Functional description of respiratory mask (as of 04/09/2020)
https://www.vogelsang.info/int/printing-against-corona/

This document describes the structure and use of a respiratory mask that is manufactured using a 3D printing process.
Use of the mask does not replace the general measures and instructions for reducing the spread of infections. The mask is not certified medical protective clothing! The selection of suitable filter materials and the use of the mask is done expressly at your own risk!

Figure 1: Perspective view of the mask

First, the structure and function of the individual parts are introduced below. Then, production using a suitable 3D printing process is discussed. Afterwards, instructions are given on how to adjust the mask to different face shapes.

Individual parts

The mask consists of two 3D-printed components and small household parts. All individual parts are shown in Figure 2 with the following meaning:

1. 3D printed body or frame
2. 3D-printed clamping ring for attaching a filter material
3. Filter material
4. Fastening strap (here using three rubber bands)
5. Thin film for check valve

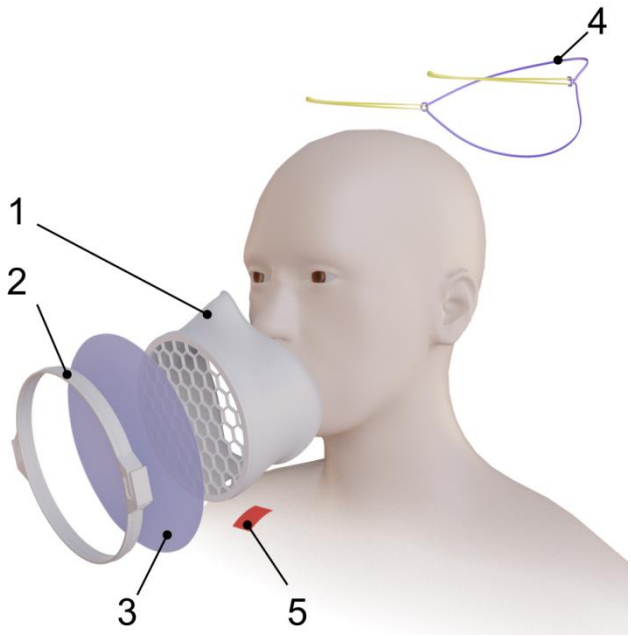

Figure 2: Individual parts of the mask

The individual parts are described in detail below.

Body or frame

The body is a thin-walled component that is manufactured using the 3D printing process “Fused Deposition Modeling.” In this process, a plastic wire is heated to a certain temperature, then changes into a paste-like state, so that the material can be distributed in a plane or layer through a nozzle. By placing multiple layers on top of each other, a three-dimensional body is created. Components that are produced in this process have a lower tensile strength between the individual layers than within a layer. Please take this into account when disassembling/assembling the clamping ring, by keeping bends and tensile forces on the thin walls as low as possible.

Clamping ring

A suitable filter material is clamped onto the body using the clamping ring. A circumferential elevation in the body and a corresponding recess in the clamping ring ensure a defined position in the assembled state. At the edge of the ring there are holders for a fastening band. Each bracket consists of an inner and an outer tab. The inner tab is intended for fastening the band. The outer tab protects the fastening band from slipping. Mount the clamping ring so that the inner tabs point downwards (see Figure 1).

Fastening band

The fastening band is used to fit the mask on the head. The band can be created using three rubber bands, for example. The three rubber bands interlock with each other through loops. The middle rubber band extends behind the head. The more the rubber is extended, the less the tensile force on the mask. Figure 3 shows the arrangement with three rubber bands.

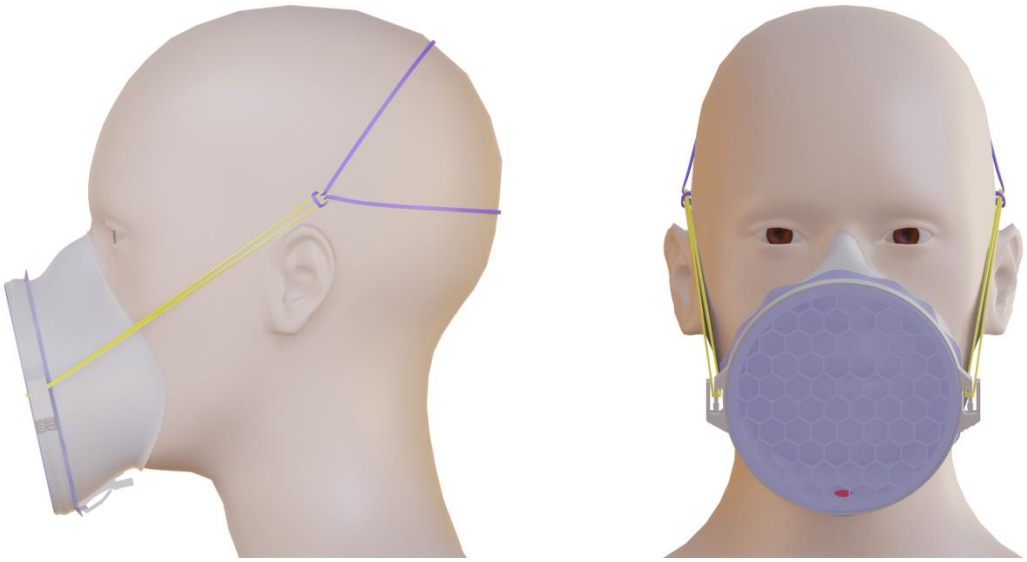

Figure 3: Fitting the mask using the fastening band

Filter unit

The selection of a suitable filter material is the responsibility of the user. Tests to determine a suitable material were carried out with vacuum cleaner bags and tea towels. At this point, reference is made to the tests from 2013 and 2008 (see [1] and [2]).

The selected filter material is cut into a circle with a diameter of 15 cm and clamped onto the base body using the clamping ring. Please do not apply excessive force to this, as the body can break under the load. If the filter material is relatively thick, it is advisable to heat the clamping ring or to print a larger clamping ring.

Check valve

The body is provided with a device for a film, which functions as a check valve. Transparent sheets or the backs of flyers are suitable as a film. The film material is cut to 19 x 24 mm and then hooked into the device. **Check the correct fit of the film before each use of the mask!** Figure 4 shows the device with the film installed.

Figure 4: Check valve with foil

Inhalation creates a negative pressure inside the mask, such that the film is sucked in and thus seals the chamber. Exhaling creates an overpressure so that the film is pressed outwards and thus opens the chamber. Figure 5 shows the function of the check valve.

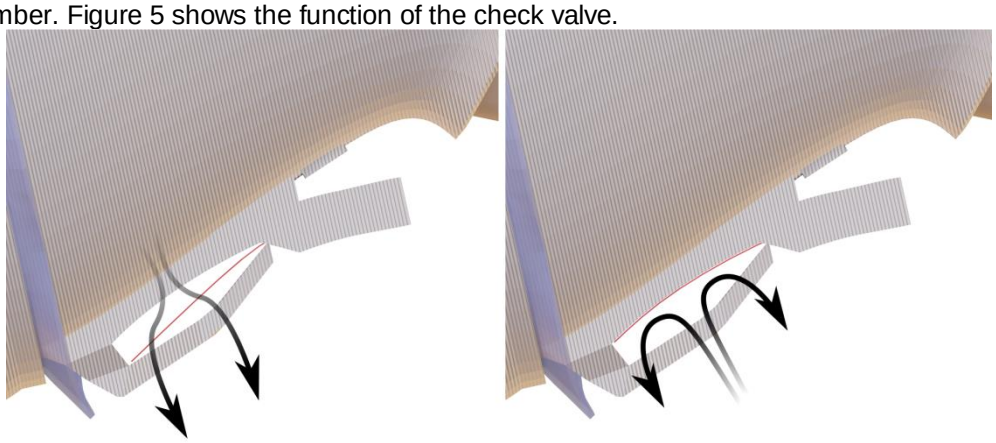

Figure 5: Opening and closing the valve when exhaling and inhaling

This function makes it possible to let moisture and warmth escape when exhaling and to facilitate breathing resistance with filters with low permeability. The goal is to improve comfort.

Please note that aerosols can escape through the check valve. **In the event of an infection, the opening must be closed with an adhesive strip!** In this case, a body can alternatively be printed without the check valve. A separate file is available for this.

Additive manufacturing (3D printing)

If you are not making the mask yourself, please continue with the section “Adjusting the mask.”
The body and clamping ring can be manufactured using fused deposition modeling. We have had good experiences with the following general conditions:

- Material: PETG
- Layer height: max. 0.3 mm
- Nozzle diameter: 0.4 mm
- Track width: max. 0.5 mm (wall thickness is at least 1 mm - at least 2 passes should be printed.)
- Flow rate "flow": minimum 100%

The guideline values for version 11 are approximately 2.5 hours and 46 g of material to manufacture a mask.

Adjusting the mask

The mask should fit evenly on the face. If you find pressure points, the shape of the body can be adjusted using heat. To do this, the corresponding area must be heated to approx. 90 degrees. Do not heat the entire mask, as it may warp. This can make the assembly of the clamping ring more difficult later.
Before using the mask, check the tightness of the check valve by covering the filter with a flat surface (e.g. table) and breathing in. No air should escape between the body and face and no air at the check valve. When exhaling, the valve opens and the air should only escape through the check valve. When switching between inhaling and exhaling quickly, you should hear a knocking sound from the check valve. If correct opening and closing of the valve cannot be guaranteed, seal the opening from the inside and outside with an adhesive strip.

Sources:

[1] Investigation of filter materials 2013:
Anna Davies, KatyAnne Thompson, Karthika Giri, George Kafatos, Jimmy Walker and Allan Bennett Testing the Efficacy of Homemade Masks: Would They Protect in an Influenza Pandemic? Disaster Medicine and Public Health Preparedness, Available on CJO 2013 doi:10.1017/dmp.2013.43 (https://www.cambridge.org/core/services/aop-cambridge-core/content/view/0921A05A69A9419C862FA2F35F819D55/S1935789313000438a.pdf/testing_the_efficacy_of_homemade_masks_would_they_protect_in_an_influenza_pandemic.pdf)

[2] Investigation of filter materials 2008:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2440799/