows second harmonic content, indicative of the presence of electrostrictive force.

The power to the device has been supplied by a Carvin DCM 2500 amplifier, through a step-up transformer, capable of increasing the voltage of the amplifier to levels suitable for a proper operation of the piezoelectric device. Both the amplifier and the step-up transformer have the same specifications like the ones used by Woodward.

3. TEST RESULTS

All the tests have been run when the pressure in the vacuum chamber was 3×10^{-6} mbar (3×10^{-4} Pa) or lower. When a sinusoidal voltage of about 200 V peak to peak with a frequency of about 40 kHz is applied to the device, a thrust signal of about 0.15 μN is produced, with reliable repeatability, provided the temperature of the device was in the range between 30°C and 60°C. The chosen operating frequency of 40 kHz corresponds to the maximum thrust production, and it has been selected after testing the device at different frequency values.

The plots displayed in Figure 5 and Figure 8 show the direct response of the balance at the activation of the device. No further elaboration has been applied at the data. The gray bands indicate the time when power is supplied to the device.

Figure 6 compares the trace in Figure 5 with a trace obtained by Woodward when operating a twin device at approximately the same power level and frequency. Although the thrust magnitude is different, in both graphs a distinctive pattern can be identified, characterized by the presence of transitory effects occurring at the start and at the end of the operating time. Three phases can be recognized: (1) a starting transient constituted by a peak going in a direction opposite to the following steady thrust, (2) a steady thrust period of about 5 seconds, (3) at switch-off, a peak going in the same direction of the thrust. Figure 7 depicts an interpretation of the structure of the signal, where noise, drift and part of the overshooting are removed for sake of clarity.

Figure 8 shows a series of three runs in a row of the device after this has been rotated by 180° (direction reversal), as indicated in Fig. 3. Figure 8 serves also to point out the good repeatability of the thrust signal.

The fact that we have this distinctive common thrust pattern, which keeps its overall shape consistently across different devices of the same sort and different testing setups[**?**], and reverses with 180° rotation of the device, without changing in magnitude, is a strong indication that the effect is originating from the device itself and not from an interaction of the device with the close surroundings, nor from some interaction between different parts of the setup. In addition, if this signature is characteristic of the device, it may offer important clues on its actual operation, and could be compared with the results of models which try to characterize Mach effects in this kind of devices, like the one presented by J. Rodal in these workshop proceedings.

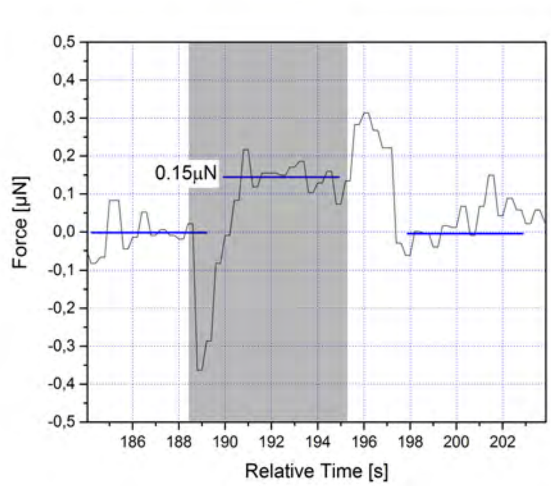

FIG. 5: Typical thrust plot. The area in gray indicates the time when the device is operating

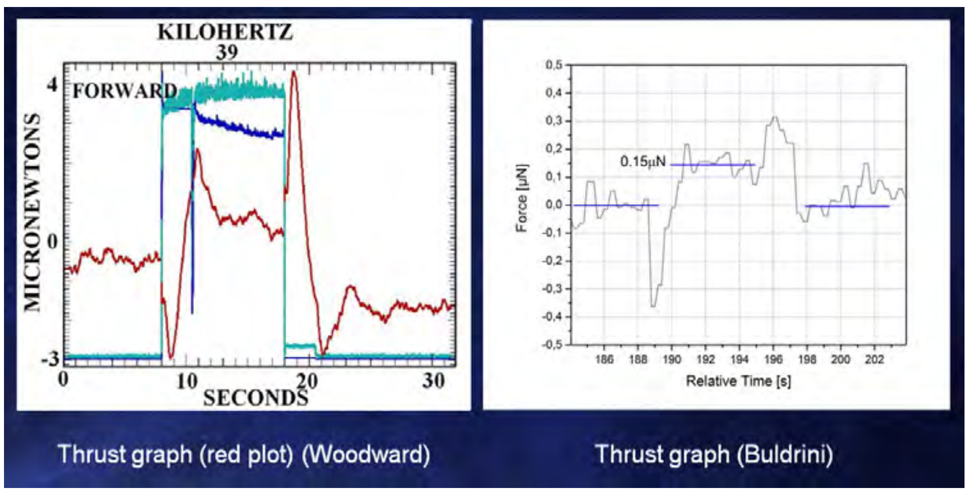

FIG. 6: Comparison with a typical MET thrust signature obtained by Woodward

Figure 9 makes a comparison of the plot in Figure 5 with a thrust plot obtained from the same device operated by Woodward at similar power level and frequency. It is interesting to note here that, while the transients are clearly visible and larger when compared with the measurement obtained at FOTEC, the steady thrust is difficult if not impossible to discern, due to what it seems a combination of noise, drift and zero-line offset.

In general, the different magnitude of the steady thrust value across otherwise similar and similarly operated devices could be ascribed to a sum of factors, these being, for example, degradation of device components (piezo stacks are sensitive to moisture), slight constructional differences between tested devices, different effective power delivered to the device and balance calibration issues. An additional factor, which would explain the mismatch in the magnitude of the transients, can be a different moment of inertia of the balances. Lighter balance beams, in fact, would react faster, showing larger transient peaks.

4. CONCLUSIONS

While previous replication efforts by the author on a different type of Mach effects device (Mach Lorenz Thruster) have produced inconclusive results [4], the kind of signal produced by the MET device here reported corroborates the results obtained by Woodward.

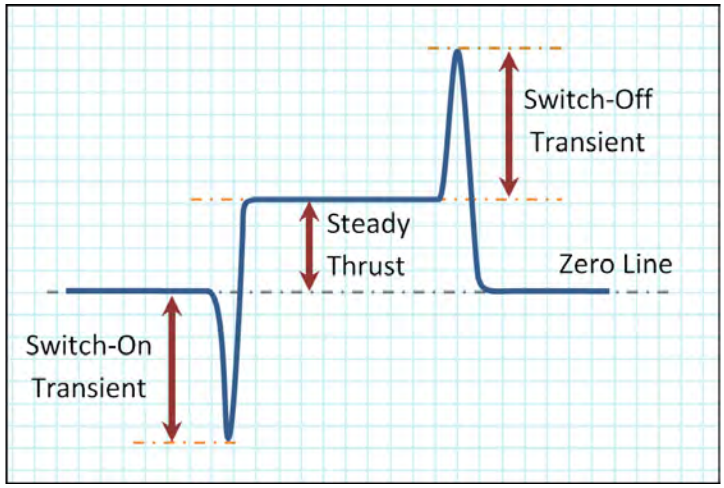

FIG. 7: Structure of the detected thrust signal.

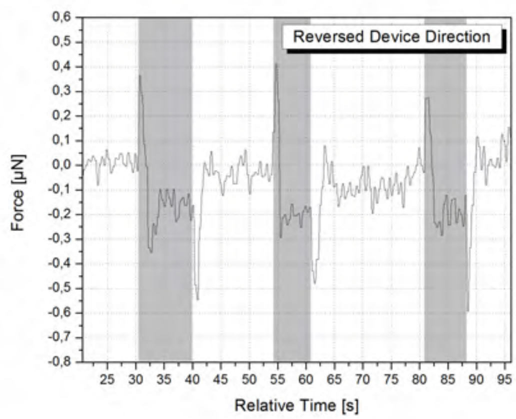

FIG. 8: Thrust plots with the device positioned in reversed direction.

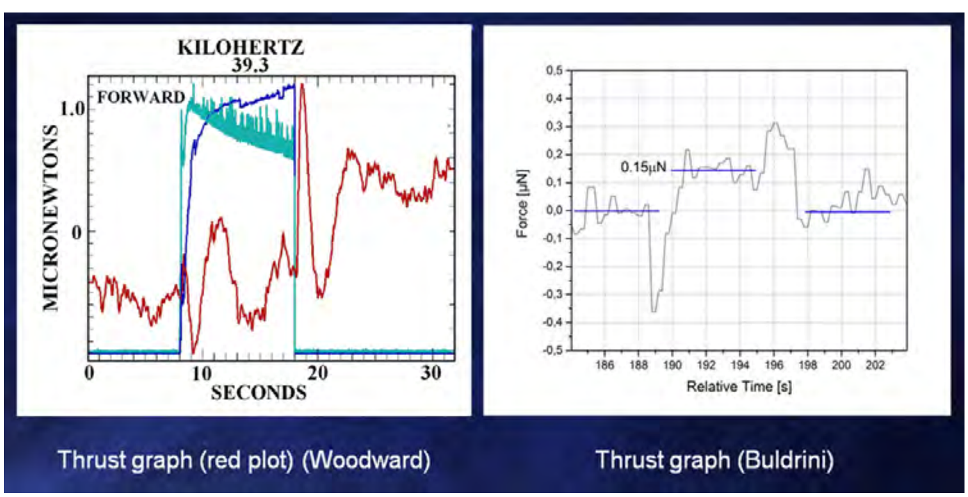

FIG. 9: Comparison of the thrust signature obtained from the same device by Woodward (left) and the author (right).

The distinctive shape of the thrust signal and its reversal with the rotation of the device allow to assert with high confidence that the effect is taking place inside the device itself, and it is not due to some sort of interaction between different parts of the experimental setup. Taking into account the small magnitude of the effect recorded to date, the possibility that other not yet considered complex (yet mundane) effects may be in play originating the signal seen cannot be totally excluded. However, the results obtained until now, together with several null tests performed (for example [5]), permit to reduce a lot the number of possible false positives and allow to focus on the device itself and its operation.

Considering the implications that the reality of Mach effects would have in many theoretical fields, for example in cosmology, and the immense benefits that propellantless propulsion would bring to space flight, further and extensive testing and characterization of this sort of devices is highly recommended.

5. ACKNOWLEDGEMENTS

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