D8.4 –Report with the design concept for the cleaning system

Hygienic Design & Hygienic Engineering

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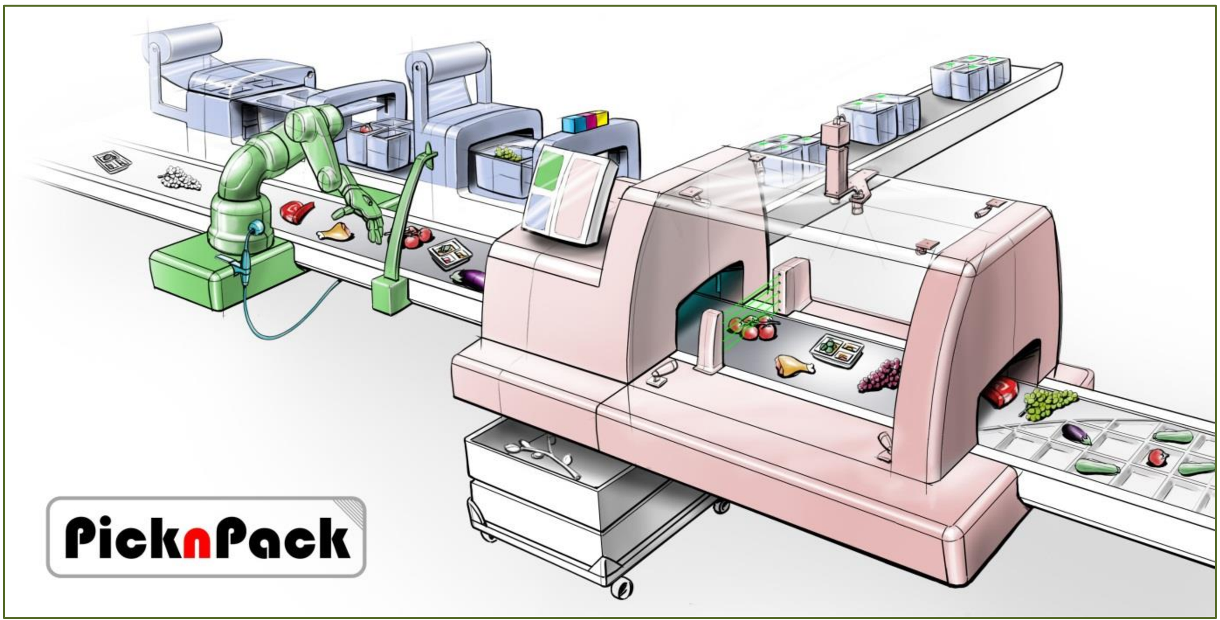

Flexible robotic systems for automated adaptive packaging of fresh and processed food products

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Dissemination level		
PU	Public	X
PR	Restricted to other programme participants (including the EC Services)	
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1 Design Concept Cleaning System

1.1 Requirements

It is necessary to clean packaging lines periodically to avoid hygienic risks. Especially product contact areas need to be set to a defined initial hygienic state in regular intervals. The cleaning process needs to be reproducible and efficient with regard to time and resources. Due to the increasing number of products and economic requirements also flexibility and adaptivity are becoming more and more important.

Normally, cleaning is done manually by an operator (not reproducible) or by a Cleaning-in-Place (CIP) system which consists of nozzles solidly mounted to the machine (not flexible and adaptive). Within this project a new technology was developed to make the cleaning within PicknPack more flexible and adaptive according to the different products which are packaged on the PicknPack line. The new concept consists of a Mobile Cleaning Device which moves automatically through the whole production line and cleans all modules according to their individual requirements.

1.2 Mobile Cleaning Device

To move through the line the Mobile Cleaning Device (Fig. 1) uses the bars of the Sectional Frames as rails which also support the web of trays during production. On these rails it can drive on wheels and by that reach all modules to clean them. As an alternative, the device can also be simply carried by a conveyor belt. The Mobile Cleaning Device contains different nozzles which can all be controlled individually with the help of magnetic valves. On this way, the device can use for example flat fan nozzles for smaller areas like tunnels or Sectional Frames where a lower flow rate is needed. For bigger areas, like the robotic modules, rotating spray heads e.g. with a high flow rate over big distances can be used. The operating pressure and the movement speed can also be controlled automatically. The device also has an on-board position sensor so that it can automatically detect in which module it currently is in and according to that which cleaning program it has to run.

The device is completely battery-driven and the engine and the valves are controlled via WiFi. Therefore, the only physical interface of the Mobile Cleaning Device is the hose connection which supplies the device with the cleaning fluid. Different cleaning agents can be used such as water, foam or alkaline solutions. The cleaning device is connected to a mobile hose drum table. This table is placed over the line in the beginning so that the cleaning device can start from there. The hose drum is also automated so that the hose can be unrolled with a synchronized speed to the movement of the cleaning device. The hose drum again only needs to be connected to the central CIP rack of the production facility. In this way not only one but also different production lines can be cleaned with one Mobile Cleaning Device by just moving the table with the hose drum and the device to the different lines and connecting it there to the CIP rack.

In the concept the hose drum table will also have a docking station for the Mobile Cleaning Device (Fig. 2). This docking station consists of a rail pair which can be moved up and down automatically. On this way the cleaning device can drive automatically from those rails into the line. When it drives back on the docking station it is fixed there and moved in the upwards position so that the hose drum table can be moved to another position.

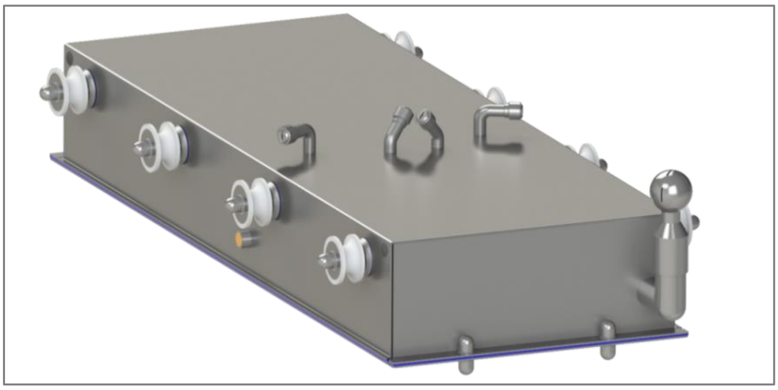

Fig. 1: Prototype of the Mobile Cleaning Device.

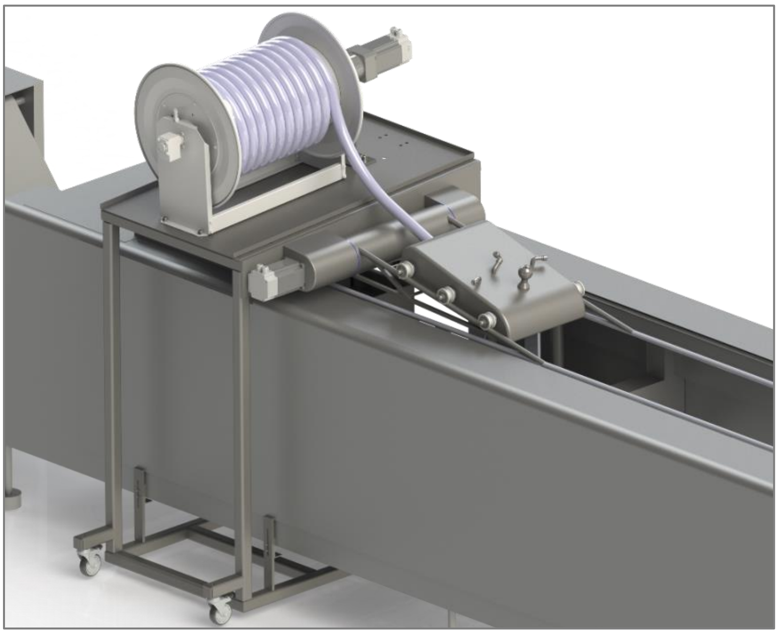

Fig. 2: The Mobile Cleaning Device connected to the hose drum table, driving into the line.

1.3 Conventional CIP-System (exemplary)

In addition to the novel concept of the Mobile Cleaning Device a conventional CIP-system has been installed in the Delta Robot module of the PicknPack line. This was done so that cleaning tests are possible to compare the performance of both cleaning systems. To find the ideal nozzle configuration for this CIP-system the first step was to find several possible solutions and compare them virtually in spray shadow simulations. The tests showed the two rotating spray heads in the lower area which do the main cleaning and three full cone nozzles in the upper area which clean the parts that cannot be reached by the spray heads are most suitable for the robot (Fig. 3). Using all five nozzles at the same time at 3 bars, the water consumption of this system is around 200 L/min.

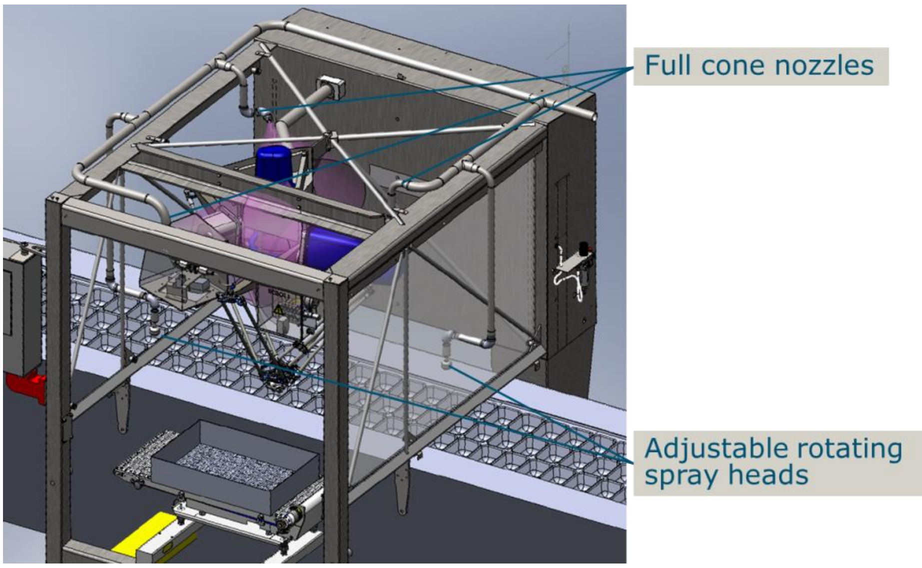

Fig. 3: Conventional CIP-system of the PicknPack Delta Robot

2 Performance Tests

2.1 Cleaning Efficiency

2.1.1 Test Method

Cleaning tests were performed to compare the performance of the different cleaning systems with different operating parameters and to study different approaches with regard to optimizing automatic cleaning systems. The tests were done exemplary on the Delta Robot and the tunnel of the Sectional Frames.

Those cleaning tests to determine the cleaning performance are not to be confused with the cleanability tests which were described in D8.3. Those tests were performed in order to determine critical areas where hygienic design needs to be improved.

Delta Robot

For the tests in the Delta Robot the whole inner rear cover of the robot was soiled with a fluorescent food model soil. The soil was applied by spraying in order to generate a very consistently spread layer which can be produced very reproducibly. In addition, a UV lamp and a camera (both IP69) were placed inside the robot to make the soil visible and to monitor the whole cleaning process. In order to make the analysis of the cleaning process very sensitive and reproducible, the robotic cell was darkened so that the fluorescent soil is shining bright on the pictures. When it is cleaned off the monitored area becomes darker. On this way the cleaning process can be quantified.

After a drying time of 20 hours the robot was cleaned with the different systems and with different operating parameters:

- Mobile Cleaning Device vs. Conventional CIP-System
- Cleaning agent (Foam) + water vs. water only
- Operating pressure: 3 bars and 4.5 bars
- Speed of the Mobile Cleaning Device: 2 mm/s (water only), 5 mm/s (foam + water), 10 mm/s (foam + water) → speed values based on first lab scale tests with rotating spray heads

Most parameter combinations were tested at least two times. For some it was only possible to test them once. For the foam cleaning tests the foam was applied manually with an Ecolab Typhoon module. After that there was a dwelling time of 10 minutes before the rinsing step with water started. In an industrial cleaning scenario the cleaning device itself would apply the foam. After the cleaning the recorded images were analyzed to determine the cleaning time. The cleaning time was defined as the time which is needed to remove 95 % of the soil.

Sectional Frame Tunnels

For the tunnels of the Sectional Frames the cleaning tests were performed at laboratory scale first and then verified on the tunnels. For the lab scale tests stainless steel plates were coated with a fluorescent food models soil. After drying they were cleaned with foam (dwelling 10 minutes) and water with different static flat fan nozzles. Afterwards the recorded images were analyzed analogous to the tests with the Delta Robot in order to determine the cleaning time and the width of the cleaned area in this time. Both parameters were used to calculate the optimum speed for the Mobile Cleaning Device so that it is able to remove the soil completely.

2.1.2 Results

Delta Robot

During the cleaning tests on the Delta Robot one of the main goals was to compare the efficiency of the novel Mobile Cleaning Device with the conventional CIP system.

Fig. 4 and Fig. 5 show exemplary the cleaning progress with both cleaning systems (water only, 3 bars operating pressure) monitored with the camera system on the inner rear cover. The pictures give a good impression regarding the differences with both cleaning systems. The conventional CIP-system uses two rotating spray heads mounted on the side covers of the robot. The Mobile Cleaning Device only uses one rotating spray head. Due to the higher resulting flow rate of both nozzles the CIP-system is able to clean all accessible areas faster than the Mobile Cleaning Device. But obviously, it uses also twice the amount of water. And the pictures also show that there are some areas which can only be reached by one of the two nozzles of the CIP-system due to spray shadows. In those areas cleaning takes more time also with the CIP-system (see marks in Fig. 4 @ 70 s). And in the top area of the robot there are spray shadow areas that cannot be cleaned at all with the CIP-system since both nozzles cannot reach them (see marks in Fig. 4 @ after cleaning). In comparison, the Mobile Cleaning Device eliminates those spray shadows due to its movement and is able to clean those areas. Therefore, it needs more time to clean the machine because the flow rate is lower but it increases food safety and uses less cleaning fluid. Soil remains in the last picture of Fig. 5 are resulting from hygienic design flaws and not from spray shadows.

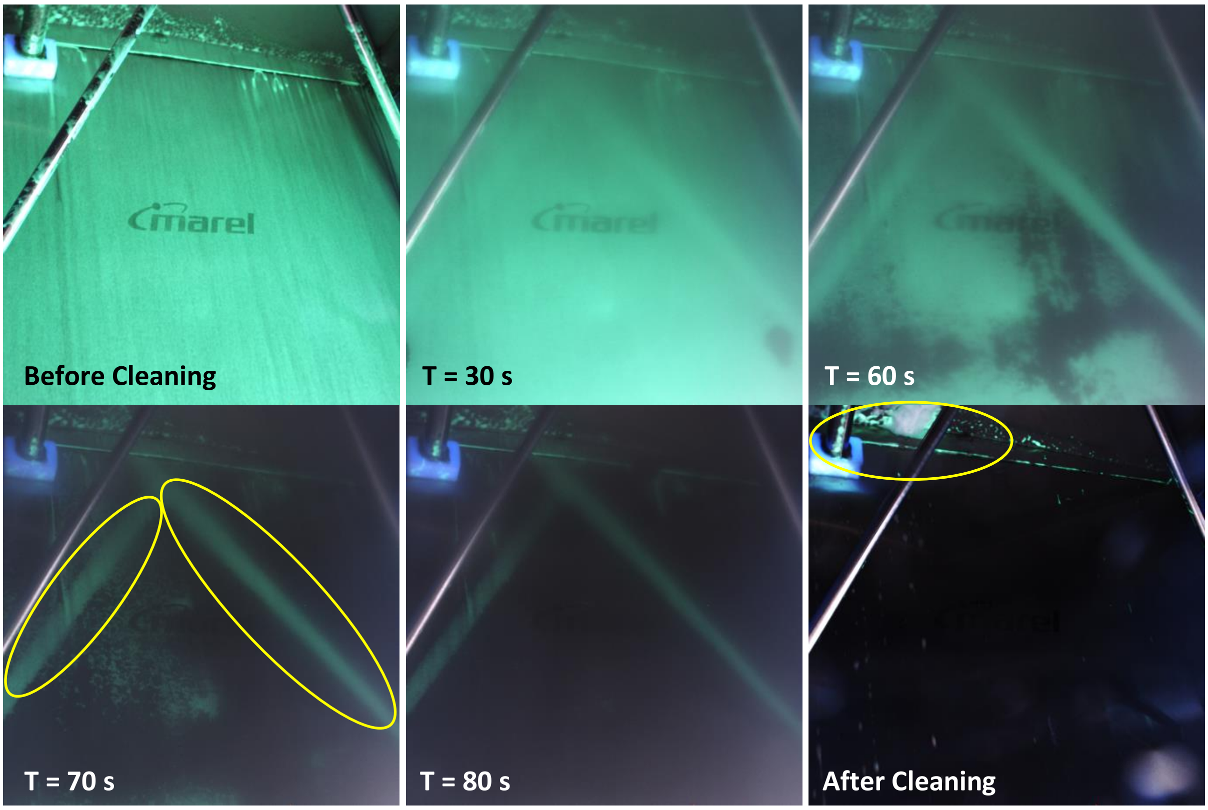

Fig. 4: Cleaning Progress exemplary for conventional CIP-System (water only @ 3 bars)

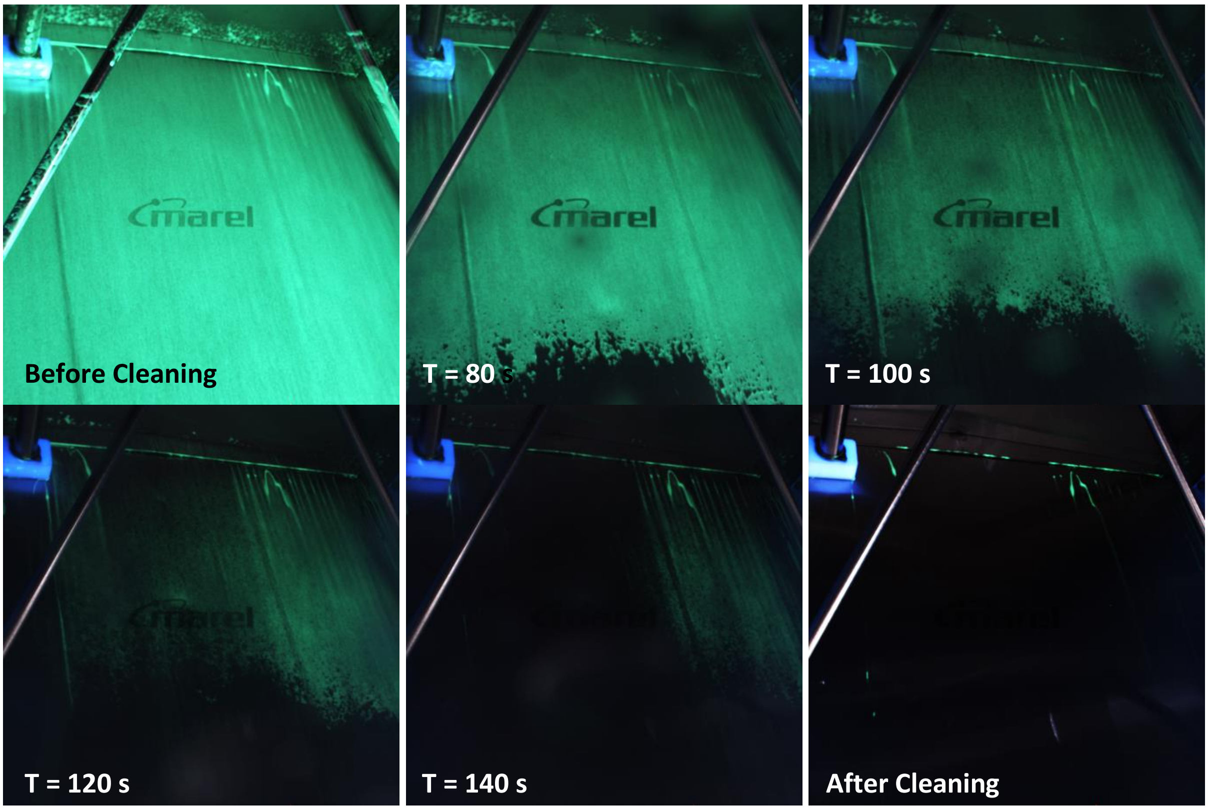

Fig. 5: Cleaning Progress exemplary for Mobile Cleaning Device (water only @ 3 bars)

The following diagrams show the quantified analysis of the cleaning tests described above. In

Fig. 6 the both cleaning systems are compared regarding cleaning time and water consumption. The results approve the impressions from the pictures above. The Mobile Cleaning Device needs longer to clean the examined surfaces but it is able to save around 20 % with regard to water consumption in addition to the increased food safety described above.

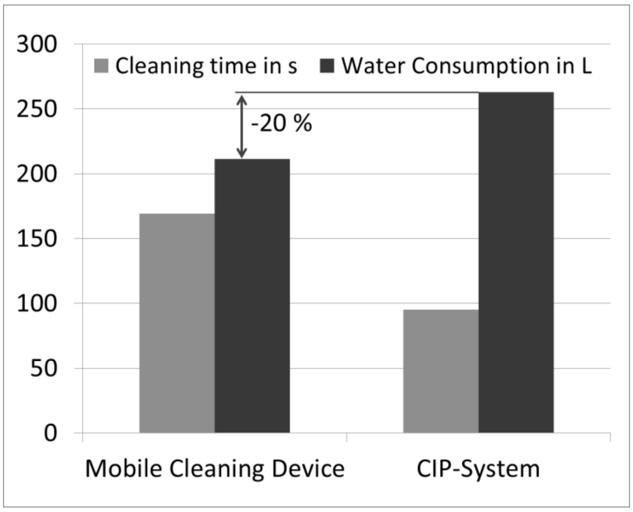

Fig. 6: Comparison of Mobile Cleaning Device and conventional CIP-system regarding cleaning time and water consumption (water and foam @ 3 bars)

Fig. 7 compares the used cleaning agents. It could be shown that cleaning with foam and water can reduce the cleaning time and the water consumption by around 60 %. Even when a dwelling time of 5 minutes is assumed between applying the foam and the rinsing with water and added on the cleaning time, cleaning with foam and water doesn't take more time than cleaning with water only.

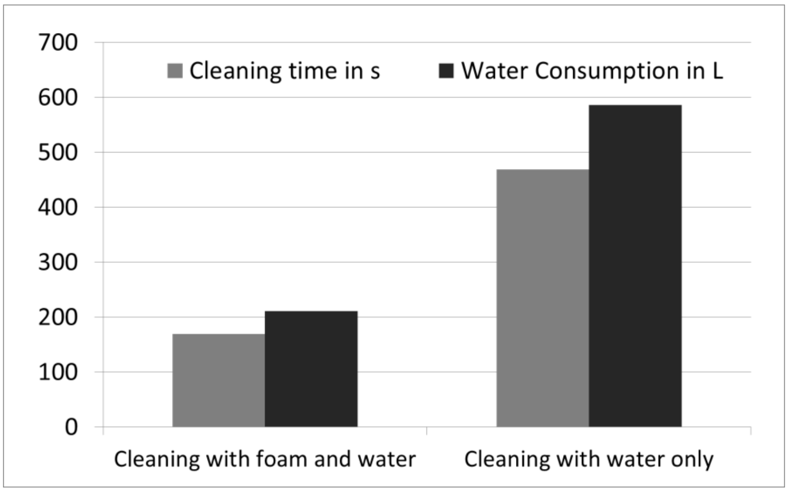

Fig. 7: Comparison of Cleaning with and without foam (Mobile Cleaning Device @ 3 bars)

Fig. 8 compares the cleaning time and water consumption with different operating pressures. It could be shown that for using the cleaning device with water and foam a higher pressure can decrease the cleaning time slightly while water consumption is nearly constant.

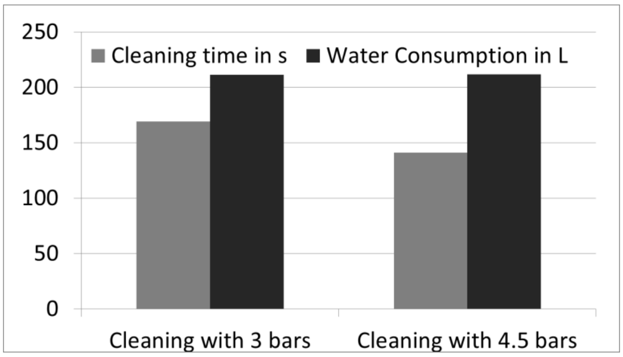

Fig. 8: Comparison of Cleaning with different operating pressures (Mobile Cleaning Device with foam and water)

<u>Sectional Frame Tunnels</u>

For the lab scale cleaning tests with the tunnels of the Sectional Frames flat fan nozzles were placed in a distance to the soiled plates that is similar to the distance of the nozzles from the Mobile Cleaning Device to the tunnel surface (350 mm) (similar to Fig. *12*). Fig. 9 shows the cleaned width on the test plates after a cleaning time of around 5 seconds. The tests showed that after a time of 5 seconds the width increased only very slowly. The width after this time was above 100 mm. The operating pressure had only little influence on the cleaning time and nearly no influence on the resulting cleaned width (Fig. 10, Fig. 11). Therefore, the recommended speed for the Mobile Cleaning Device when it is cleaning the tunnel is 20 mm/s. The recommended operating pressure is 3 - 4 bars.

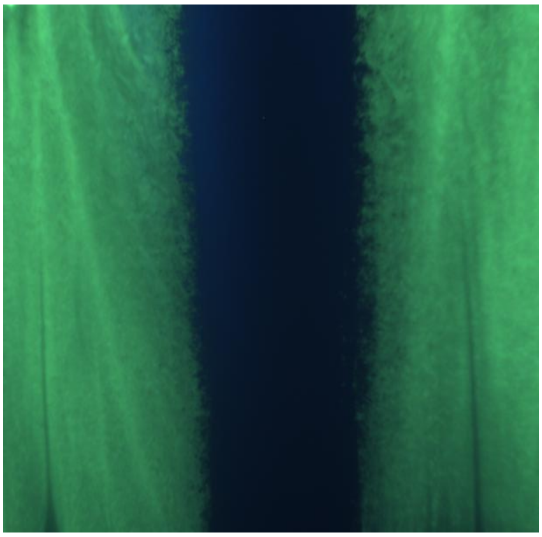

Fig. 9: Width of the cleaned area after 3-5 seconds

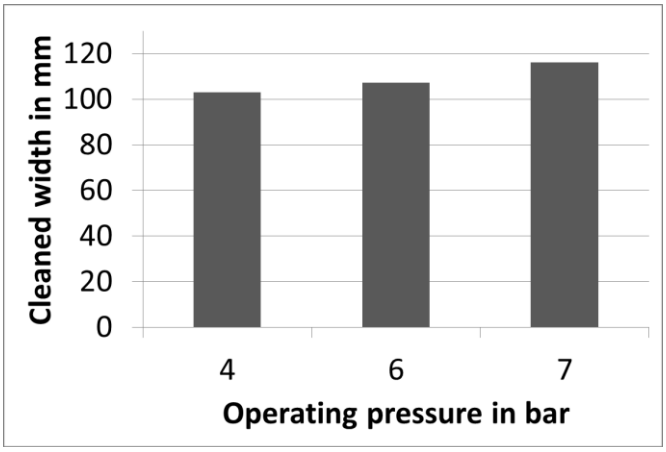

Fig. 10: Cleaned width resulting from flat fan nozzles depending on the operating pressure

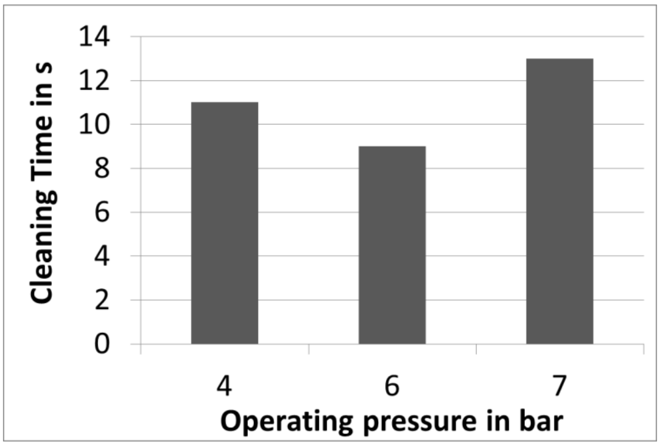

Fig. 11: Cleaning time resulting from flat fan nozzles depending on the operating pressure

Those recommended parameters were verified with the real Mobile Cleaning Device and Sectional Frame tunnel. Therefore, small plates were soiled with the food model soil and stuck on the inner tunnel surface in different positions (Fig. *12*).

Then they were cleaned by the Mobile Cleaning Device with foam (dwelling time: 10 minutes) and water at an operating pressure of 3 and 4.5 bars and a movement speed of 10 and 20 mm/s. The tests showed that the cleaning device was able to clean the test plates completely at all parameter combinations so that the results from the static lab scale tests could be proven. No Soil remains could be detected on the plates after the Mobile Cleaning Device passed them with its flat fan nozzles.

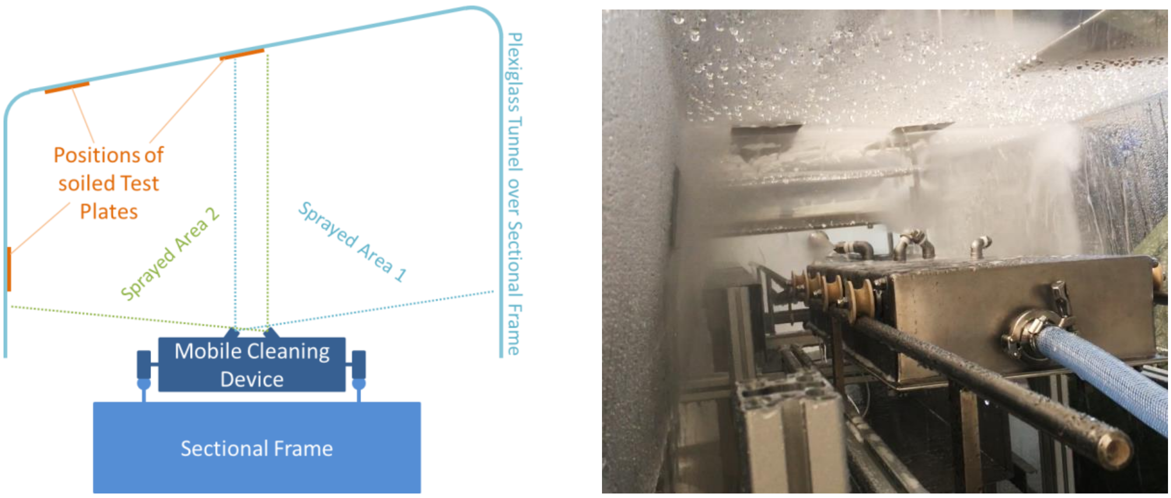

Fig. 12: Sketch of test set-up with cleaning device in plexiglass tunnel and positions of soiled test plates

2.2 Other Performance Indicators

Movement speed of the Mobile Cleaning Device

To clean the PicknPack line within a certain time the Mobile Cleaning Device needs to be able to drive with a certain speed according to the required cleaning time. Therefore, tests were done to determine the minimum and maximum speed the device is able to realize and if those speeds are suitable for cleaning.

Cleaning tests showed that a movement speed of 5-10 mm/s is necessary in order to realize the cleaning time. This speed could be realized successfully without any issues. The maximum speed which was tested was 50 mm/s. So the tests showed that the cleaning device is able to realize the necessary speed and even way more if required. Also very low speeds of 1 mm/s are possible.

Battery duration

Since the cleaning process is taking some time, it is necessary that the batteries which are supplying the engine and the valves with energy are able to last for the whole time. Therefore, tests were performed to determine the duration during cleaning.

The cleaning device contains two batteries. One supplies the engine with power, the other one supplies the valves, sensor and WiFi-module. The tests showed that both batteries have a similar consumption and are lasting for around 2-3 hours and more, depending on the intense of usage. Cleaning the PicknPack line requires approximately 30 minutes. Therefore, the battery duration from the tests is suitable for this purpose.

Cleaning Fluid Range

The cleaning device needs to be able to work with water and foam. It needs to be able to apply them over distances of around 2 m to the machine surfaces with a high enough impact and flow rate. Therefore, tests were performed to determine if the device is able to spread foam on all relevant surfaces and if it is able to remove the foam again and also the soil with water. This was part of the cleaning tests.

The tests regarding the different cleaning agents were performed in combination with the cleaning tests on the Delta Robot since this is the biggest module within the PicknPack line. The tests showed that the Mobile Cleaning Device is able to spray water as well as foam. It was able to cover all areas of the Delta Robot with foam as long as they were accessible (Fig. 13). Afterwards, it was also possible to rinse the foam completely from all surfaces within acceptable time.

Fig. 13: Delta Robot covered with foam (applied by Mobile Cleaning Device)

Line Communication

One of the main features within PicknPack is the online communication between all the modules in order to share information and to make the production process as flexible as possible. The same applies to the cleaning system. There is communication with the line necessary during cleaning do interact with other modules, e.g. to open valves or to tell several modules to start moving.

Line communication was integrated exemplary for the communication with the Delta Robot. When the cleaning device enters the robotic module, the Delta Robot is supposed to start moving in order to support the cleaning process. This could be successfully implemented. While running the cleaning program the cleaning device sent a message to the robot shortly before it entered. The robot successfully received the message and started the movement.

3 Future Concepts

The current version of the Mobile Cleaning Device is a prototype to show the feasibility and its advantages in comparison to conventional cleaning methods. The module will be developed further. Size will be reduced and the hygienic design will be improved to increase its suitability for the use in product contact areas. There will also be a version without wheels which is only carried by conveyors.

To make the device also more adaptive, it is planned to add an optical sensor system for automated soil detection. Since most food products contain fluorescent ingredients, it is possible to make them visible for a camera with a UV light. Both components will be integrated into the Mobile Cleaning Device. With this sensor system it will be possible to improve adaptivity during the cleaning process. It will be possible to determine which areas are really soiled and require cleaning and which areas don’t need to be cleaned. And it will also be possible to determine if all surfaces were successfully cleaned or if further cleaning is required.

Figure Fig. 14 and Fig. 15 show the smaller conceptual design of the cleaning device with and without wheels and including the camera sensor to detect soil.

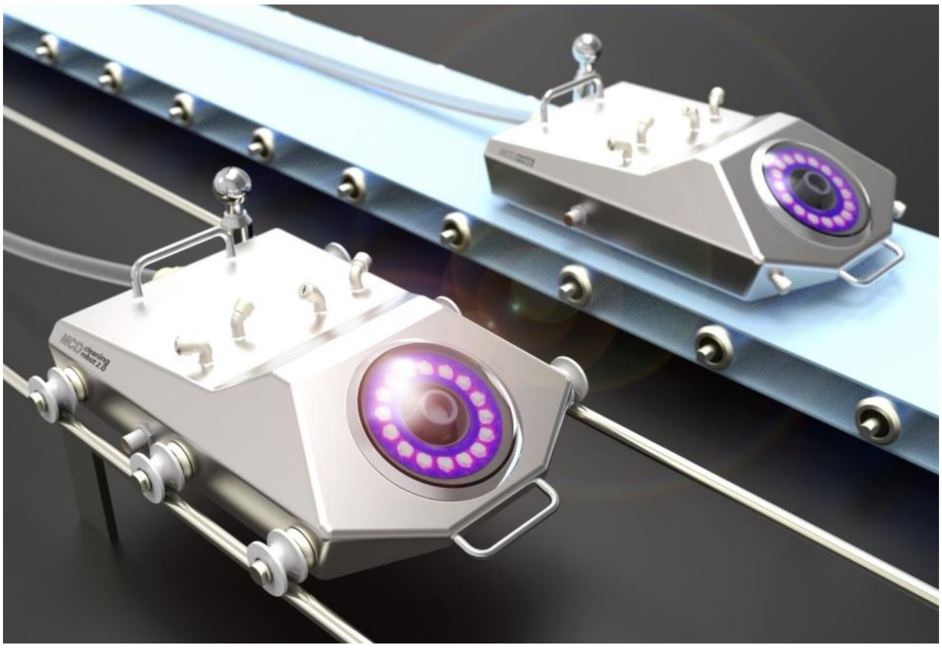

Fig. 14: Design Concept Mobile Cleaning Device with optical cleaning sensor.

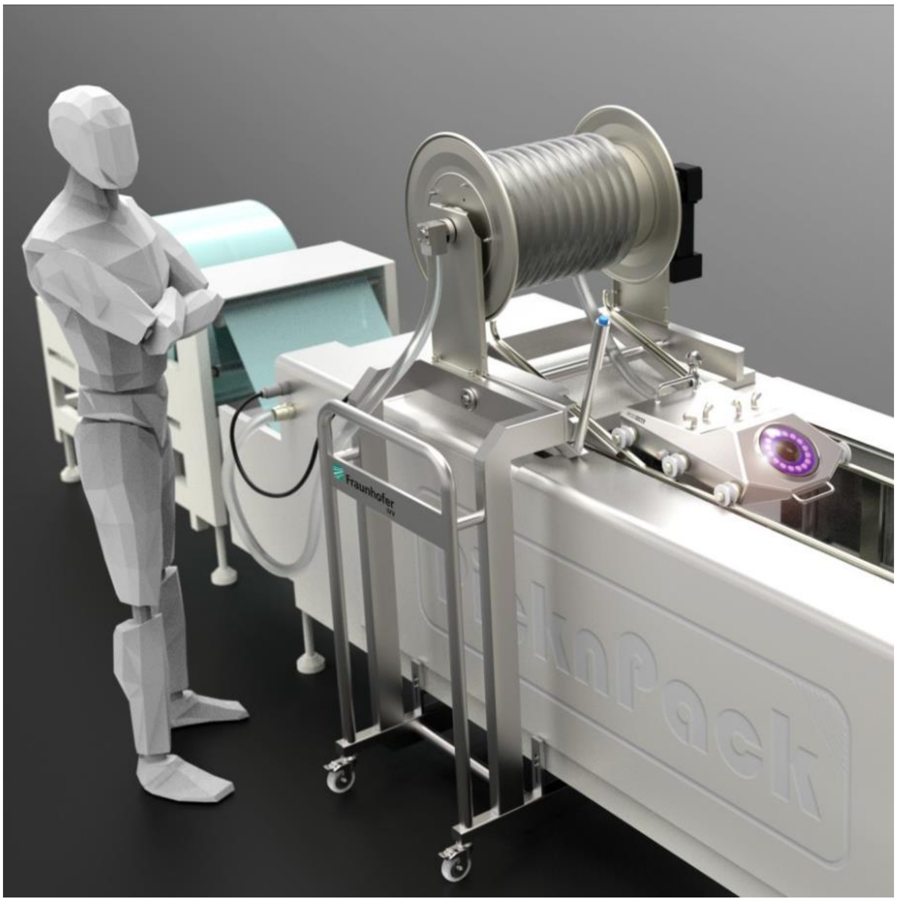

Fig. 15: Design Concept Mobile Cleaning Device and hose drum table with docking station.