



Trainers for Visually Impaired Students Introduce 3D Printing

Tutorial Module 4 Autonomous Utilisation of FDM Printers

Tutorial for the T4VIS-In3D trainer course

Published by the
T4VIS-In3D project consortium



The project “T4VIS-In3D” was co-financed by the “ERASMUS+” Programme of the European Commission

The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

This Tutorial is published by the T4VIS-IN3D project consortium.

Licensing

Trainers for Visually Impaired Students Introduce 3D Printing is licensed under [Attribution-ShareAlike 4.0 International \(CC BY-SA 4.0\)](#)



Printed:

August 2021 by Berufsförderungswerk Düren gGmbH

The T4VIS-In3D Project Consortium:

Berufsförderungswerk Düren gGmbH (Project co-ordination)

Karl-Arnold-Str. 132-134, D52349 Düren, Germany, <http://www.bfw-dueren.de>

Fundacion Aspaym Castilla Y Leon

C/ Severo Ochoa 33, Las Piedras 000, 47130, Simancas Valladolid, Spain, <https://www.aspaymcyl.org/>

Hilfsgemeinschaft der Blinden und Sehschwachen Österreichs

Jägerstrasse 36, 1200 Wien, Austria, <https://www.hilfsgemeinschaft.at/>

Instituttet for Blinde og Svagsynede, IBOS

Rymarksvej 1, 2900 Hellerup, Denmark, <https://www.ibos.dk>

Istituto Regionale Rittmeyer per i ciechi di Trieste

Viale Miramare 119, 34136 Trieste, Italy, <http://www.istitutorittmeyer.it/>

NRCB

24 Landos Str., Plovdiv, 4006, P. Box 11, Bulgaria, <http://www.rehcenter.org>

Content

Content.....	3
1 General.....	4
2 Starting up FDM printers	4
2.1 Turning on the machine and transferring print data	4
2.2 Print bed adjustment.....	6
2.3 Heating up the build plate, extruder and filament feeding.....	8
2.4 Start of the print.....	9
3 Removing the component from the build plate	10
4 Decommissioning FDM printers.....	13
4.1 Maintenance of the printer	13
5 Error in printing	14
5.1 Insufficient Build Plate Adhesion	14
5.2 Warping	17
5.3 Elephant foot	17
5.4 Over- and Under Extrusion	19
6 List of figures	21

1 General

The technical development of 3D printers is proceeding rapidly. The machines are increasingly more user-friendly and convenient. Setting and adjustment functions are increasingly handled by the devices themselves. The more expensive the printer, the greater the range of functions available.

For the operation of a 3D printer, the corresponding operating manuals provide detailed instructions and safety information. In addition, every manufacturer offers online user forums where problems related to the device can usually be solved more quickly than via a support hotline.

This tutorial will only describe the basic operation of FDM printers and the basics of a correct setup.

2 Commissioning FDM printers

The main steps in commissioning an FDM printer can be described as follows:

1. Switch on the device
2. Insert data carrier with GCode file into the device
3. Check print bed adjustment and readjust if necessary
4. Heat up the extruder to the printing temperature of the filament (see data sheet filament)
5. Heat up the print bed to the required temperature (see filament data sheet)
6. Place the filament roll in the filament holder
7. Insert filament into filament tube until approx. 5cm protrude
8. Insert the filament into the filament feeder on the extruder and load it by means of the menu until the colour of the filament comes out
9. Remove the leaked filament from the print bed and extruder nozzle using tweezers
10. Start printing

2.1 Turning on the machine and transferring print data

FDM printers have their own electronics, often based on Arduino single-board computers. These computers are used to control electronic components and can be expanded with additional boards. These include, for example, the LCD displays that control the printer. Depending on the level of expansion, most FDM printers have a USB-B and USB-A connection and possibly also an SD card slot. Increasingly, more expensive devices are also equipped with Ethernet and WiFi interfaces. The transfer of GCode files therefore varies from device to device.



Figure 1 USB and SD interface for data transfer

To avoid data loss or reading errors of the electronics, it is recommended to insert the data carrier before powering up the unit. Since the electronics are started after power-on, they automatically read the existing data carriers.

Due to the integrated electronics, the operating voltage in the units is 12 V DC.

Therefore, power supplies are used that are either external or integrated in the unit. To avoid overvoltage when powering up, replaceable fuses from automotive accessories are usually installed between the power supply and the electronics.



Figure 2 Fuse on the power supply unit (removed)

The printer is switched on via a power switch on the printer. After activating this switch, it can take up to five seconds for the display to light up. If this is not the case, the correct plug connection must be checked. If this does not produce a result, the previously mentioned fuse should be checked. If this fuse burns out frequently, the power supply unit must be replaced. Especially with low-cost printers, these are low-quality products and are therefore vulnerable to failure with frequent use. Since these power supplies also constantly consume standby power, it is recommended that a socket board with overvoltage protection be connected in front of them.

2.2 Print bed adjustment

Print bed adjustment means the correct setting of the distance between extruder nozzle and print bed top. This distance is usually between 0.3 and 0.5 mm for nozzle openings of 0.4 mm. However, the exact parameters can be found in the manual.

Exact nozzle spacing is extremely important for good adhesion of the filament to the print bed. If the distance is too wide, the filament does not adhere sufficiently and the component can detach from the print bed or show an unevenness on the bottom side.

If the distance is too narrow, the filament will not be applied with sufficient thickness. This can also lead to insufficient adhesion of the first layer, but also to a low thickness of the first layer. Subsequent layers sometimes show furrows because the filament is "rubbed away" by the hot nozzle.

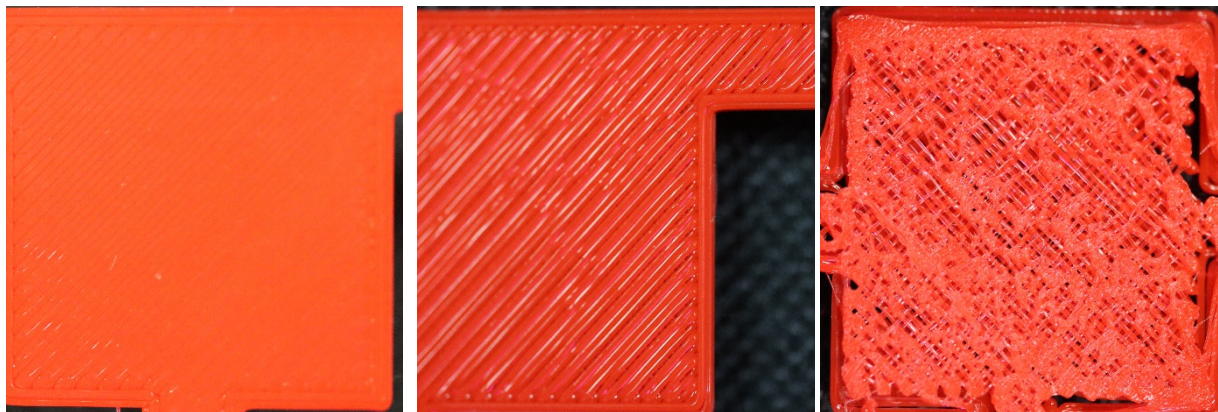


Figure 3 Levelling, from left to right: correct, too wide, too narrow distance

FDM printers are increasingly equipped with a levelling sensor that measures the correct distance by means of a sensor and adjusts the distance. However, this requires that the build plate is set flat over the entire print area and has the identical distance to the nozzle at every position. This is usually achieved by manually turning spring screws underneath the build plate. For this purpose, the nozzle must be moved to different X and Y positions of the build plate and checked on the Z0 position by means of a feeler gauge.

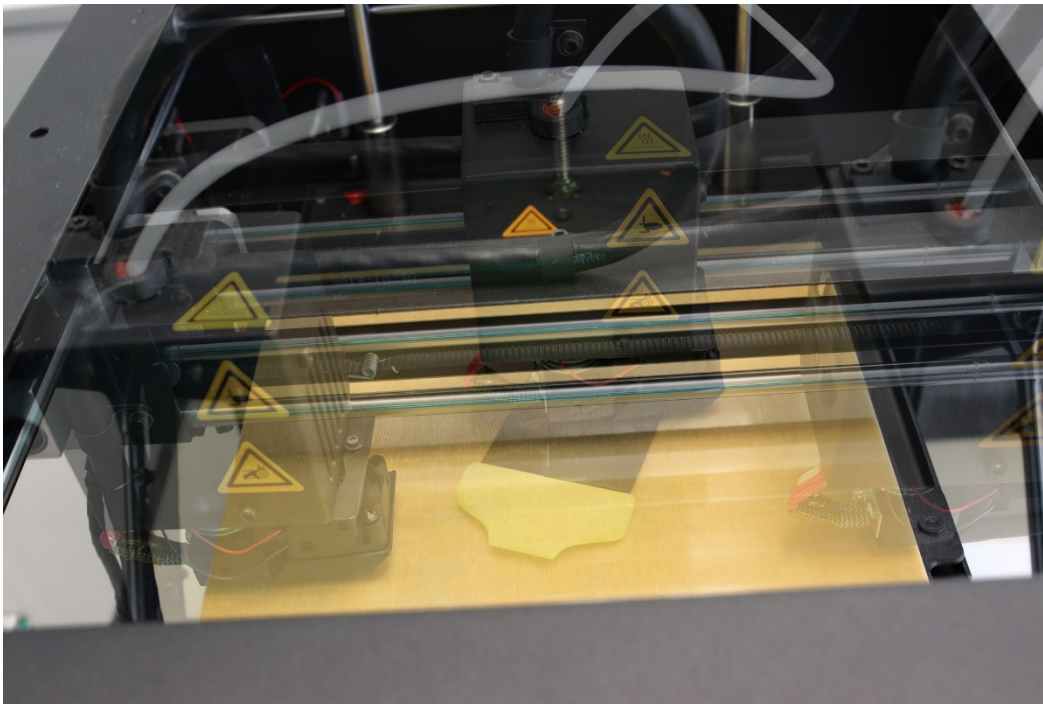
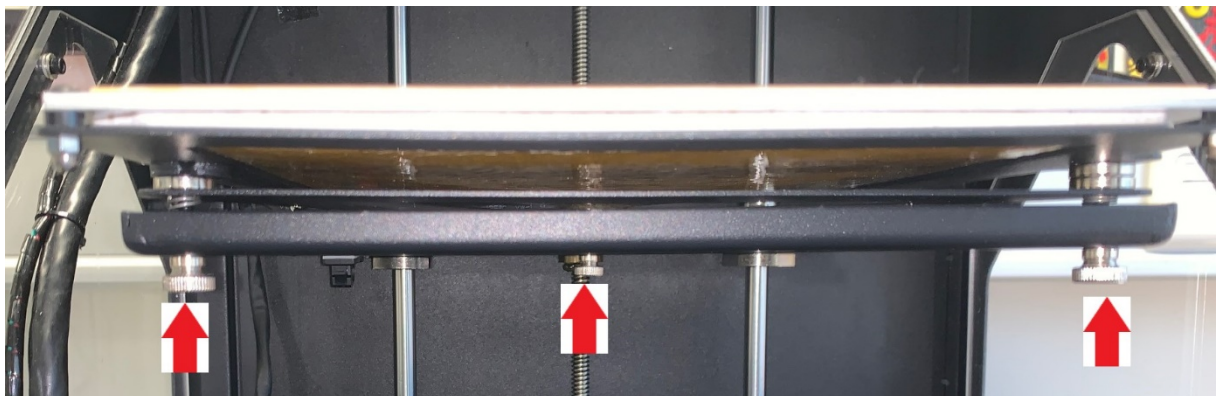


Figure 4 Checking the levelling of the build plate at several positions

If the distance is too large or too small, the build plate is raised or lowered by turning the spring screws at the respective position. The correct distance is reached when a slight resistance is felt when pushing the feeler gauge under the nozzle.



Once this adjustment has been made, the levelling sensors function reliably. Even without this component, one can start further prints without readjusting. After transport, change of the build plate or mechanical impact, it must be readjusted. Many FDM printers offer a menu for adjustment.

2.3 Heating up the build plate, extruder and filament feeding

Before the print starts, the desired filament must be attached to the filament holder of the printer. As filament is usually supplied on rolls, the holders are provided as a cylindrical device on the printer housing. Care must be taken to ensure that the filaments are drawn from the roll through the extruder stepper motor without resistance or knots. Especially with the 1.75mm diameter filaments, knots often occur in the winding. For long print jobs, it is therefore advisable to rewind the filament rolls manually beforehand.

Before printing can be started, the filament must be fed into the extruder. To do this, however, the nozzle must be preheated as filament residues from the previous print job have hardened in the print nozzle. The new filament can only be transported into the nozzle when the nozzle is heated, and the filament residues become viscous. In addition, the build plate must be preheated to the temperature intended for the filament. FDM printers without a heated build plate are only seldom sold, as only PLA can be processed with such printers.

Almost all manufacturers provide their own menu steps for this process, which more or less automate the procedure.

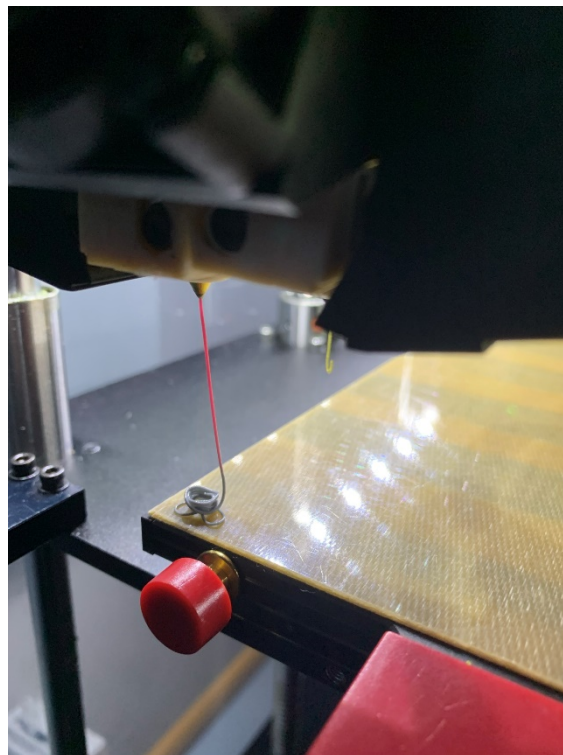


Figure 6 Feeding Filament

As soon as the new filament comes out of the nozzle, the loading process is to be stopped. The filament that has emerged should be removed from the nozzle with tweezers before starting the print job to ensure a clean print start.

2.4 Start of the print

Starting the printing process is a simple procedure. If the correct file is available on the storage medium, the print command is executed via the menu and the relevant print file is selected. The printer then enters the print mode. The print parameters are set and shown on the display. The level of detail of the display depends on the display size and varies from the display of the temperature of the components, the print time, the print progress to the graphic representation of the printed component.

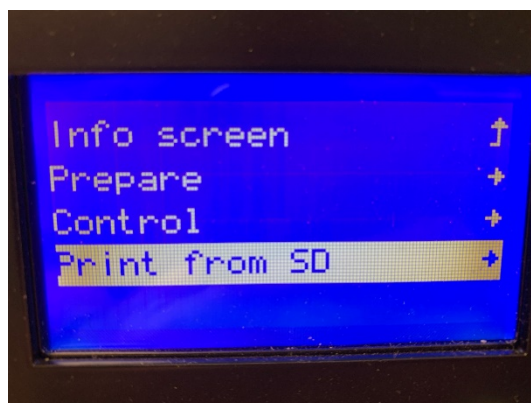
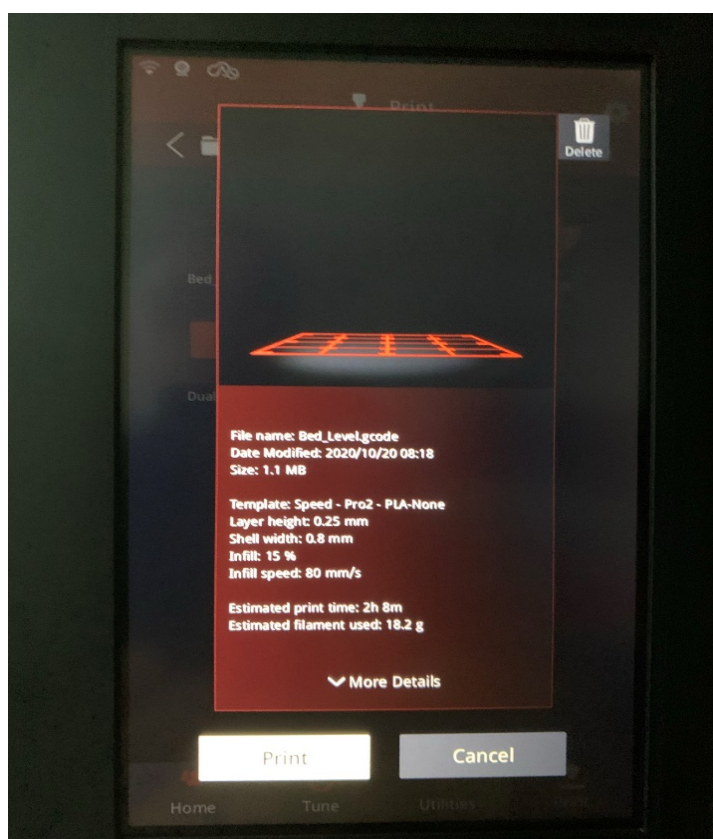


Figure 7 Different print menus

Before printing begins, any residual filament should be removed from the nozzle again. In any case, the adhesion of the first print layer should be monitored. If filament peeling from the build plate can be observed at the very beginning of the print run, the print run must be stopped. Then check the adjustment of the build plate and readjust if necessary, before starting the print again.

3 Removing the component from the build plate

Manufacturers usually equip their FDM printers with a build plate surface made of glass or metal. These are often mounted on a printing table by means of magnets or screws and can be removed for the removal of the printed component.

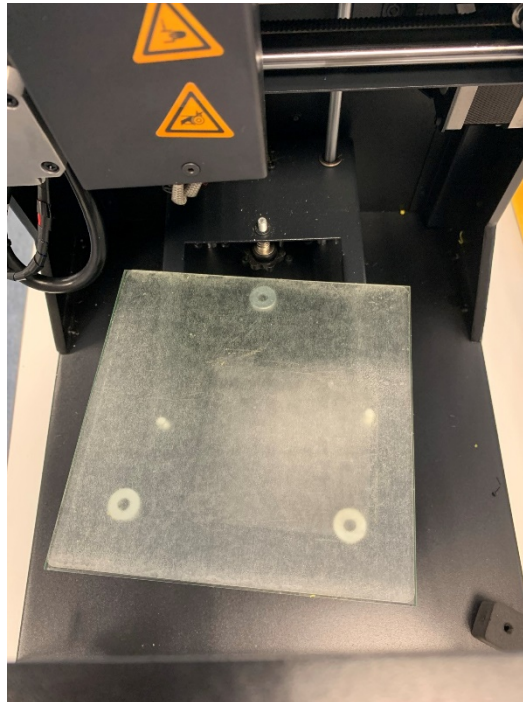


Figure 8 Removable build plate

Depending on the type of filament, components can adhere very strongly to the building board. It is often necessary to use aids to improve adhesion (see chapter 5.1 for more details). Manual removal of large components is therefore rarely possible without tools. A spatula is needed to remove the components. When using the spatula, make sure that neither the component nor the surface of the build plate is damaged. Often the component is damaged by the spatula in the first layers if it is not handled properly. If the spatula is applied too vertically to the build plate in order to get under the first layer of the component, the surface of the build plate can be damaged. Even micro-cracks in the surface of the build plate reduce the adhesion for subsequent prints.

To avoid this, you should carefully use the edges of the spatula to loosen smaller areas around the component. This reduces the adhesion effect and allows a larger contact area of the tool to be used between the component and the build plate.

It can be helpful to grind one side of the spatula like a knife blade. This makes it easier to get between the component and the building panel with a flat approach of the spatula.

To solve this problem, BuildTak has developed a special spatula with thin edges and curvatures and an ergonomic handle to allow an easier and damage-free removal of the components.



Figure 9 BuildTak and classic spatula

Since this procedure for removing the components is very inconvenient, some suppliers offer technical alternatives. These include above all:

1. Flexible build plates
2. Permanent build plates

Flexible build plates are mounted on the build plate supplied. They consist of a magnetic base plate and a flexible metal foil. This can be removed from the magnetic plate after printing. The component is then released from the foil by bending it.

Figure 10 Flexible build plate



Permanent build plates are made of plastic and are adhered to the original build plate by heat-resistant double-sided adhesive tape. The advantages of these permanent build plates are:

1. Smooth surface of the first layer;
2. Components separate automatically from the permanent build plate as soon as it has cooled down to room temperature;
3. Improved adhesion without the need for adhesives



Figure 11 Permanent build plate from MTPlus

4 Decommissioning FDM printers

The decommissioning of the FDM printer is carried out in the reverse order of the commissioning procedure. The filament should always be removed from the printer during long printing breaks of 8 hours or more. This prevents the filament from absorbing moisture. In addition, possible clogging of the filament inside the extruder is avoided.

1. Heat up the extruder as for commissioning
2. When the temperature is reached, transport the filament out of the extruder via the menu
3. Remove filament from the extruder
4. Clean filament from nozzle with tweezers
5. If necessary, set the extruder temperature to 0°C via the menu
6. Clean excess filament from nozzle with tweezers
7. Wait until extruder fan switches off
8. If necessary, oil the slide rails and grease the threaded spindle of the build plate.
9. Switch off the machine

4.1 Maintenance of the printer

The slide rails, slide bearings and threaded spindles should be cleaned, oiled or greased regularly. Printer manufacturers sometimes recommend certain lubricants in their manuals. If none are specified, the following recommendation applies:

1. Slide rails should be oiled with non-resinous oils such as sewing machine oil
2. Threaded spindles should be greased with PTFE greases such as "Magnalube"

The need for maintenance is easy to determine.

1. If there are dirty edges on the slide rails, clean them with a lint-free paper towel. Oiling is then done with an oil-soaked paper towel or cotton swab. Excessive oiling must be prevented. If oil drips onto the building board, this will prevent the filament from adhering.
2. If there are no dirt marks, run your finger over the slide rail after a long printing session. If they feel dry, oil them as described in point 1.
3. If dirty grease residues can be seen on the threaded spindles, the grease should be removed from the threaded spindle with a lint-free cloth. Then apply the PTFE grease in a very thin strip vertically onto the spindle. The application should be at least half the height of the spindle. Then move the build plate up and down manually using the menu.

5 Error in printing

Misprints cannot be ruled out. There are many possible causes for misprints. The most common errors are addressed in the following.

5.1 Insufficient Build Plate Adhesion

Lack of build plate adhesion can have several causes. These are:

1. Incorrect build plate adjustment
2. Wrong build plate temperature
3. Printing speed is too high
4. Overlaid filament
5. Low adhesion of the build plate

If the adhesion is too low, an area of the component will initially detach from the build plate. The detachment area progressively increases and the detached parts deform. Therefore, the process must be stopped if such detachment is detected.

In the worst case, the component detaches completely from the build plate and the extruder continues to feed filament.

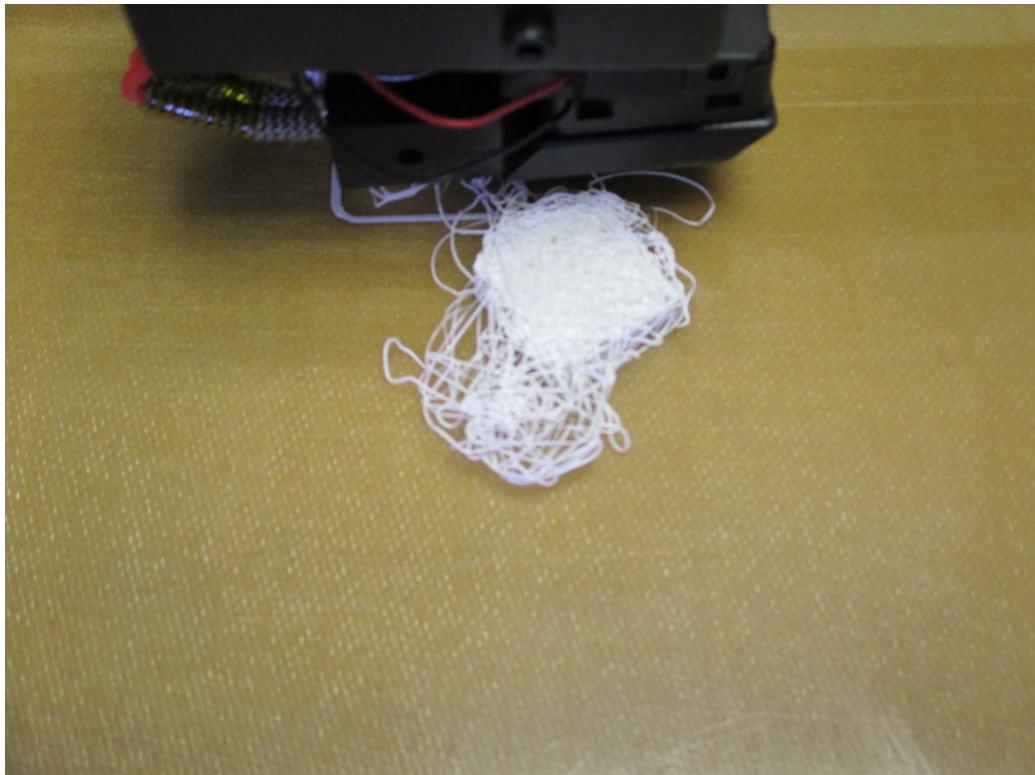


Figure 12 Detachment of the build plate

To solve the problem, the first thing to do is to check the build plate adjustment and, if necessary, to re-level it. Then, check the print parameters used, such as extruder and build plate temperature and print speed. This data can be taken from the filament data sheet enclosed. It may be necessary to recreate the GCode file with the parameters in

the slicer. If the component has a small surface area with which it contacts the build plate, a brim or raft should be added as a build plate adhesion in the slicer if necessary. This will increase the surface area of adhesion. The instructions for this are explained in more detail in Tutorial 3.

If the new print also fails to adhere to the build plate, either the surface finish of the build plate or the quality of the filament could be the cause.

If the filament has not been stored properly, it can absorb moisture. For this reason, quality filaments are also supplied in a vacuum bag with silica desiccant. After opening this packaging, the filament should again be stored in a dry place. Vacuum bags are recommended for this purpose, as they are available inexpensively for storing clothing. More expensive products for storing filaments are available from specialist retailers.



Figure 13 Storage containers: DryBox right, Vacuum bag left

There are various solutions for increasing the adhesion of glass and metal surfaces of build plates.

Hairspray is often used as a household remedy, which is mainly sprayed onto the glass plate to increase adhesion. However, there are more suitable adhesives for 3D printing that are either sprayed or applied as a glue stick. When spraying, it is important to ensure that this is done outside the 3D printer, otherwise the spray mist of the special adhesive or hairspray can contaminate the construction space and impair the function. Thus, this procedure is not applicable for fixed build plates that cannot be removed.

To further improve the adhesion as well as the additional surface protection, it is also possible to combine the adhesives with different adhesive tapes. Very often, the blue crepe tape from the company 3M, also called "Blue Tape", is used here. This is stuck to the glass or metal surface and the adhesive is applied to it.

Well-known adhesives for improving adhesion are, for example, the glue sticks Magigoo, UHU Magic Stick and the AprintaFix Spray.



Figure 14 Different 3D printing adhesives

For uncoated and shiny metal surfaces, the more expensive and heat-resistant Kapton tape is also used. This is much thinner than the aforementioned Blue Tape and can be recognised by its transparent brown colour.

When using the adhesive tapes, make sure that the adjustment of the build plate is made with them, otherwise the distance to the nozzle is too close.

Do not use any of the above adhesives on permanent build plates as they will damage the properties of the surface.

5.2 Warping

Warping is the deformation of the component on the bottom of the component.

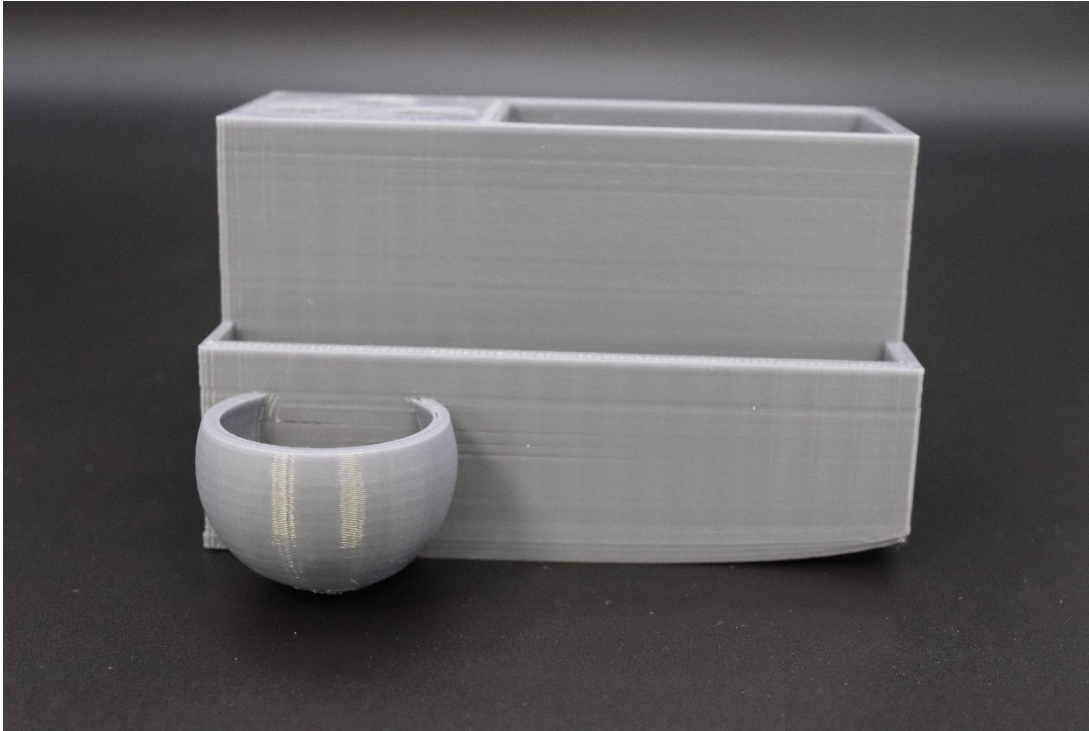


Figure 15 Warping effect

Warping is caused by unbalanced cooling processes in a component, which lead to different material tensions. This can be seen clearly in the example shown above. The right side of the component is open like a tub or shell. The left side, on the other hand, is closed and has an infill of 30%. The right side therefore cools faster and the material here shrinks quicker as it is cooling. Here, the area also detaches from the printing plate which intensifies the effect.

There are several possible solutions to avoid the warping effect:

1. Increase the temperature of the build plate
2. Improve the adhesion of the build plate with adhesives. In the case of permanent build plates, these should be degreased with alcohol.
3. If possible, reduce the infill density in case of uneven distribution.
4. Use an enclosure for the printer.

5.3 Elephant foot

Elephant foot is a curvature of the component on the bottom of the component. This occurs mainly with large parts when the weight of the part presses on the plate. If the lower layers have not cooled and hardened sufficiently, the effect can occur. When using PLA, which is perfectly adequate and suitable for tactile models, this error only occurs in a few cases. However, with materials that require higher extruders and plate temperatures, like ABS and PETG, this can certainly happen.

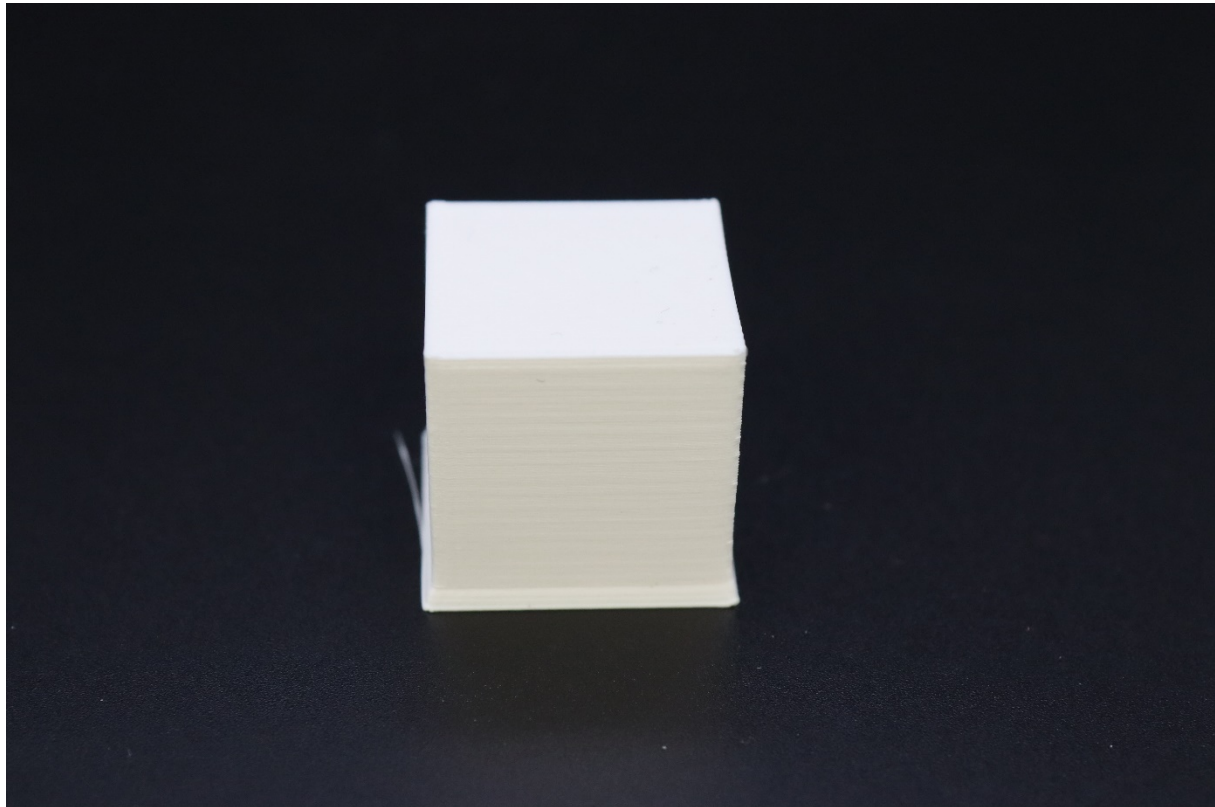


Figure 16 Elephant foot

To solve the problem, some settings can be made in the slicer.

1. Switch on the nozzle fan from the 1st print layer onwards.
2. Printing a raft as printing plate adhesion.
3. Lowering the plate temperature

5.4 Over and Under Extrusion

In case of over extrusion, too much material is fed out of the nozzle. The surface of the component is uneven and has excess layers of material.

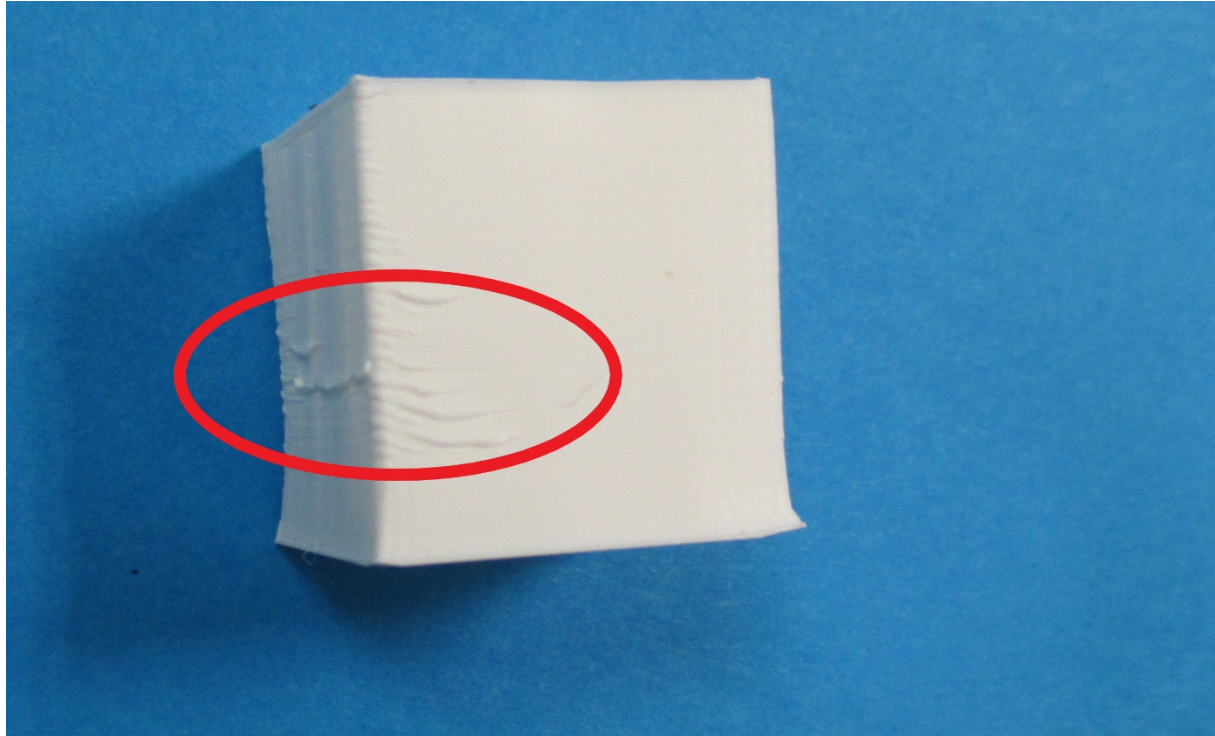


Figure 17 Over extrusion

Reasons for over extrusion can be the following:

1. The printing temperature is too high and the filament is too viscous as a result.
2. The flow rate in the slicer is set too high. Reduce in steps of 5% and test again.
3. The line width to be printed is set too high. Reduce by 0.1 mm and try again.

In case of under extrusion, the opposite is the cause. Too little filament is ejected permanently or partially. This results in gaps in the print and a lack of adhesion between the layers. The causes of under extrusion are more varied than in the previous case, but can usually be remedied. Reasons for this error can be:

1. There were knots on the filament spool, which made it difficult to feed the filament through the stepper motor.
2. The contact pressure of the gear wheel, which guides the filament into the extruder, is too low. Many FDM printers have a screw with which this contact pressure can be increased.

3. There are filament residues in the extruder or Bowden tube that block the transport. This residue must be removed.
4. The filament flow in the slicer is set too low.

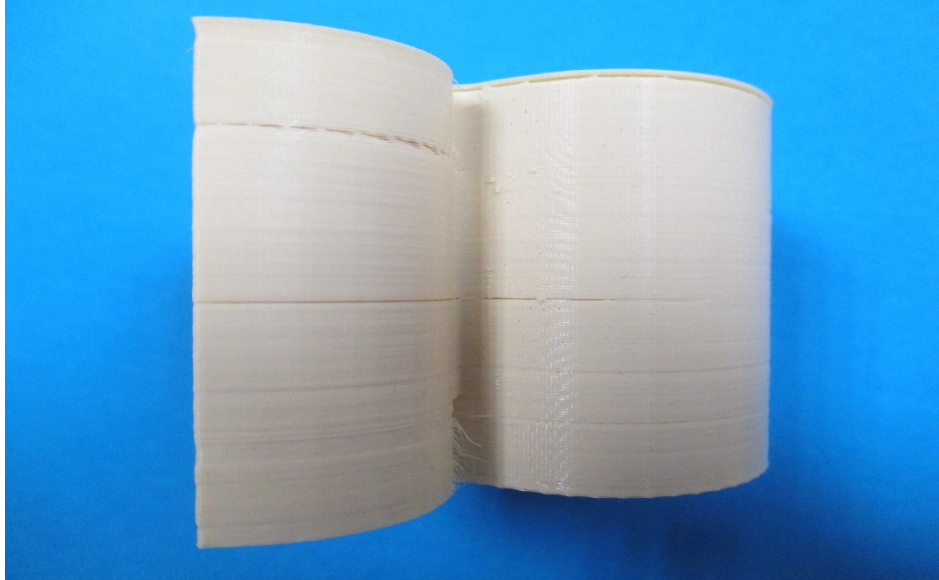


Figure 18 Gaps in print by under extrusion

6 List of figures

Figure 1 USB and SD interface for data transfer	5
Figure 2 Fuse on the power supply unit (removed)	5
Figure 3 Levelling, from left to right: correct, too wide, too narrow distance	6
Figure 4 Checking the levelling of the build plate at several positions	7
Figure 5 Example of levelling screws	7
Figure 6 Feeding Filament	8
Figure 7 Different print menus	9
Figure 8 Removable build plate	10
Figure 9 BuildTak and classic spatula	11
Figure 10 Flexible build plate	11
Figure 11 Permanent build plate from MTPPlus	12
Figure 12 Detachment of the build plate	14
Figure 13 Storage containers: DryBox right, Vacuum bag left	15
Figure 14 Different 3D printing adhesives	16
Figure 15 Warping effect	17
Figure 16 Elephant foot	18
Figure 17 Over extrusion	19
Figure 18 Gaps in print by under extrusion	20