The Design and Testing of Fluidic Oscillators made in LTCC

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The interest in using fluidic devices as replacements for electronic logic circuit devices has seen renewed interest as NASA looks for ways to operate in harsh interplanetary environments. The size, multi-layer capabilities and ability to incorporate fluidic channels in a ceramic substrate make Low Temperature Co-Fired Ceramics (LTCC) a viable platform for development of these fluidic devices. Fluidic oscillators and fluidic diodes are being developed at BSU in LTCC. Fluidic oscillators can be used for measuring flow rates, fluid viscosity as well as a replacement for electronic oscillators. Fluidic diodes can be used as check-valves or as replacements for electronic diodes. In this work, we will describe the development and testing of a fluidic oscillator in LTCC.

Introduction

Fluidic oscillators use the Coanda effect [1] to oscillate. The Coanda effect is the tendency of fluids to stick to a surface that is close. In a fluidic oscillator the internal geometry forces the fluid to go one way and then flip back to the other. This can be visualized with the help of Figure 1. The fluid enters the channel at A and goes through a nozzle (B in Figure 1), after the nozzle it attaches on one side. As it goes down the channel it comes across an entering to loop back. The loops are shown in Figure 1 as C and D. Parts of the fluid will loop back and bump the fluid to the other side, were it will repeat the same thing. The result of this constant flipping is that the fluid will oscillate back and forth.

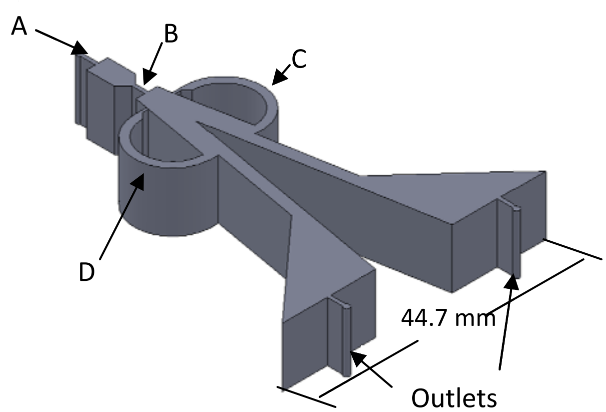

Figure 1: The first cannel design (channel thickness not to scale)

The oscillation of the fluid depends on the mass flow rate as well as the split angle [2]. This is the angle after the nozzle, between the opposite surfaces to which the surfaces stick. The purpose of these experiments is to find a relationship between the mass flow rate, the split angle and the frequency.

Design and Production

The standard C-MEMS fabrication process was used to produce the parts, which is based on DuPont's literature [3, 4]. To cut the layers a high power density laser was used. The design was adapted from the work of Rigerio Furlan and his group. [5] They constructed fluidic oscillators in acryl. However the layered building process of LTCC created a problem by making "islands". "Islands" are describing pieces of LTCC that have no connection to the main body of its layer. The islands can be seen in Figure 1, were there are two holes surrounded by the channel of the loops C and D. The adaption of the design was changed in a way that there would be no "islands". In Figure 2 you can see the tunnel in a lower level that enable the flow of the fluid without creating islands in the design.

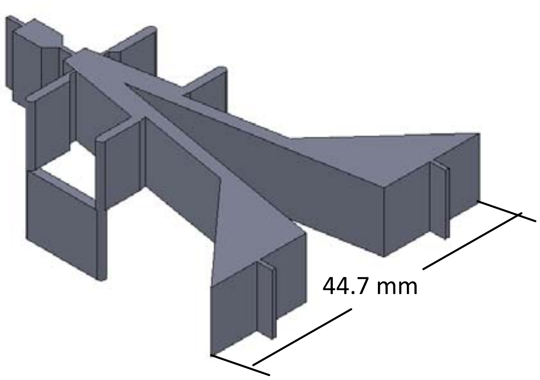

Figure 2: The new channel design, with tunnels in a lower level (channel thickness not to scale)

To prevent the channels walls from caving in during the pressing process, a carbon tape was inserted in them. This was important because it enabled the walls of the LTCC to maintain their geometry. Without it, the first devices were flat, with barely any channel. During the firing step the carbon tape burns away at 600°C leaving the device through the LTCC.

To visualize the flow through the device a window is part of the design. Two options are used. The first uses a sapphire lens that is embedded into the device in the second layer below the top. This deforms the top layer slightly, but ensures a tight seal. The other option uses clear acryl boards. Using an epoxy the acryl and the LTCC can be glued together. This is faster than the first form of a window but comes off sometimes.

Testing

Initially a hand held syringe was used to test the devices. However it turned out that the flow rate is very specific to the internal geometry of the design. Due to the inconsistent pressure applied in a hand held syringe, the device oscillated only seldom and only momentarily. A more consistent pressure can be applied using a syringe pump. With a syringe pump, the pressure is applied consistently to the fluid. The pump that was selected is a Syringe Pump NE-1010, by New Era Pump Systems, Inc. Due to delay in the shipping of the pump, no test has been made at this time. Once the pump has arrived, the following tests will be made.

One of the main points that will be tested is the effect of the split angle. The results would be graphed on a mass rate verses frequency graph. Several different angles could be graphed on the same graph, which would maybe show a pattern on how the angles effect the frequency at a given mass flow rate. The frequency will be found by measuring the outlet flows, with two pressure transducers.

Acknowledgment

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