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"ColdBreaker" Ceramic Hot End for DIY 3D Printers

Summary: A ceramic thermal barrier hotend has been created based on thermal barrier principle, with cold end conduction heat loss at about 30% that of comparable metal barrel design. In addition to its DIYer oriented design that can be easily assembled with off the shelf components, this "ColdBreaker" hotend also demonstrated that future lightweight, compact, high temperature hotend can be achieved with customized ceramic parts.

Backgrounds

Creating an effective thermal breaker has always been the focus of hot end design. To achieve so, there are two different approaches.

1. Create a thermal barrier with low thermal conductivity material, as with the original PEEK thermal barrier J hot end design. However PEEK is a poor material of choice for mechanical structural support at high temperature, which post limits on hotend's working temperature.

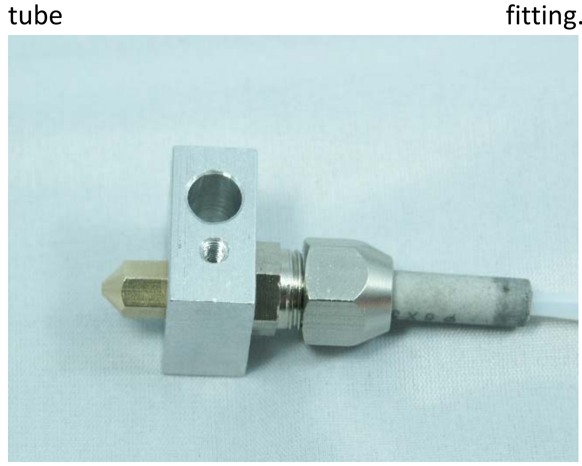
2. As an alternative a thermal breaker can be created with enhanced filament feeding barrel cooling. E3D hotend took this approach to the extreme by employing a large heat sink and active fan cooling.

The thermal breaker design gained popularity mostly due its robustness, metal parts availability and simplicity in machining, however in such design a large amount of heat is dissipated through the heatsink, not only it reduces heating efficiency and put stress on the heating element/RAMPS board FET, in effect it raises thermal mass of the hotend which impedes hot end temperature response. Weight and size added by heatsink and fan also post mechanical limit on maximum extruding speed.

There has always been ideas on hotend design with glass and ceramic, owing to their excellent thermal property and outstanding high temperature mechanical performance. However, due to difficulty in sourcing and machining/assembly, these design never became practical in the past.

"ColdBreaker" hotend

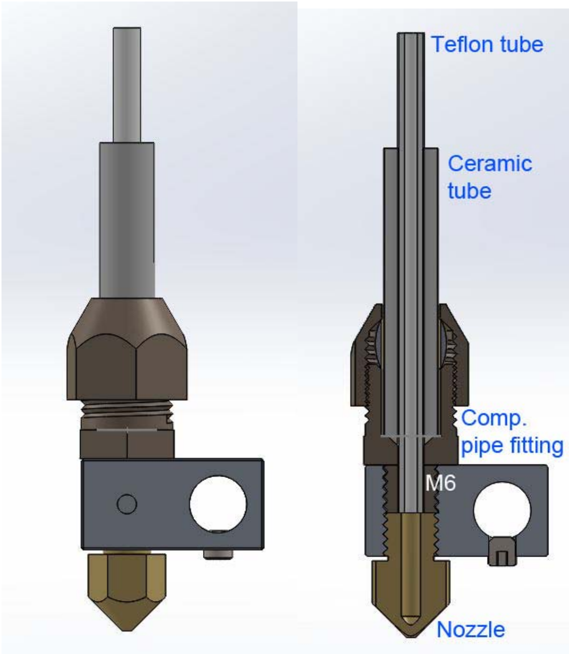
This holdend design create an effective thermal barrier with ceramic tube from commonly available 6mmX30mm ceramic tube fuse, that is secured with general 6mm or ¼" compression tube fitting.



https://www.youtube.com/watch?v=PeMEPQdnoeE

Video showing the assembly and a working "ColdBreaker" hotend printing 0.5mm thin wall box with ABS.

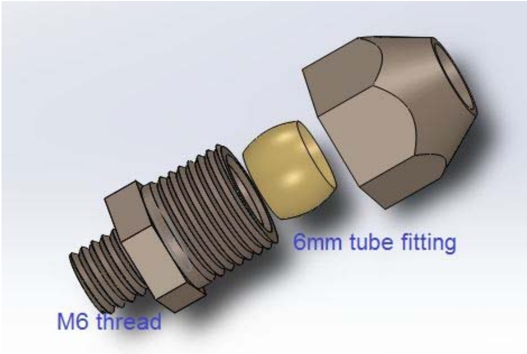
Hotend cross section view is shown as in the picture below.



Bill of Material

1. 6mmX30mm ceramic tube fuse. Ceramic tube fuse generally use ceramics with low thermal conductivity. The ceramic tube I sourced is of 5.7mm OD, 2.85mm ID. Less than $2 for 20Pcs as available on Ebay, such as: http://www.ebay.com/itm/271550337155.

2. 6mm or ¼" compression tube fitting. Ideally with M6 thread mate, or use 6mm ¼" to 1/8 NPT/BSP fittings, with a flow diameter about 0.188" or less (This is important as it is about the minor diameter of M6 tap so a M6 stud can be attached to the tube fitting).



McMaster parts: 50915K314, $1.78, 6mm metric fitting is a better fit for the 5.7mm OD ceramic tube however it will cost $9 a pc. The parts I initially sourced is ¼" fitting with M5 threads.

3. Stock extruding nozzle, heater block and Teflon tube lining at 3mm OD, 2mm ID. M6 stainless hotend barrel as needed for modifying the compression tube fitting.

Total BOM cost should be less than $10.

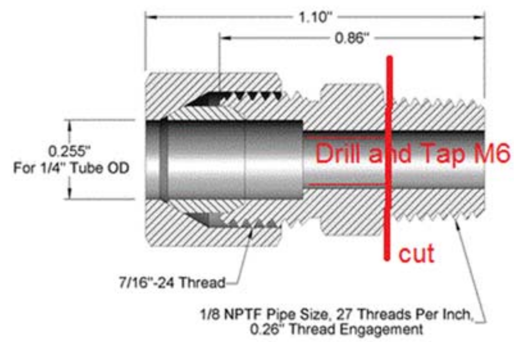
Assembly Instructions

Step by step:

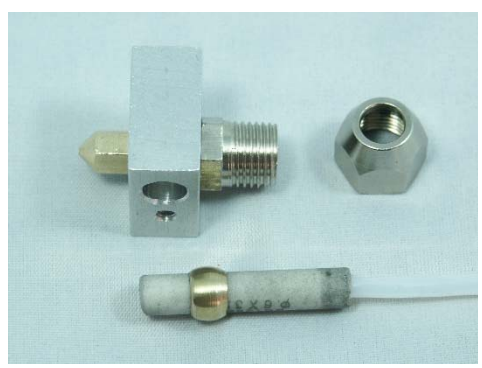
1. Take off the metal cap end on 6X30 ceramic fuse, simply grab and pull, or cut with a flush wire cutter if available.
2. Create a 0.1mm necked region on ceramic tube where the compression ring will be engaged, as shown in photo as marked with RED line. This can be done with drill and sand paper.

This is an essential step that made this design possible, as to mitigate the loose fitting problem once the hot end heats up. Metal tube fitting's thermal expansion rate is about 0.5% higher than that of ceramic at 250°C, such that the compression ring will lost grip once the hotend heats up. The 2% necked region created in this step ensures that the compression ring will be secured to the ceramic tube at desired working temperature.

3. Modify the compression tube fitting to M6 fitting, this can be done as illustrated with the McMaster part 50915K314.
    - Cut off the 1/8" tube fitting end
    - Drill and tap M6 thread.



    - Cut a stud piece from a stock M6 hotend barrel and affix this stud to tube fitting's M6 tap.

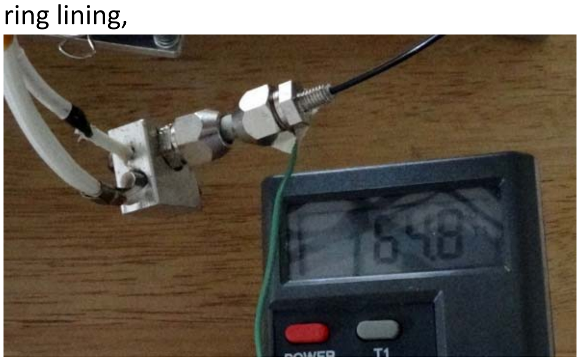


4. Assemble ceramic tube and compression tube fitting. The brass compression ring comes along with the tube fitting is too stiff in this application so obtaining a tight

compressing fit against the ceramic tube can be challenging. A softer copper compression ring will be ideal in this case. To fully secure the ceramic tube with brass compression ring:

- Tighten the compression fitting nut until ceramic tube is no longer loose. Rotate the ceramic tube when tightening to ensure that the brass ring is not jammed.
- Tightening more until the ceramic tube cracks, in this step the brass compression ring is pre-compressed and you also get a feel on the torque requirement. Ceramic tube is expendable as they only cost about 10 cents each.
- Replace ceramic tube with the pre-compressed brass ring and tighten the compression fit until ceramic tube is no longer loose, give the nut about 1/8 more turn for compression.

5. Following the assembly procedure as animated in the youtube video, affix extruder nozzle and Teflon tube lining. Teflon tube comes with 3mm OD so it will be a tight fit for the 2.8mm ID fuse ceramic tube, fortunately Teflon is highly stretchable so elongating the Teflon tube by roughly 10% will yield a 2.8mm OD size tube with 1.8mm ID, a perfect fit for 1.75mm filament.
6. This ceramic hotend can be mounted to extruder with clamping, sets screw on metal ring lining,



or another compression fitting on the cold end, as shown in photo in this particular measurement setup.

Results & Performance

Cold end temperature as measured with a K thermocouple is 64.8°C, with hotend temperature at 245°C, 28°C ambient, cold end is unmounted and cooled by natural convection only.

Heater PWM duty cycle in my set up at idle state is about 23/127, compare to M6 metal stainless tube at 45/127. Hotend temperature 245°C, 28°C ambient, 40Watts heater cartridge. This is in agreement with initial design estimation, 3 Watts of heat conducted to the cold end with ceramic tube, compare to 10 watts conduction as with a stock M6 stainless barrel. Natural convection cooling and thermal conduction on copper wiring account for rest of the thermal dissipation at 4 watts.

Alternative & Future Development

As shown in photo, the lower part is created by drill and tap the heater block with pipe fitting threads so the heater block can act as the compression nut, which further reduces the size and weight of the assembly, however in this case aluminum heater block material is not suitable for compression nut application and initial trail is plagued with oozing, also partially due to poor drill and tap tolerance.

Other alternative including wrapping heating wire around the compression fitting body, with which the heater blocker can be eliminated and result in a very lightweight and compact design, however this adds complexity for DIYers, unless suitable ring heater can be directly sourced.

This particular design is created for 1.75mm extruding filament however 3mm filament design achieved based on the sample principle, with larger ceramic fuse tubes.

There are also ongoing efforts in Induction heating, a super high temperature hotend can be created with ferromagnetic extruding nozzle material.

Collaboration is welcome at industrial & academic level, especially in the area of common extruding material rheology behavior, as is essential for CFD simulation.