Improved and more gentle atomic method to clean the nozzle of a 3D-printer

Introduction:

The "**atomic method**", sometimes also named "**atomic pull**" or "**cold pull**", is a well known method to clean the inside of the nozzle of a 3D-printer. It is done by manually inserting a piece of filament into the hot nozzle, extruding some plastic, and then let it cool down until solid again (usually about 80°C for PLA). Then by pulling it out hard, accumulated dirt is dislodged and removed from the nozzle. Although this method works very well to clean the inside of the nozzle, it has a risk of causing damage to the printer due to pulling quite hard.

I could not find the original references, but if I remember well, the name "atomic method" was derived from the user "MostlyAtomicBob" who is said to have introduced this method in the 3D-printing community. So, credits go to him for inventing this, or at least for making it widely known.

Here we present an **improved atomic method** that gives equal cleaning results, but with far less risks of causing damage, by being much more gentle. The method is optimised for the Ultimaker2 printers, but I believe the general idea should work on other FDM/FFF 3D-printers too.

This method is only applicable to FDM/FFF 3D-printers (= Fused Deposition Modeling / Fused Filament Fabrication, thus printers that work similar to how a glue gun works, by melting thick wires of plastic into very thin sausages and then applying them to the model).

Safety warnings and Disclaimer:

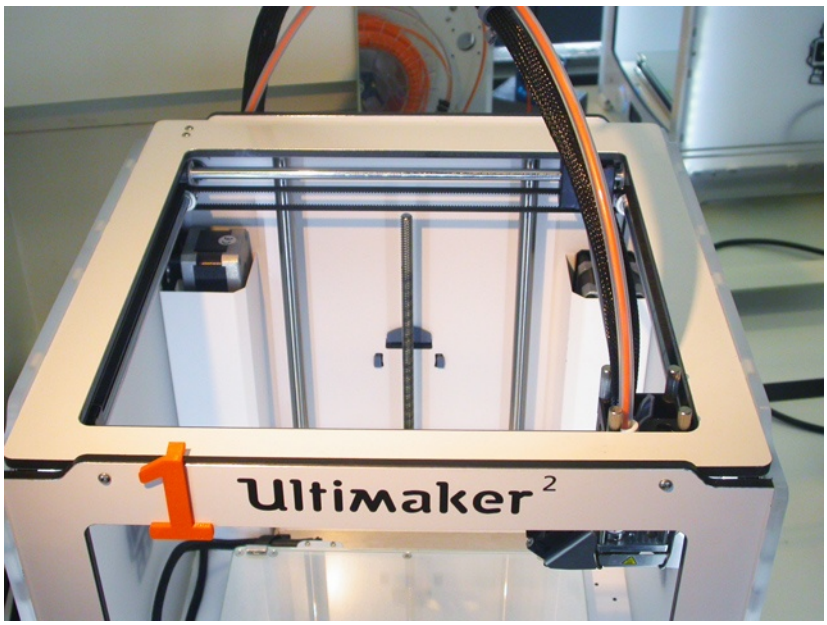
This method works very well on our Ultimaker2 printers. So I hope it will work well for other people too. But I can not guarantee it. You will have to evaluate this method for yourself, using good judgement and common sense. Also keep in mind that a hot 3D-printer nozzle can easily reach 260°C, which would cause immediate very severe burns upon skin contact. I can not be held responsible for your results, or the lack thereof, nor for any damage or injury you might cause while trying this method. It is up to each user to correctly evaluate this method for his situation and to take proper safety measures. This method should not be used by people with reduced mental or physical abilities, or who are not sufficiently familiar with this sort of complex equipment and its risks.

Usage and Distribution License:

Procedure:

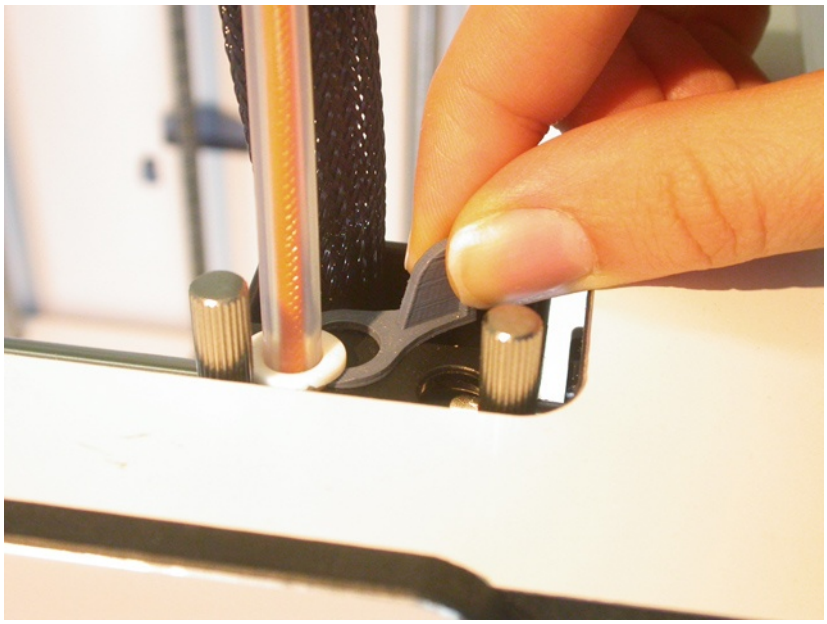
The detailed procedure for this improved atomic method goes as follows:

• Move the print head to a front corner of your choice in the printer. This will reduce the risk of damaging and bending the rods during the atomic method.



Move the print head to the left or right front corner of the 3D-printer.

• Remove the small horseshoe clip from the bowden tube clamp; it is situated on top of the print head. This usually is a small red or blue horseshoe shaped clip.



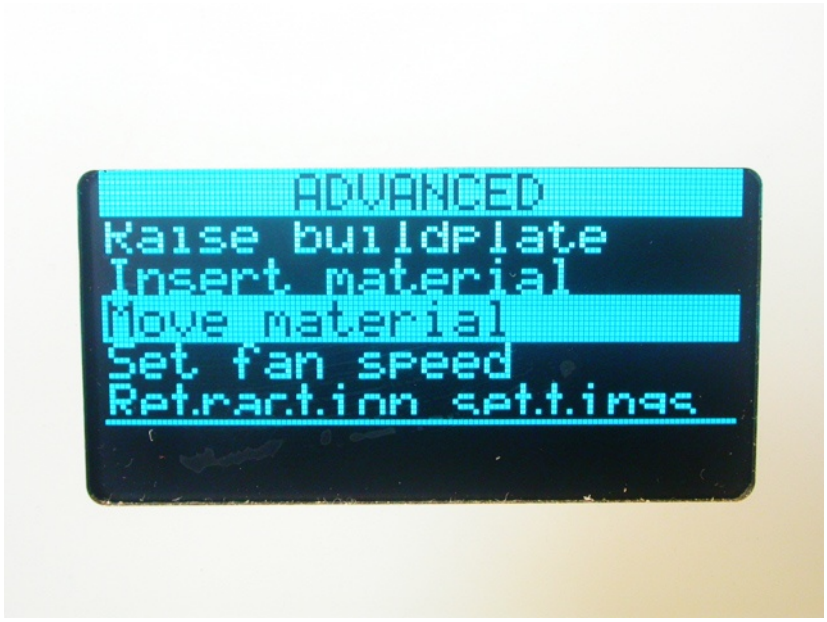
Removing the horseshoe clip. Note that I am using a custom design here, instead of the standard small clips. This one is much easier to handle, as you see. The clip has the same inner diameter and height as the standard version, so the fit should be identical.

• Next, push the white ring around the bowden tube down with one finger, and gently pull the bowden tube out. Normally this should go well without need to heat up the nozzle, since at the end of each print, the Ultimaker2 does a fairly big retraction that breaks the link between the fresh filament and the molten material in the nozzle. But if necessary, you can always heat up the nozzle.

Press down the white ring and gently pull out the bowden tube. Heating the nozzle is usually not required.

• The bowden tube is now separated from the print head, with the filament still in it. There is no need to remove the filament from the tube. We will only cut off the heat-deformed tip.

• In the Advanced Maintenance menu, select "Move material" and move the filament forward a little bit, until about 1cm sticks out of the bowden tube.



Move the filament out a little bit, until 1cm sticks out of the bowden tube.

• With a sharp wire cutter, as used in electronics, cut off the irregular molten end of filament sticking out of the bowden tube. Preferably cut it off under an angle of 45°. This will make it easier to insert the filament in the nozzle again later on.

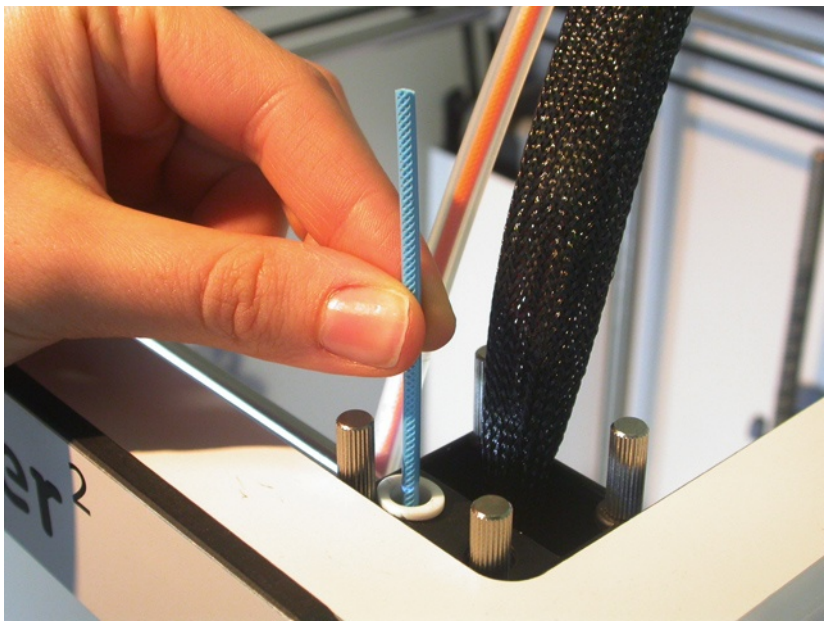
Cut off the deformed filament tip in an angle of 45°. Then you can leave it hanging there.

• Now that the bowden tube is removed and the nozzle is accessible from above, we can **start the actual atomic pull**.

• **Heatup the nozzle to ca. 210°C for PLA.** For other materials the optimal temperature will be different.

Heat the nozzle to 210°C for PLA. For other materials, read the datasheets or experiment until you find the best temperature.

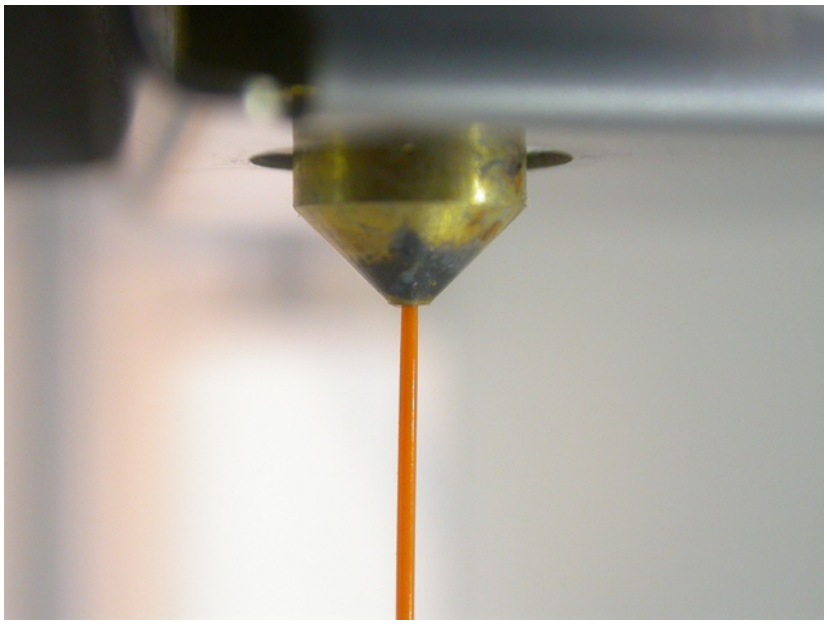
• Take a superfluous piece of filament, length 20cm or more, straighten it, and gently push it into the nozzle from above.



Insert a piece of filament into the nozzle and gently push it down to extrude some material.

• Gently keep pushing until the material is extruding well from the nozzle, in a nice thick stream without debris. As soon as you get a nice even flow you can stop pushing. It makes no sense to waste a lot of filament.

In case the nozzle would be totally blocked, of course you will not be able to extrude anything. Try pushing gently, but do not exagerate, so that you do not cause any damage. Whether you can extrude filament or not, or how well, will already give you a good indication if the nozzle is dirty or blocked.

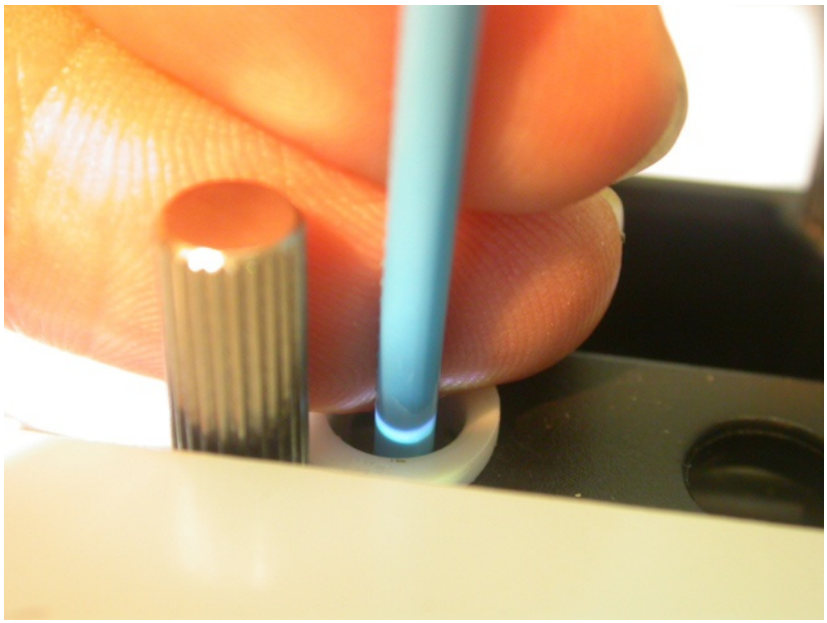


A nice even stream without debris. (Note that this photo is from a different atomic pull, with orange filament instead of the blue one from some other photos.)

• Quickly dial down the temperature to 0°C, or at least to below room temperature. Gently keep extruding filament for a few more seconds, until the nozzle temperature reaches 190 à 200°C. Then stop pushing.

Dial down nozzle temperature to below room temperature. And do a "manual retraction" of the filament.

• When you stop extruding, **immediately do a small manual retraction: pull the filament up a few millimeters, and hold it there with your fingers**. About 3 to 4mm should be okay. The goal is to reduce the sideways pressure of molten material in the teflon insulator, so that the filament can be pulled out easier once cooled down. On a brand new teflon insulator this is not really necessary. But on a worn-out and deformed teflon insulator this will make the difference between being able to do a good atomic pull, or not at all, or even causing damage! This is a key factor of this method.



After the "manual retraction", keep the filament in this retracted position until it is solid again.

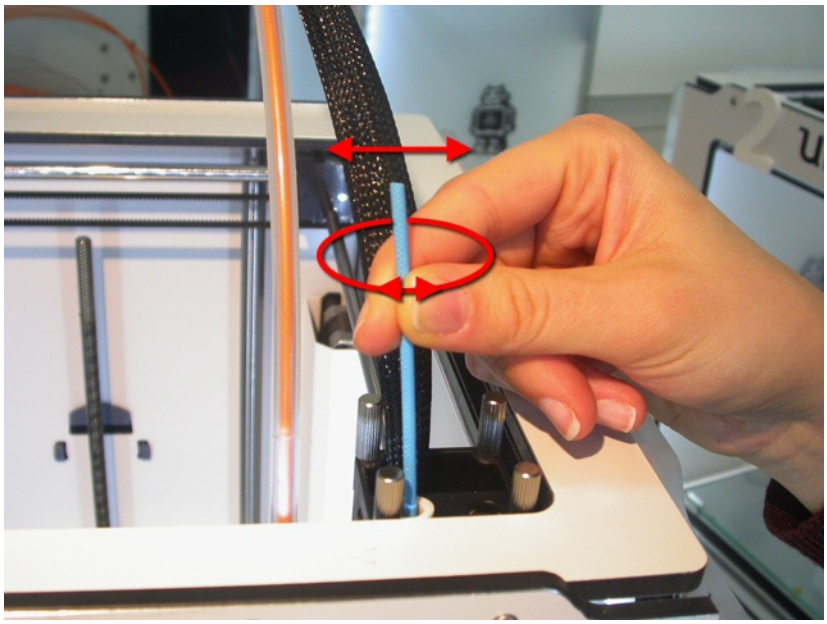
• **Keep the filament "retracted", so don't move, and wait until the molten material in the nozzle is solidified enough at about 80°C (for PLA). Then you can take your fingers away, and let it cool down further to room temperature**. Letting it cool down to room temperature also solidifies the inner core of the filament: this will avoid stretching the filament during the atomic pull, and it removes more accumulated dirt due to the deeper temperature cycling.

• If you have compressed air available (from a compressor, not from a spray can), you can greatly speed up cooling by gently blowing air onto the nozzle. **Beware: never use spray cans with "compressed air"**: they may contain compressed explosive gasses instead of air, and you may cause a huge fire when blowing onto a hot nozzle! And you would waste way too much cans anyway. If you have no compressor, you just need to wait a bit longer. Or use the "compressor" in your lungs to blow air onto the nozzle... :-)

• **Leave the nozzle at room temperature for a few minutes.** The inner core of the filament inside the teflon insulator takes much longer to cool down than in the brass nozzle, since it is well insulated by the teflon. I usually let it sit at room temp for about 10 min, while doing something else.

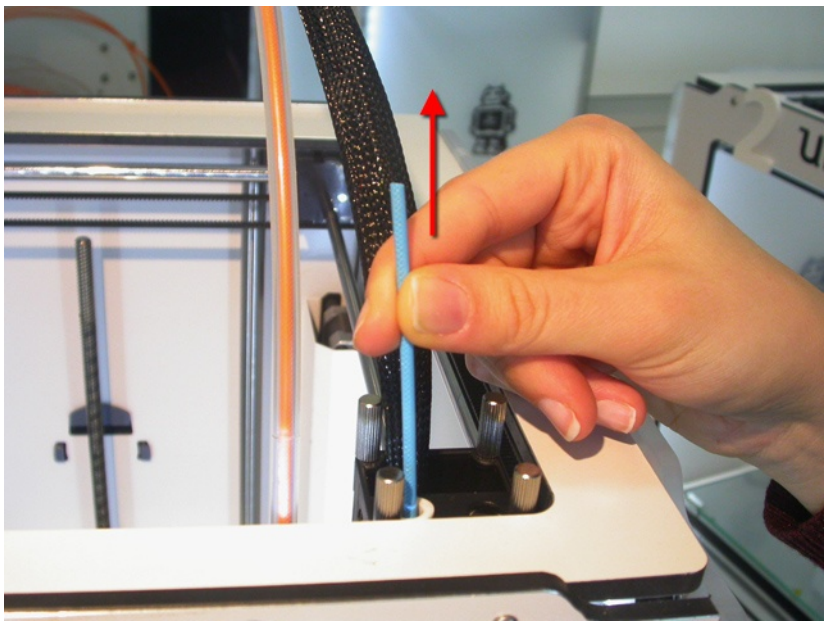
• **Then dial up the temperature again to 80°C for PLA.** The optimum temperature may depend on the brand of filament, and may be different for other materials. For me, 80°C seems to work well on ColorFabb PLA/PHA- and Ultimaker PLA-filament.

• **While the nozzle is warming up, gently try to rotate the filament, and wiggle it.** But gently!!! This will help loosen the filament from the nozzle, and will help peeling off accumulated dirt. Especially the rotating motion is beneficial: since the nozzle's inner opening is produced by drilling (or equivalent), it has circular scratches on the inside. When you rotate the filament, this moves the accumulated dirt in the direction of the least resistance: it slides easier sideways in the grooves than upwards. An another advantage of rotating is that this does not execute upwards forces on the print head, so it does not dislocate the nozzle or teflon coupler, and it creates less risk of bending the rods.



While the nozzle is warming up again, gently (try to) rotate the filament, and wiggle it. Especially rotating helps to peel off accumulated dirt from the nozzle. Be gentle, don't use brute force.

• **As soon as you feel that the filament is coming loose when rotating and wiggling, gently pull it out.** Always gently!!! This method works by feeling, not by brute force. Very often, it starts coming out around 60°C indicated on the LCD panel.



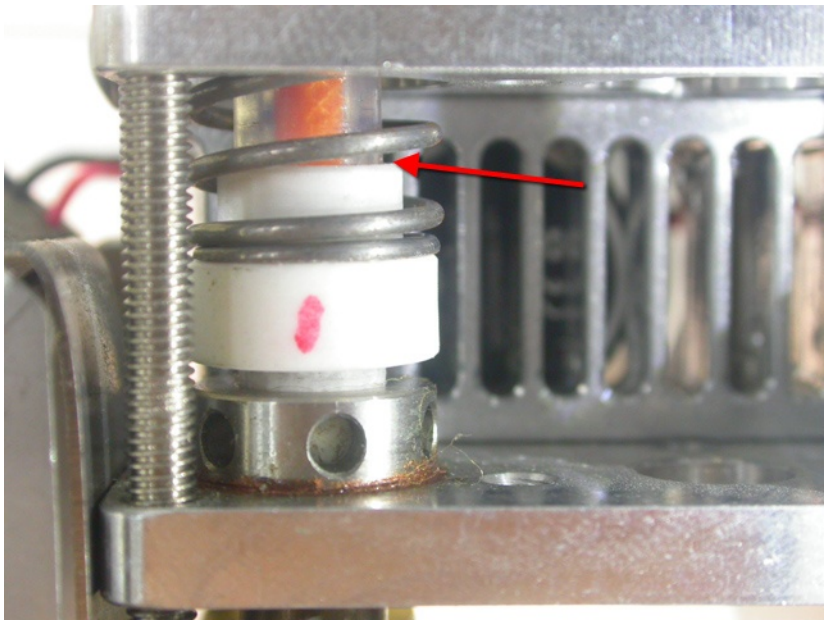
Once you feel the filament is becoming loose, gently pull it out. Almost no force should be required. If done well, the filament will not be stretched out, since its inner core is still cold and solid. Only the outer edge is warmed up and softened yet.

• Check if the filament that is pulled out is clean. Sometimes one atomic pull will be sufficient, if you do it regularly. But sometimes it may take a few attempts before you get one that is free of burnt residu.

A dirty blue filament, and an almost clean orange one. The orange was still too warm when I started reheating and rotating it, so it got twisted. I should have left it cooling a bit longer.

Results of a couple of atomic pulls. Some from dirty, and some from clean nozzles. Some when swapping filament colors. The stretched-out ones were pulled out when still too hot. The ones with big blobs or lips where the teflon coupler meets the brass nozzle, are done without manual retraction on a worn out and deformed teflon coupler (that was before I developed this method).

• As soon as the nozzle is clean, replace the bowden tube, and make sure it is seated well on the teflon insulator.



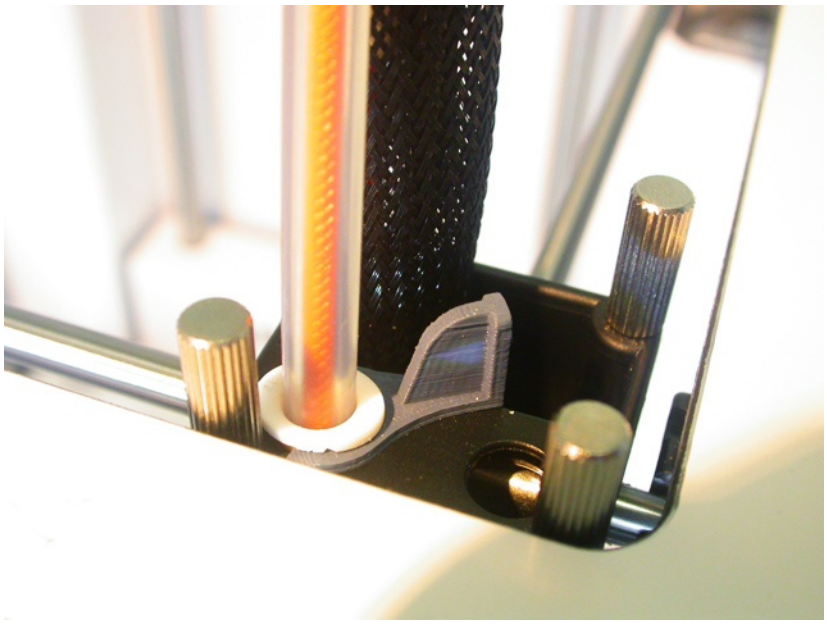
The bowden tube must be correctly seated in the white teflon coupler.

• Then while pushing down the bowden tube with one hand, lift the little white ring around the tube by putting your finger nail under it, and replace the small horseshoe clip to lock the bowden tube in place.

• And that is it. Now you can start the next print. It is a lot more complex to describe this procedure, than to do it. It just takes a bit of time due to the warming up and cooling down cycles.

Remarks:

• Note that in my photos I am using a custom designed horseshoe clip, instead of the standard horseshoe clip. This custom model is much easier to handle than the standard clip, with far less risk of accidentally dropping it in the printer. You can find these design- and STL-files on my personal webpages at: "www.uantwerpen.be/geert-keteleer". Surf to the section on 3D-printing manuals. I designed this clip from scratch, and publish it under a CC BY-SA license, so anyone can use it for free, also for commercial purposes. You may also make derivations and share them, as long as you do it under the same license. You are not allowed to limit the free use of this design.



Custom designed horseshoe clip for easier handling. You can print this yourself. Find the STL-file on my webpage at: "www.uantwerpen.be/geert-keteleer". Licensed under a Creative Commons CC BY-SA license.

• It is a good idea to print a skirt of 2 or 3 lines around any objects to print. This will help purging the nozzle at the start of the print; it shows if the nozzle is clean indeed; it gives you time to adjust the build plate if necessary; and it makes it less critical how far you inserted the filament after an earlier atomic pull.

• Always pull gently during these atomic pulls; never use brute force: this may bend the rods in the printer. Remember, even if the rods are only bent 0.1mm, which is almost nothing, this will cause a deviation in the height or left/right position of the print head of 0.1mm too, equal to the usual layer height of 0.1mm.

• If you pull too hard, you may also dislocate the brass nozzle and its inox coupler (the ring with six holes) from their seating in the aluminium plates. Or you may pull up the teflon coupler, if its inside is worn out and deformed too much, and then filament may get stuck between the nozzle and the teflon coupler, making things worse instead of better.

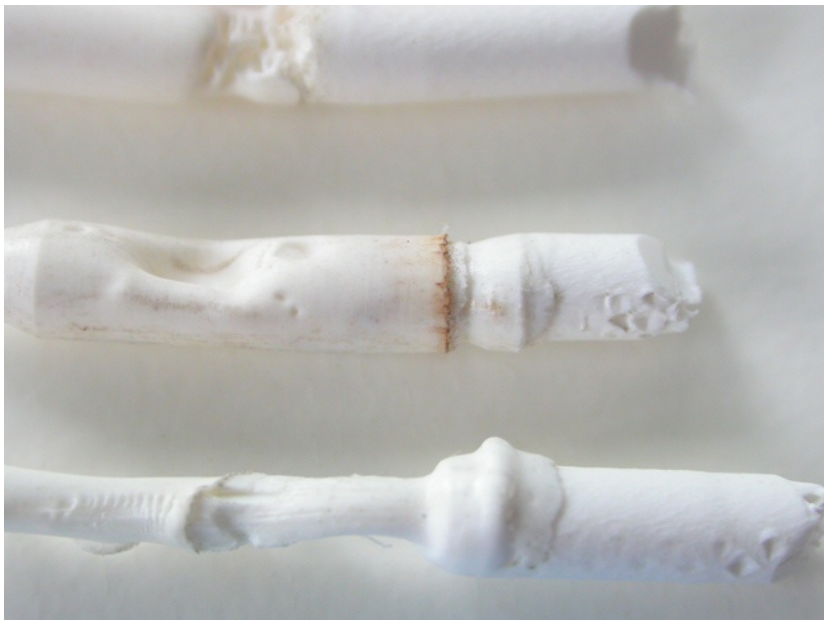
• If you can't get the filament out by pulling gently, then increase temperature a bit.

• The cooling down to room temperature has two advantages: it peels off more accumulated dirt due to the deeper temperature cycle and the different shrinking characteristics of metal and plastic. And it makes sure that the inner core of filament is still solid when reheating the nozzle and doing the atomic pull. Only the outside of the filament is molten, so it releases easier from the nozzle, without stretching. In a regular atomic pull it is the opposite: the core is still molten, but the outside is solid, causing the outside to get stuck and the filament to stretch if you pull hard, with risk of damage.

• If you still can't pull out the filament gently at higher temperatures, increase temperature to normal printing temperature again, thus about 210°C for PLA, extrude a bit more material, and then do a **bigger manual retraction** when the nozzle is cooling down again, so that more pressure is taken off the nozzle and teflon piece, and no blob of material is formed at the bottom in the teflon insulator.

• **Especially on worn out teflon insulators, doing a "manual retraction" and gentle handling is important.** At the underside in the teflon piece, some deformation and widening may have occured. Without manual retraction you may get a thick blob of filament that gets stuck and can't be pulled out. When using brute

force, you are likely to cause damage, or at least dislocate the nozzle and teflon coupler from their seating.

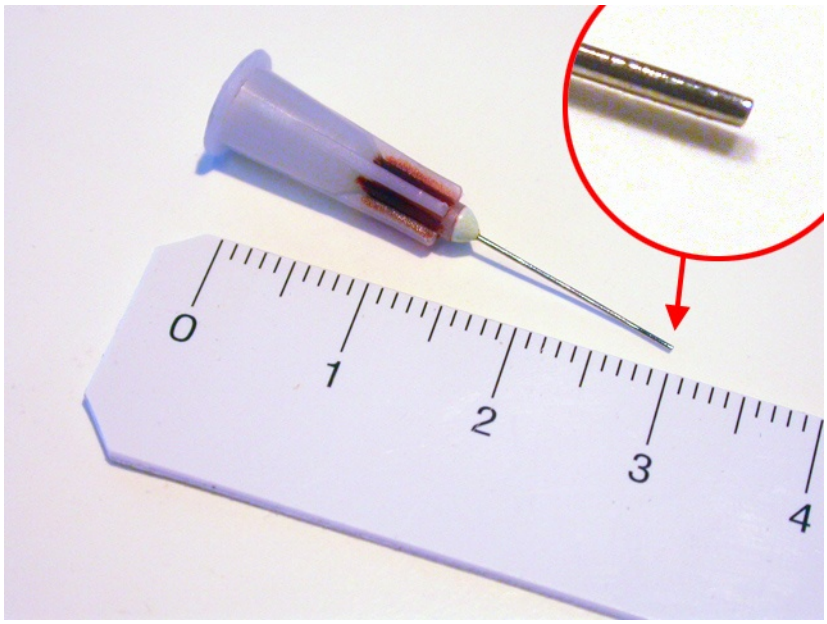


An atomic pull from a dirty nozzle in the middle. On the bottom sample, no manual retraction was done, and the teflon coupler was already quite worn out, causing a big blob of material to get stuck in there. This sample was very hard to pull out, and it dislocated the nozzle and teflon coupler from its seating between the aluminium cooling plates. This happened even though the filament was rather hot, as indicated by the stretching further down to the tip. Hence my search for a more gentle approach with "manual retraction", cooling down to room temperature, rotating and wiggling, and gently pulling, to avoid causing damage.

• To remove any burnt residu in the nozzle opening, while the nozzle is empty after the first atomic pull, you could try poking into it from below with a **very fine medical injection needle**.

Before using the needle, **cut off the sharp tip** first, as this razor blade sharp steel point may damage the nozzle opening. Use a Dremel-style drill with ceramic or nylon cutter disk to gently cut the needle. Don't use electric wire-cutters/pliers: this would damage both the wire-cutter (which is designed for cutting copper wire, not steel), and the injection needle (it would get flattened), and then consequently this damaged needle tip would also damage the printer nozzle when you force it in. Next, round off the tip of the needle with fine sanding paper, so it has no more sharp edges: steel is harder than brass, and you do not want the steel needle to damage the brass nozzle. If the needle tip is a little bit too wide, sand the whole needle down a few microns. (Mine was 0.41mm wide, so I had to sand it down to 0.39mm before I could push it through the nozzle without damaging it.)

Then gently poke from the bottom through the nozzle opening with this needle. This is a good way to remove bigger pieces of debris inside the nozzle. Sometimes, it may help to heat the nozzle to around 100°C. Next, do a gentle atomic pull as described above, to remove all loose debris from the inside of the nozzle.



Fine injection needle used to poke into the nozzle opening from below. Its sharp tip was cut off with a rotating ceramic cutter disk and then rounded on fine sand paper to avoid damaging the nozzle.

• You can remove some more burnt residu from the inside of the nozzle and teflon coupler by gently scraping the inside with a brass M3 screw thread. Take a long thread of ca. 20cm, and round off one end, so that it has no more sharp corners, and so that you do not damage the inside of the nozzle when poking into it. It needs to be a brass thread. Do not use a steel or inox one: they are way too hard and can easily damage the nozzle or teflon coupler inside. A nylon tread would be too soft. Gently lower the thread into the nozzle and feel if there is any resistance (there shouldn't be any, since an M3 screw is around 2.9mm, while the nozzle opening should be 3.2mm). Then very gently (!) scrape the walls of the nozzle and the teflon coupler. After scraping the inside, do a few more atomic pulls to remove the loose dust from the nozzle. I found that this helps to prolong the life of the teflon coupler a bit (but it doesn't do miracles).

Brass M3 Thread used to gently scrape the inside of the nozzle and teflon coupler. It is about 2.9mm wide and should fit well into the nozzle, without any resistance.

• If the filament is totally stretched out when doing the atomic pull, temperature was too high. Next time, let it cool down a bit longer.

• I do an atomic pull every time when changing colors. And also about once a week to prevent built-up of burnt residu.

• Some filaments seem to work better for an atomic pull than others, even within one brand. For example, colorFabb's pure PLA/PHA ("Natural", uncolored, with a translucent ivory color) appears to be more sticky and to pull out more dirt, than its higher filled Standard White. Ultimaker's Pearl works even better. Other people report good results with nylon, but I have no personal experience with that.

• Obviously, this method may not work with materials that are too brittle, or too weak. Use a strong or tough filament only.

• To switch filament spools and colors, I never use the "Material wizard" of the Ultimaker2. I just remove the bowden tube from the print head, as at the beginning of this atomic pull. Then I cut off the deformed tip of filament, and then I manually pull the filament out of the bowden tube via the back of the printer. Then I manually insert the new filament in the feeder, and move it forward using the "Move material" function, until it is flush with the front end of the bowden tube. And then I do an atomic pull to clean the nozzle of the old color and of any burnt residu. Finally I insert the bowden tube again in the nozzle, attach the clip, and I am ready to go.

This method of changing colors avoids the risk of pulling a string of molten filament into the feeder mechanism, and blocking it, requiring disassembly of the feeder. Further, it also removes all traces of the old color from the nozzle in one shot. So I do not have to waste a lot of new filament to purge the nozzle. Especially when switching from an intense or dark color to white, it is astonishing how long it takes before the extruded sausages are pure white.

Doing an atomic pull when changing filament colors, removes all traces of the old color in one shot, and it cleans the nozzle also.

Summary:

The "atomic method" is a well known way to clean the inside of the nozzle of 3D-printers, by manually inserting a piece of filament into the hot nozzle, extruding a bit, letting it cool down until solid again, and then pulling it out, together with any accumulated dirt.

What is new in this improved version is:

• To do a "manual retraction" when cooling down the filament, to avoid the formation of thick blobs in the teflon piece, which are hard to pull out. This is especially important on worn out teflon couplers.

• To let the nozzle cool down much deeper, to room temperature, and only then heating it up again. So that the inner core of the filament is solid, and only the outside gets soft. This avoids stretching the filament, and it makes removing it much easier.

• To rotate and wiggle the filament while it is warming up, to dislodge more dirt, and to get a good feeling of when to pull out the filament.

• Also the much gentler handling is very different from the standard atomic method, which recommends pulling hard. This gentle approach greatly reduces the risk of damage to the nozzle, to the teflon insulator, or to the rods. This method does not use brute force, but gentle feeling.

Feedback:

If you would like to give feedback, you can reach me at: "**geert . keteleer @ uantwerpen . be**" (remove all spaces). Please give your e-mails an appropriate and descriptive subject title, and avoid attachments other than JPG-pictures, so that they don't get eaten up by our spam filters and anti-virus.

Suitable languages are Dutch and English. I can read German too, but can not write it well enough.

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