UNIV. PROF. DIPL.-ING. DR.-ING. ALFREDO SOLDATI - STRÖMUNGSMECHANIK UND WÄRMEÜBERTRAGUNG

Technical annex for Blue Italy Group

ANALYSIS OF MASKS PERFORMANCE : MODEL TECHNOMASK CLASSIC

TR 02-20

Contents

1 Background and motivation

Blue Italy Group is a company specialised in the processing of fabrics, leather and plastic materials, using the latest process technologies. The group carries out projects for the most important international fashion brands. In this challenging times, *Blue Italy Group* produces innovative masks under the brand "Technomask", which are water-repellent and cover both nose and mouth. The masks are equipped with velcro strips and can be used in two different configurations: open at the bottom and closed at the bottom.

The skin-friendly mask (no silicone) is hand washable with cold water and soap. Thanks to its good fit, it is very comfortable to wear. Although the masks are not medical devices, they can considerably reduce the distance at which drops are spread by people who wear it.

A scientific analysis of the masks has not been performed yet. To achieve this goal, *Blue Italy Group* asked the technical support of the research group of Prof. Soldati at the Institute of Fluid Mechanics and Heat Transfer, Vienna University of Technology (Vienna, Austria).

1.1 Objectives

The objective of the present scientific project is the **qualitative performance evaluation of the Technomask model CLASSIC performance in conditions that may strictly represent the realistic situation of mask common use.** Protective masks shield the wearer's nose and mouth from contact with droplets, splashes and sprays that may contain germs. Masks may protect others by reducing exposure to the saliva and respiratory secretions of the mask wearer and are considered a fundamental tool to prevent the spread of the Covid-19 virus in absence of a vaccine [1]. Ultimately the scope of a mouth and nose protection system, is to prevent exposure to direct contagion. By direct contagion we mean here the exposure to the direct emission of droplets ejected from the mouth or to the droplets carried by the puff propelled forward by the emitter during normal breathing, coughing, sneezing, talking etc. [2]. The aim is to analyse the performance of the Technomask CLASSIC against droplets spread, which is the main requirement for so-called "Community masks".

The analysis has been conducted at the Institute of Fluid Mechanics and Heat Transfer at TU Wien (Vienna, Austria). The performance of the mask will be evaluated experimentally with the aid of high-speed laser and cameras.

1.2 Research team

The research team at the Institute of Fluid Mechanics and Heat Transfer at TU Wien consists of two senior scientists, one junior researcher and two support technical staff members:

- Prof. Ing. Alfredo Soldati (senior);
- Dr. Ing. Marco De Paoli (senior);
- Dr. Ing. Mobin Alipour (junior);
- Mr Werner Jandl (technical staff);
- Mr Franz Neuwirth (technical staff);

2 Experimental facility

2.1 Imaging system

The size of the drops emitted during a normal breath is of the order of few micrometers (μm), which makes accurate and reliable measurements of droplets concentration and distribution hard to obtain. In particular, extremely sensitive high-speed and high-resolution cameras are required to record the motion of the drops. The laboratory at TU Wien is equipped with an up-to-date, leading edge flow visualisation facility constituted of: i) laser, ii) cameras, iii) post-processing analysis software and iv) workstations.

However, at such speed due to the small size of drops involved in breathing processes, drops are not visible at day light, and additional high-energy light sources are required. For this specific configuration, a high-speed laser is used (Litron LD60-532 PIV). It consists of a double-pulse laser (25 mJ per pulse) illuminating the measurement region at a frequency corresponding to the acquisition rate of the cameras. The cameras consist of Phantom VEO 340L, with sensor size of 2560×1600 pixel at 0.8 kHz. Camera and laser are shown in the figure 1(a). High-precision synchronous activation of laser and camera is required. To this aim, an accuracy of the order of few microseconds is necessary and it is obtained via a high-speed synchroniser. Synchronisation, data collection and processing is performed via Davis 10 (LaVision GmbH, Germany).

2.2 Flow conditions

Object is to analyse situations which are as close as possible to realistic scenarios. Since it is dangerous to use a powerful light source as the laser necessary to perform the experiments with human beings, in order to mimic the human breath and coughing processes, we designed a dummy head equipped with a special pump, which works as seed generator. The dummy head, shown in figure 1(b-c), has a circumference analogue to that of a human head, equivalent to 57 cm. Nozzles corresponding to nose and mouth, shown in figure 1(d), are placed inside the dummy head and connected via pipes to the pump. The system head+pump is controlled by electrical tuner by which it is possible to create a variety of flow conditions, i.e different flow velocities and durations.

To mimic the few micrometer drops size emitted during a human breath, flow is seeded with nearly mono-dispersed (2 μm) neutrally-buoyant and non-evaporating drops, consisting of an aqueous and non-toxic solution (Safex-inside Nebelfluid, Dantec Dynamics). The drops emitted during human breaths that fall in this size range are not evaporating [2], and could persist in the surrounding environment for a long time.

We distinguish in the study three flow conditions (see [3] and references therein):

1. Deep exhale : flow from mouth, duration 3 s and maximum velocity 0.5-0.7 m/s.
2. Coughing 1 : flow from mouth, duration 0.5 s and maximum velocity 3.0-3.3 m/s.
3. Coughing 2 : flow from mouth and nose, duration 0.5 s and maximum velocity 3.0-3.3 m/s.

and two different configurations

A : Without mask;

C : With Technomask CLASSIC.

Finally, each mask is considered in both open and closed cases. A summary of all the experiments performed is provided in table 1.

(a)

(b) (c) (d)

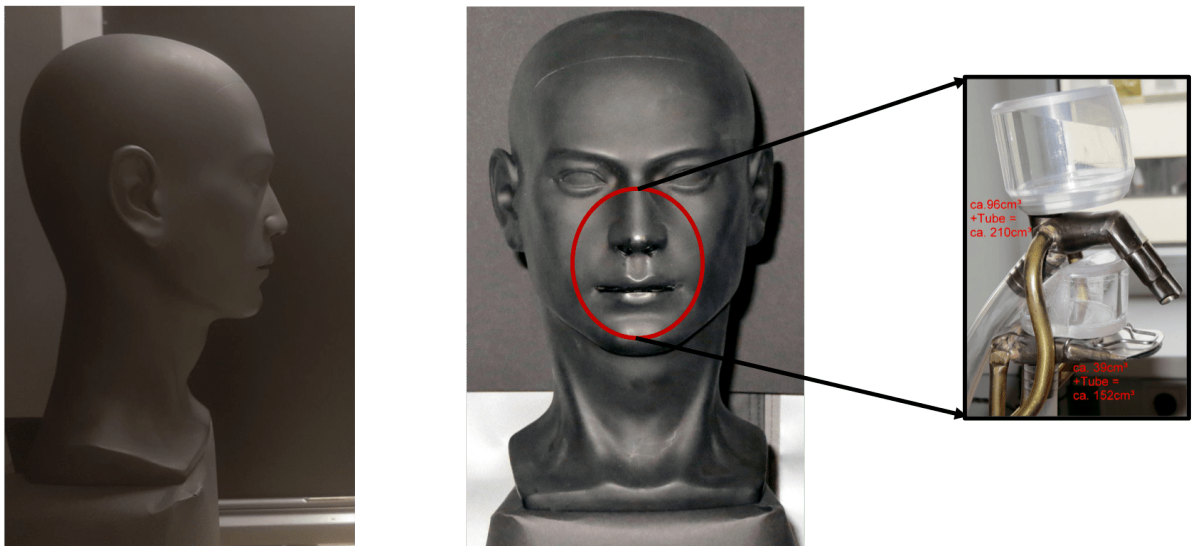


Figure 1: The experimental setup is shown in (a). High speed camera, high power dual cavity laser and dummy head are indicated. Side, (b), and front, (c), view of the dummy used in this experimental report. The reservoir located inside the dummy head, used to control the air flow blown though nose and mouth, is also shown in (d).

2.3 Experimental procedure and test setup

The experiments are performed as follows:

1. Mask is applied to the dummy head.
2. Camera field of view is set and space calibration (pixel to space) is performed. Sample image of the dummy head in the view of the camera is shown in figure 2. The field of view of the camera is set to cover 40 cm ahead of the dummy.
3. Appropriate laser power, according to the velocity of the flow, is set.
4. Pump is started and the flow is produced. The flow conditions employed are set to reproduce at the laboratory scale human respiratory flow, such as breathing and coughing.
5. Camera, laser and smoke generator are synchronised and images with an appropriate acquisition rate are taken.

The data collected are preprocessed and analysed via 2 workstations consisting of 36 cores each. To this aim, the software Davis 10 is employed.

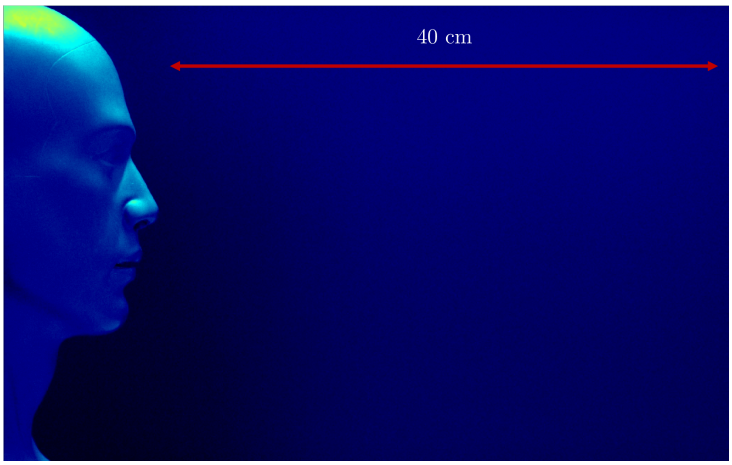


Figure 2: View of the dummy head in the field of view of the camera.

TechnoMask CLASSIC masks (size 11-13 cm) are analysed in this experimental report. Sample image of this type of masks is shown in figure 3 as extracted from the packing (a) and in open configuration (b). The mask is equipped with a velcro strip, which allows the mask to be open or closed at chin level, close to the neck. Both cases (open and closed) are considered in this report, as described in table 1.

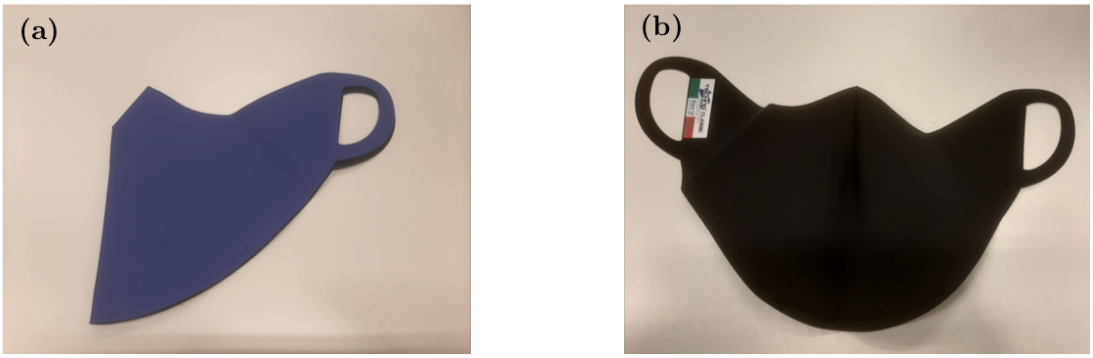


Figure 3: Samples of the Technomask CLASSIC used in the experiments; (a) and (b) are as extracted from the packing and in open configuration, respectively.

Table 1: Summary of the test cases used in the experiments. Different flow conditions are used: 1) Deep exhale corresponds to a flow from the mouth, with a duration of 3 seconds and velocity of 0.5-0.7 m/s. 2) Coughing 1 corresponds to a flow from the mouth, with a duration of 0.5 seconds and velocity of 3-3.3 m/s. 3) Coughing 2 corresponds to a flow from both mouth and nose, with a duration of 0.5 seconds and velocity of 3-3.3 m/s. A) no mask is used. C) Technomask CLASSIC is used.

#	Condition	flow		Mask	
		mouth	nose	yes/no	neck strip
A1	Deep exhale	✓		no	
A2	Coughing 1	✓		no	
A3	Coughing 2	✓	✓	no	
C1	Deep exhale	✓		yes	open
C2	Coughing 1	✓		yes	open
C3	Coughing 2	✓	✓	yes	open
C4	Deep exhale	✓		yes	closed
C5	Coughing 1	✓		yes	closed
C6	Coughing 2	✓	✓	yes	closed

3 Results

3.1 Deep exhale

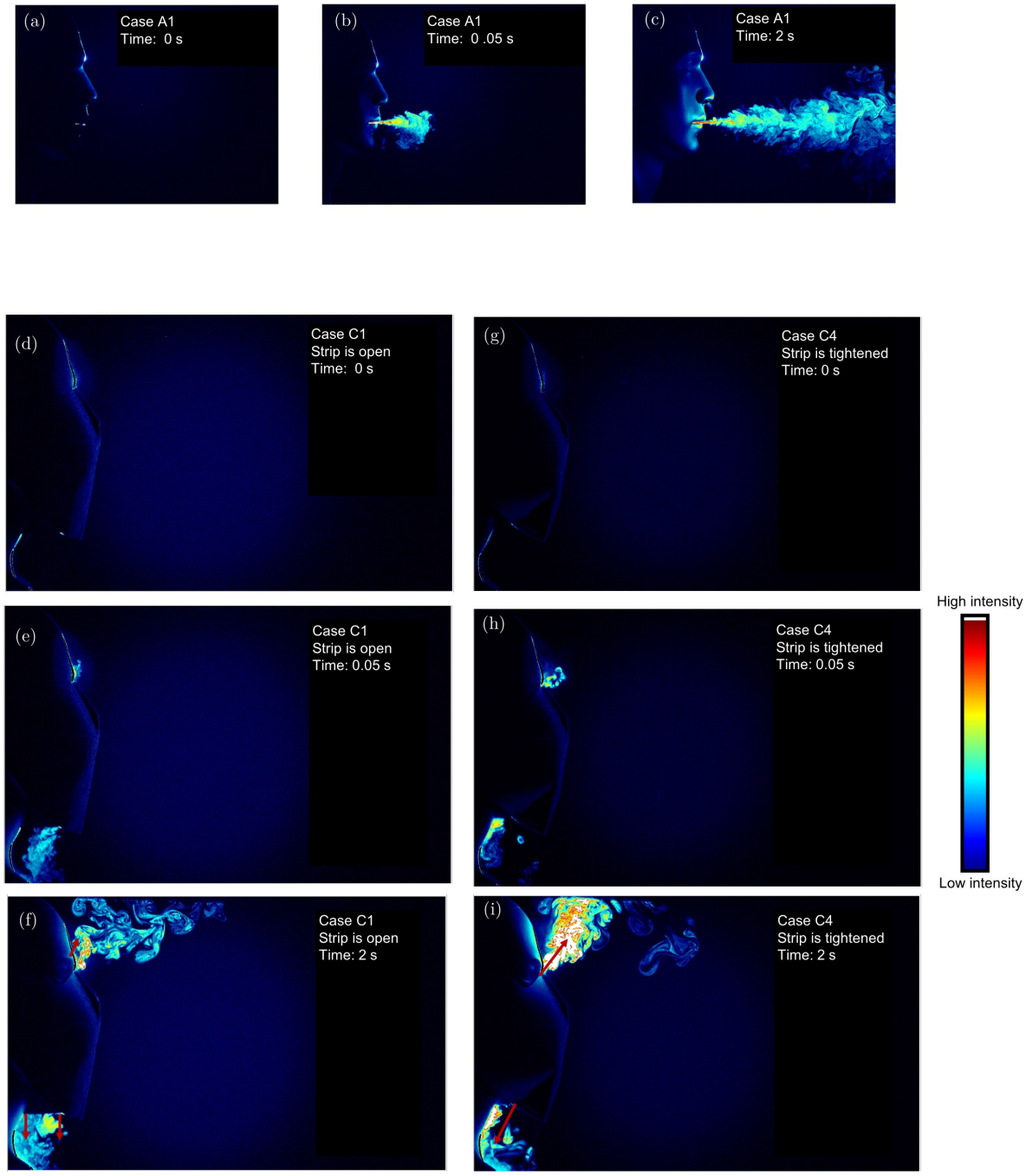


Figure 4: Snapshots of the experiments performed for deep exhale cases (A1, C1 and C4) are shown in panels (a-c) for three times (Time = 0, 0.05 and 2 s). Snapshot of the experiments in the same instants are shown in panels (d-f), closed strip, and (g-i), open strip. Colours refer to amount of light scattered by the drops, which depends on local drops concentration: black and white regions correspond to low and high light intensities, i.e. to low and high drops concentration, respectively.

3.2 Coughing 1

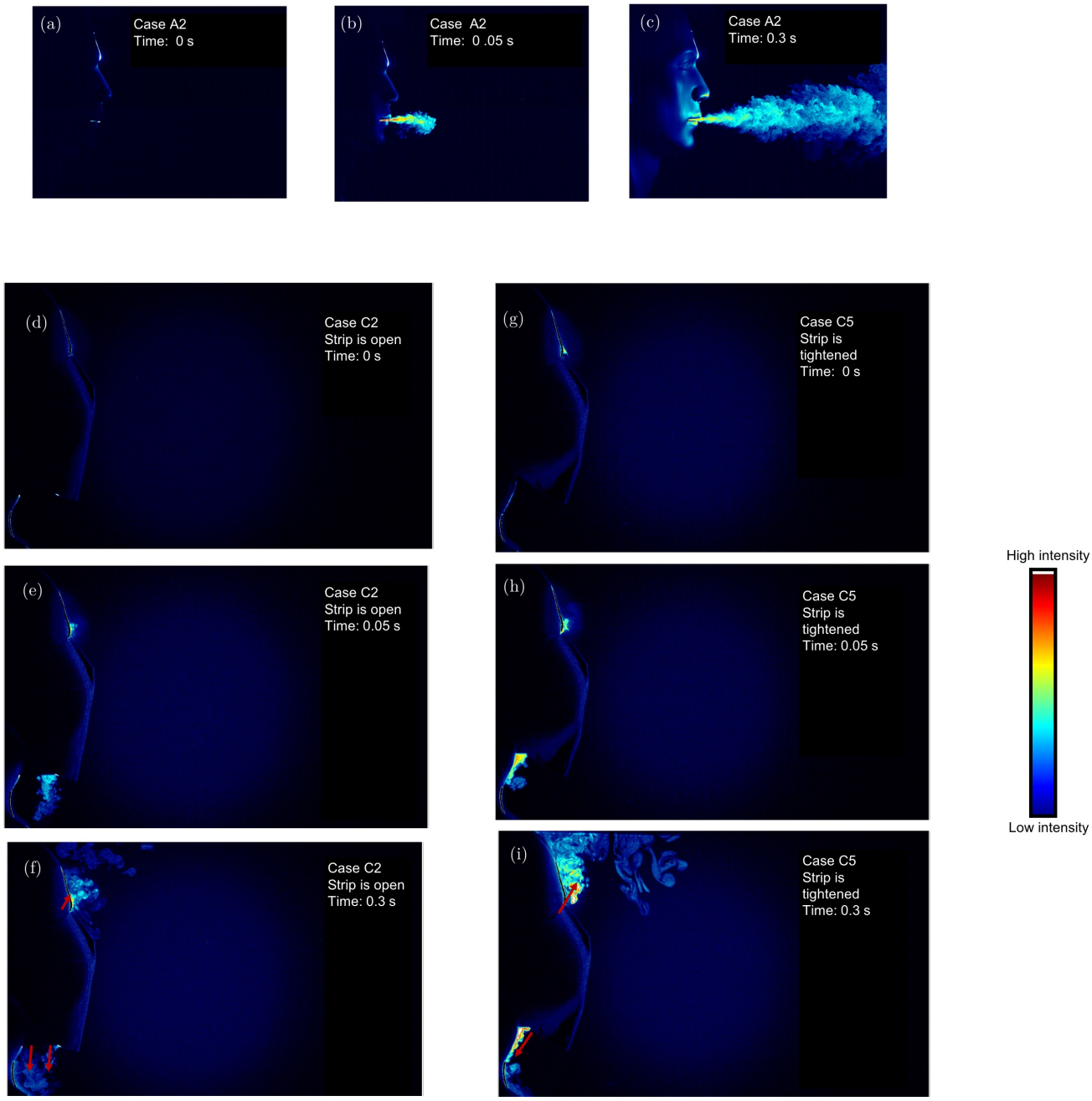


Figure 5: Snapshots of the experiments performed for coughing 1 cases (A2, C2 and C5) are shown in panels (a-c) for three times (Time = 0, 0.05 and 0.3 s). Snapshot of the experiments in the same instants are shown in panels (d-f), closed strip, and (g-i), open strip. Colours refer to amount of light scattered by the drops, which depends on local drops concentration: black and white regions correspond to low and high light intensities, i.e. to low and high drops concentration, respectively.

3.3 Coughing 2

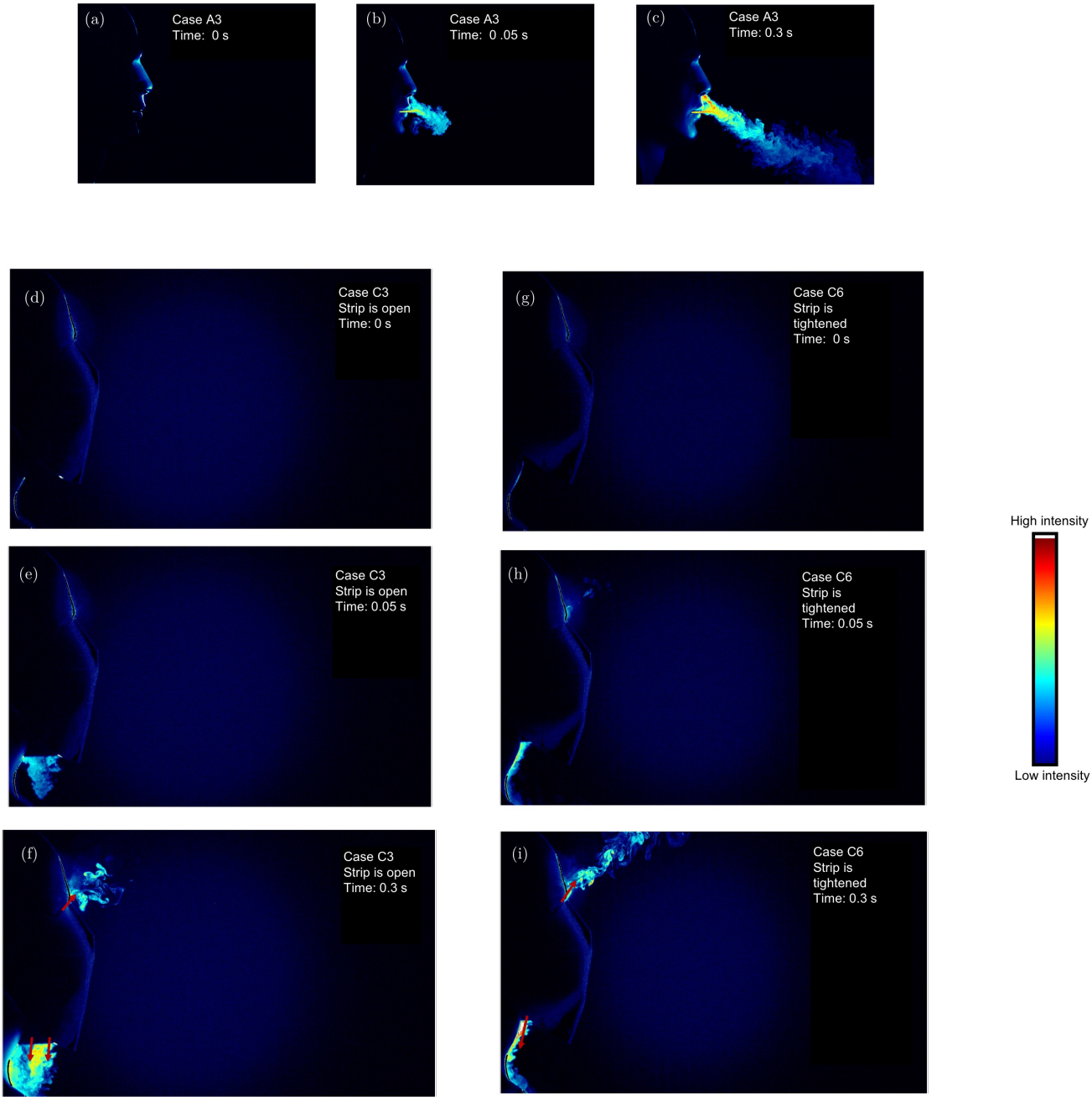


Figure 6: Snapshots of the experiments performed for coughing 1 cases (A3, C3 and C6) are shown in panels (a-c) for three times (Time = 0, 0.05 and 0.3 s). Snapshot of the experiments in the same instants are shown in panels (d-f), closed strip, and (g-i), open strip. Colours refer to amount of light scattered by the drops, which depends on local drops concentration: black and white regions correspond to low and high light intensities, i.e. to low and high drops concentration, respectively.

4 Supplementary material

Two comparative movies are attached to this report. In each movie, the droplets spreading observed with the Technomask CLASSIC is qualitatively compared with i) absence of protection, ii) monolayer cotton mask and iii) surgical mask.

- In figure 7 we show a "still" frame of Movie C3: with reference to table 1, flow condition is Coughing 2 and mask configuration is C3 (strip open). The instant considered is the same for all cases shown, and corresponds to time $t = 0.25$ s, being $t = 0$ is the instant at which the flow starts.
- In figure 8 we show a "still" frame of Movie C6: with reference to table 1, flow condition is Coughing 2 and mask configuration is C6 (strip closed). The instant considered is the same for all cases shown, and corresponds to time $t = 0.25$ s, being $t = 0$ is the instant at which the flow starts.

These visualisations do represent just a qualitative picture of the distribution of droplets emitted. To provide reliable quantitative measurements, further analyses related to the concentration of aerosol and to the velocity field are required.

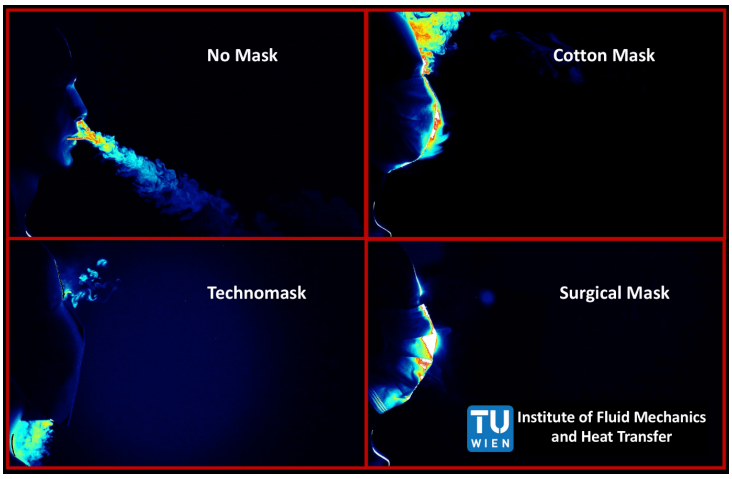


Figure 7: "Still" frame taken at $t = 0.25$ s from Movie C3.

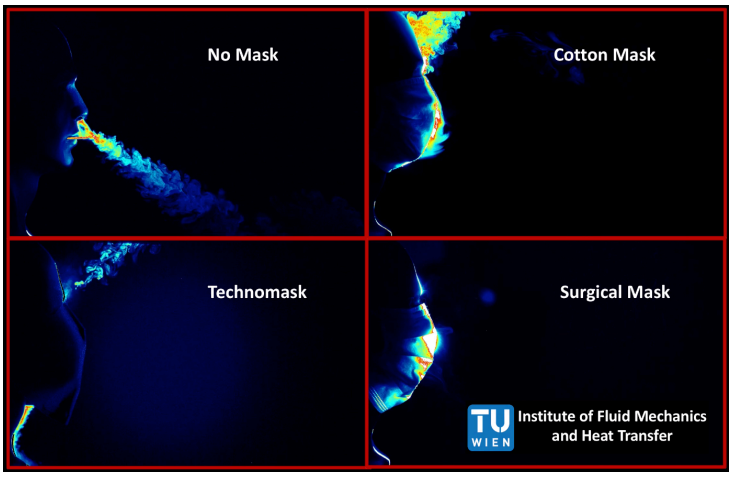


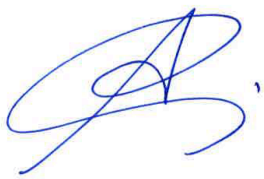
Figure 8: "Still" frame taken at $t = 0.25$ s from Movie C6.

5 Conclusions

In this report, we used advanced imaging techniques to qualitatively evaluate the action of the Technomask CLASSIC protective masks produced by *Blue Italy Group* against droplets spread. The specific object of the experimental campaign conducted here is to examine from a qualitative and yet repeatable procedure, the capability of Technomask CLASSIC to act as a mouth and nose protection system suitable to prevent the possibility of host-to-host direct contagion. By direct contagion we mean here the exposure to the direct emission of droplets ejected from the mouth or to the droplets carried by the puff propelled forward by the emitter during normal breathing, coughing, sneezing, talking etc. [2]. We considered three different flow conditions (labelled as deep exhale, coughing 1 and coughing 2) and three different mask configurations (no mask, mask open at bottom and mask closed at bottom). With the aid of laser and high-speed cameras, we qualitatively analysed the distribution of the droplets emitted by the mask wearer from mouth and nose, and we observed that:

- in all flow configurations considered, in the time window investigated, the advection-diffusion process of the droplets in horizontal forward direction is decreased with respect to the case without mask;
- the breathing puffs are mainly evacuated from the venting occurring at the gaps between the mask rims and the face of the dummy;
- when the mask strip is open, puffs are mainly evacuated downward (i.e. towards the neck of the dummy);
- when the mask strip is closed, compared to the case of mask strip open, a much reduced flowrate of puffs is evacuated downward/backward towards the neck of the dummy. However, evacuation from the upper rim (i.e. in the nasal bridge area) is observed larger than in the open strips case;
- the behaviour of the puffs escaping from the mask appears qualitatively similar to that characterizing other mouth and nose protection systems (e.g. cloth masks, surgical masks).

Univ.Prof. Dipl.-Ing. Dr.-Ing. Alfredo Soldati
Institute of Fluid Mechanics and Heat Transfer,
Getreidemarkt 9,
1060 Wien



6 References

1. Kumar, S., & Lee, H. P. (2020). The perspective of fluid flow behavior of respiratory droplets and aerosols through the facemasks in context of SARS-CoV-2, *Physics of Fluids*.

2. Balachandar, S., Zaleski, S., Soldati, A., Ahmadi, G., & Bourouiba, L. (2020). Host-to-host airborne transmission as a multiphase flow problem for science-based social distance guidelines, *International Journal of Multiphase flow*.

3. Abkarian, M., Mendez, S., Xue, N., Yang, F., & Stone, H. A. (2020). Speech can produce jet-like transport relevant to asymptomatic spreading of virus. *Proceedings of the National Academy of Sciences*.