

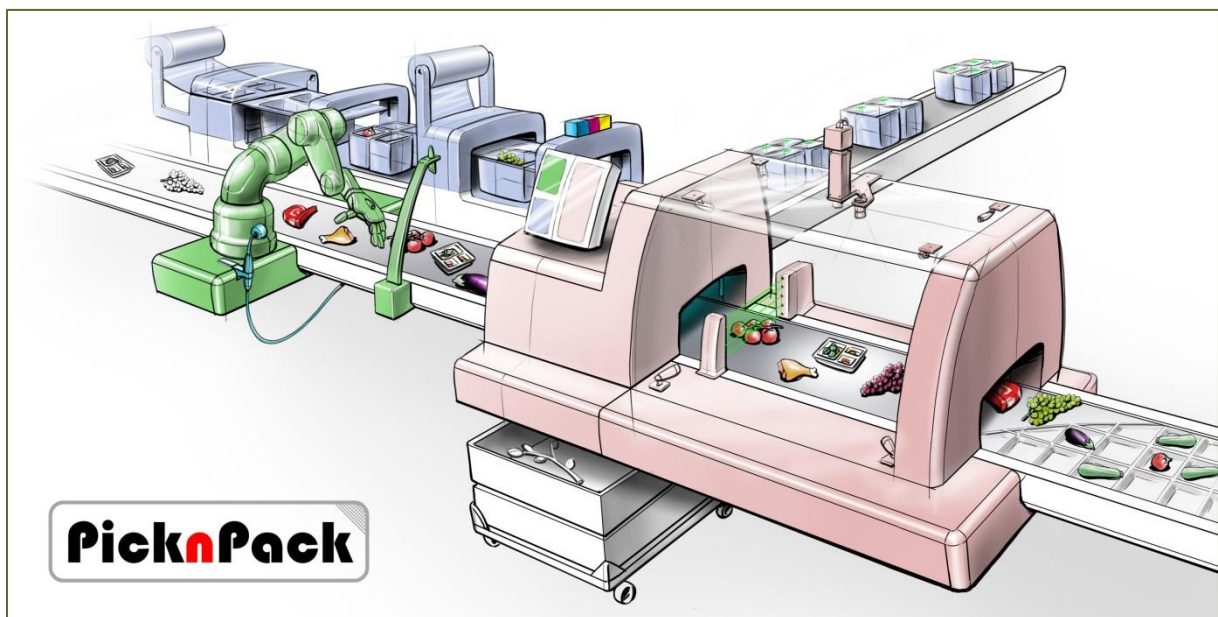
D8.3 –Test Report on Hygienic Design including Suggestions for Revision and Improvement

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) | |
| RE | Restricted to a group specified by the consortium (including the EC Services) | |
| CO | Confidential, only for members of the consortium (including the EC Services) | |

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1 Product Contact Areas in the PicknPack line

1.1 General

It was defined that all food contact areas of the machinery modules, which will be developed by the project partners, shall be cleaned automatically. The non-food contact areas will be cleaned manually in accordance with the relevant hygienic standards. According to DIN EN 1672-2 food contact areas are defined as areas which come intentionally or unintentionally in contact with the product (direct or splashes) and from where the food or other substances can get back to the product [DIN EN 1672-2].

In comparison only those surfaces are considered as non-product contact if there is no risk of cross-contamination occurring from them.

Due to these definitions the product contact surfaces within the PicknPack line were determined by tracking the path of the product. All areas of the PicknPack line which have been defined as product contact surfaces and which are developed within the PicknPack project have to be cleaned automatically. This means that they have to meet the hygienic design requirements so that they are easily cleanable with an acceptable effort. To ensure that this is the case cleanability tests have been done with the relevant modules. Special attention has been paid to the grippers and to the Delta Robot because these modules are providing the highest hygienic risk if they are not being cleaned sufficiently.

1.2 Fresh Food Line

In the line for fresh food (Fig. 1) the product (vine tomatoes or grapes) is brought in crates into the Delta Robot module, where it is picked up by the gripper and placed in the tray. Therefore the whole inner part of the robot has to be seen as product contact area because the product can splash nearly everywhere and drop back into the trays or be a breeding ground for germs. The trays are transported through the whole line on Sectional Frames which are part of every module.

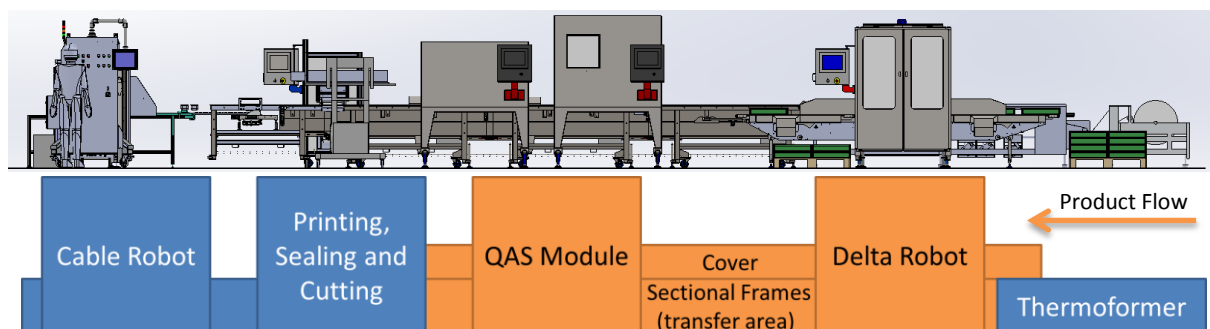


Fig. 1: Product contact areas (orange) in the fresh food line.

The next part after the Delta Robot is the transfer area followed by the QAS module. Both areas are shielded by a tunnel to protect the product from the dirt of the environment. The products placed in the trays by the Delta Robot can pollute the sectional frames and the shielding tunnels of the transfer

area and the QAS module in case of a pick-and-place-failure when the product was not put correctly into the tray. This means that the inner surfaces of the shielding tunnels and also the upper part of the sectional frames there have to be considered as product contact areas. After passing the QAS module the trays are sealed by the laser. This means this point on there is no risk of cross-contamination anymore and all following areas can be considered as non-product contact.

1.3 Ready Meal Line

The line for ready meals is very similar to the fresh food line. The chicken breasts come also in crates to the Delta Robot where they are picked and placed into the trays. Splashes can also occur and therefore the whole inner part of the robot has to be considered as product contact area.

The transfer area differs from the fresh food line. It contains additional dispensers for peas and mashed potatoes. This means in addition to the risk of a pick-and-place-failure by the Delta Robot there is another chance of product splashes from the dispensers which can pollute the tunnels and sectional frames. The product contact areas for the transfer area and the following QAS module are therefore also the inner tunnel surfaces and the upper sectional frame parts. The dispensers are situated beside the sectional frames so that only the nozzles will penetrate the line. They are purchased parts and will be cleaned out of place. All following areas can be seen as non-product contact since the next step is to seal the trays with the laser.

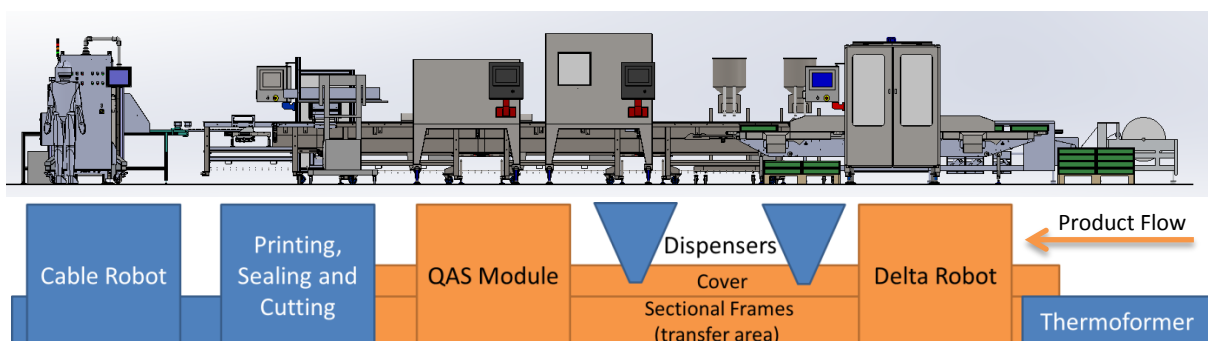


Fig. 2: Product contact areas (orange) in the ready meal line.

2 Cleanability Tests

2.1 Cleanability Concept

Cleanability is defined as the suitability of equipment to be freed from soil easily [EHEDG Guideline No. 2]. Product contact areas have to be easily cleanable with reasonable effort. This is only possible by following the hygienic design criteria (Hygienic Design Workshop, Bilbao, 04/26/2013). To evaluate the proper hygienic design of a part or module cleanability tests are done. Cleanability tests are ascertaining if the module can be cleaned or not and which parts are critical ones because they are hard to clean. The test is a screening test and indicative of performance in industrial cleaning situations. The onus lies on the users of the machines to verify the cleanability their products. Therefore, often a reference part is used which is cleaned with the same cleaning system. The

reference part and the regarded module are soiled reproducibly and cleaned afterwards in a defined way. When the reference is clean, the module is examined for areas which did not get cleaned.

2.2 Cleanability Tests with the Grippers

2.2.1 Test Method

The Grippers used in the PicknPack project are meant to be in direct contact with the food product. This means that all hygienic criteria must be fulfilled. All parts of the grippers, not only the ones which are in direct food contact, have to be easily cleanable with acceptable effort.

A two-step-approach was used to verify the cleanability of the two grippers. In the first step it was determined which parts are not cleanable at all. Therefore, an easily removable soil was used for the cleaning tests. In the second step it was determined which parts are hard to clean. For these cleaning tests a more persistent soil was used. The cleanability is tested against a cylindrical pipe (Fig. 5).

Because of the complex geometry of the grippers it was decided to clean them in a washing machine. The cleaning fluid was water at 40 °C.

The used soil in the first step was a liquid solution consisting of a strong red azo dye and a high amount of ethanol. It is called RET medium (supplied by GIR - The German Institute of Rehygienization GmbH) and is often used to determine spray shadow areas in food processing machines. The red colour can be easily detected. It can be easily applied to objects with a spraying device and dries very fast because of its high amount of ethanol. The cleanability tests in the washing machine were stopped after 2 minutes. After that time the grippers were taken out and examined for areas which were not cleanable from the RET medium

In Fig. 3 a gripper soiled with RET medium is shown. The soil crawls especially into critical areas like crevices. On big surfaces it tends to form droplets so they are only spottily soiled. But these surfaces are considered to be easily cleanable.

In the second step the tests were repeated with a persistent food soil to see which areas are harder to clean than others, what might also be critical regarding hygiene. Therefore custard was used as food model soil. It was poured over the grippers which then were dried for 24 hours. The custard has the advantage that it is fluorescent so that also small amounts can be detected under UV light (Fig. 4). The grippers were cleaned in the washing machine with water at 40 °C again. The progress was stopped after 3 minutes which was twice the time that was needed to clean a simple reference object (cylindrical pipe, soiled only on the outside, Fig. 5). A second test was done with a longer cleaning time of 30 minutes.

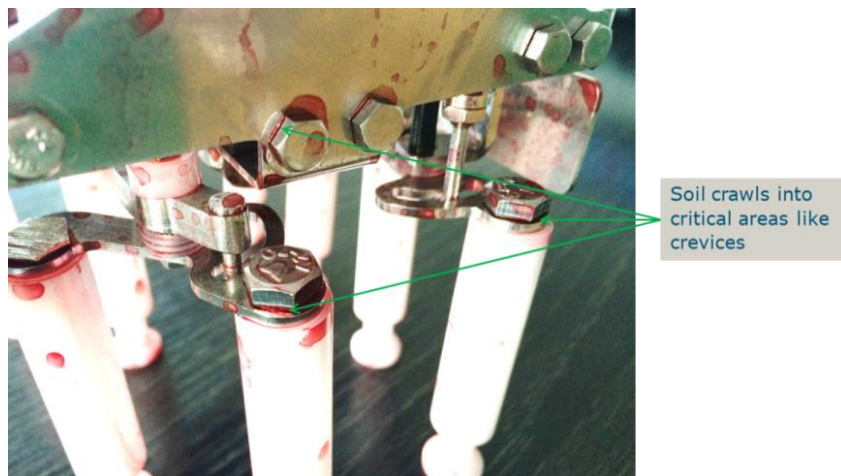


Fig. 3: Gripper soiled with RET medium.

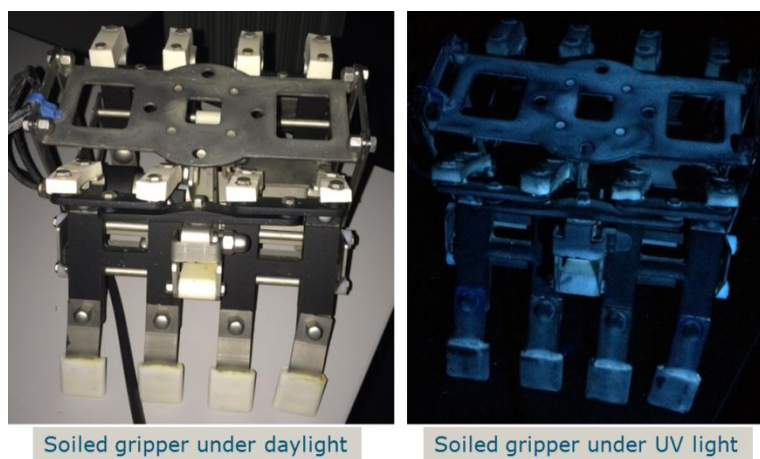


Fig. 4: Gripper soiled with custard under daylight (left) and UV light (right).



Fig. 5: Clean reference part (left) and reference part soiled with custard under UV light (right).

2.2.2 Assessment of general Cleanability

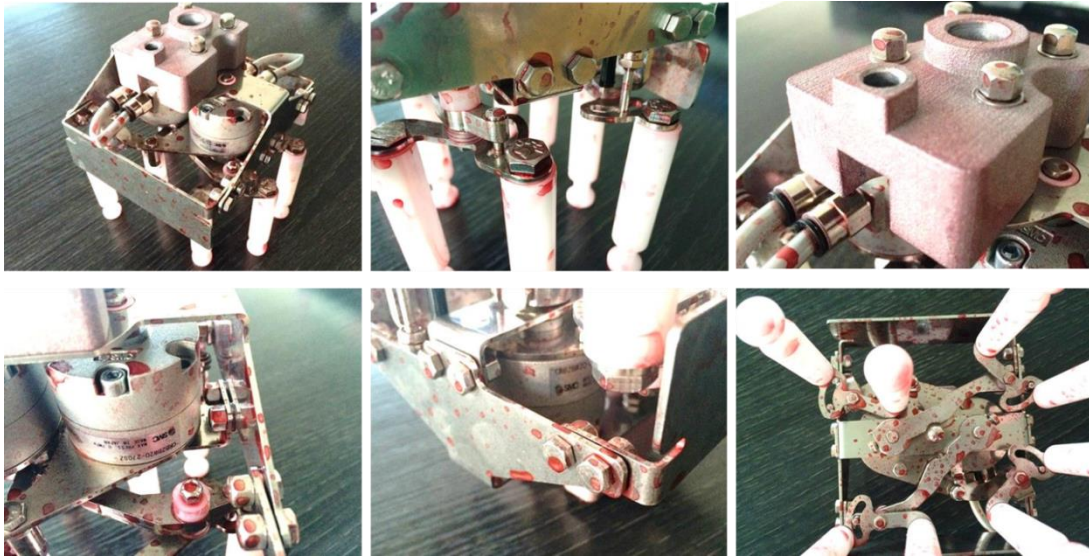


Fig. 6: Chicken Gripper soiled with RET medium before cleaning.

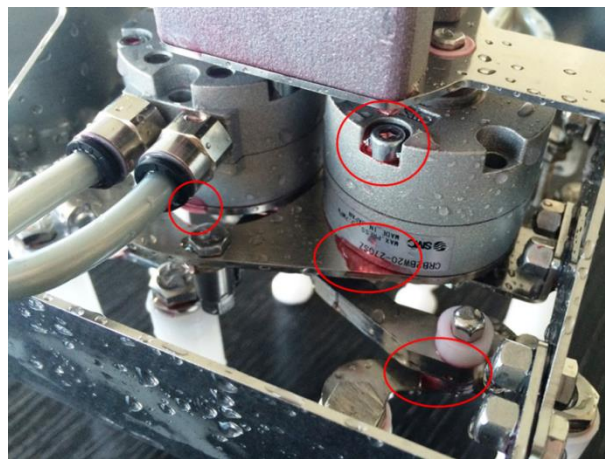


Fig. 7: Chicken Gripper after Cleaning – Critical parts: Metal-to-metal-connections.

The cleaning tests showed that most of the open surfaces were wetted and cleaned. But after the cleaning was stopped the soil started “bleeding” from critical areas revealing them as not cleanable. In Fig. 7 and the following figures these critical areas are marked for the Chicken Gripper.



Fig. 8: Chicken gripper after Cleaning – Critical parts: Metal-to-metal-connections.

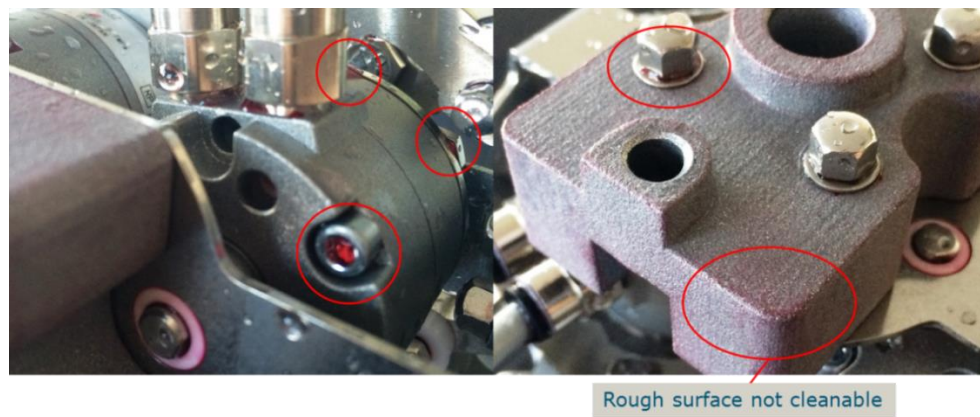


Fig. 9: Chicken gripper after Cleaning – Critical parts: Metal-to-metal-connections, hexagon socket (left), rough surfaces (right).

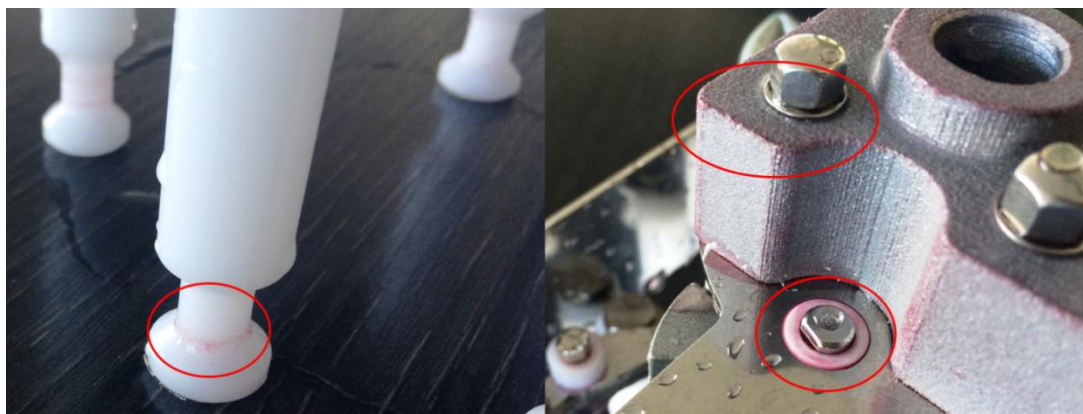


Fig. 10: Chicken gripper after Cleaning – Critical parts: non-cleanable material (left), rough surface, crevices (right).

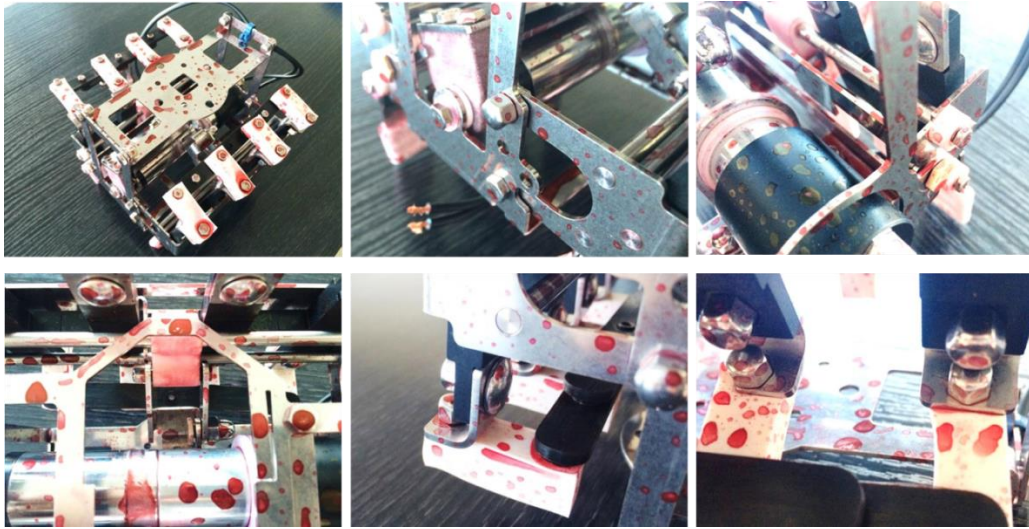


Fig. 11: Tomato Gripper before Cleaning.

Fig. 11 shows the soiled Tomato gripper before cleaning. The following figures show the gripper after the 2 minutes of cleaning and the resulting critical areas.

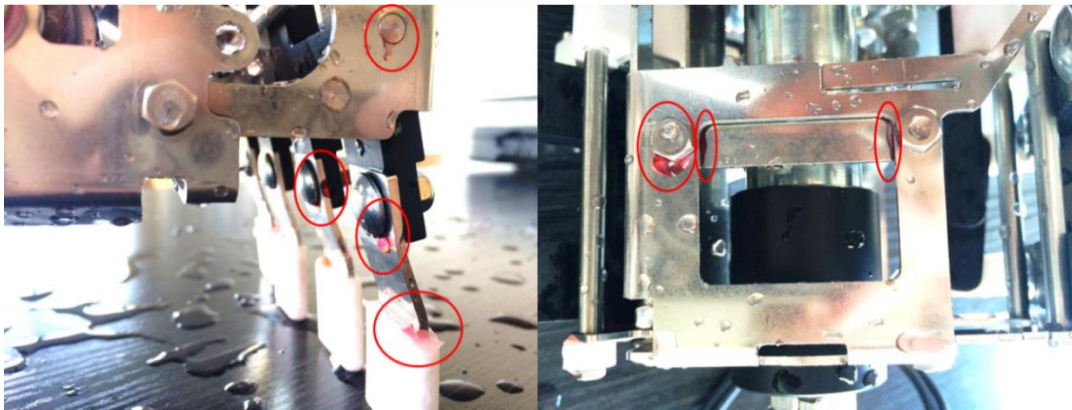


Fig. 12: Tomato Gripper after Cleaning – Critical parts: Metal-to-metal-connections, crevices, small gaps, sharp edges.

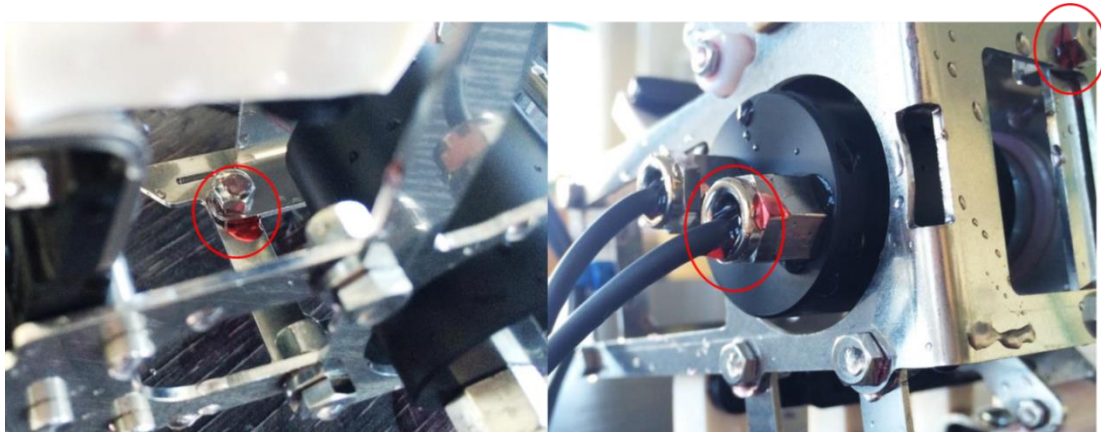


Fig. 13: Tomato Gripper after Cleaning – Critical parts: Metal-to-metal-connections (left), non-hygienic cable glands (right).

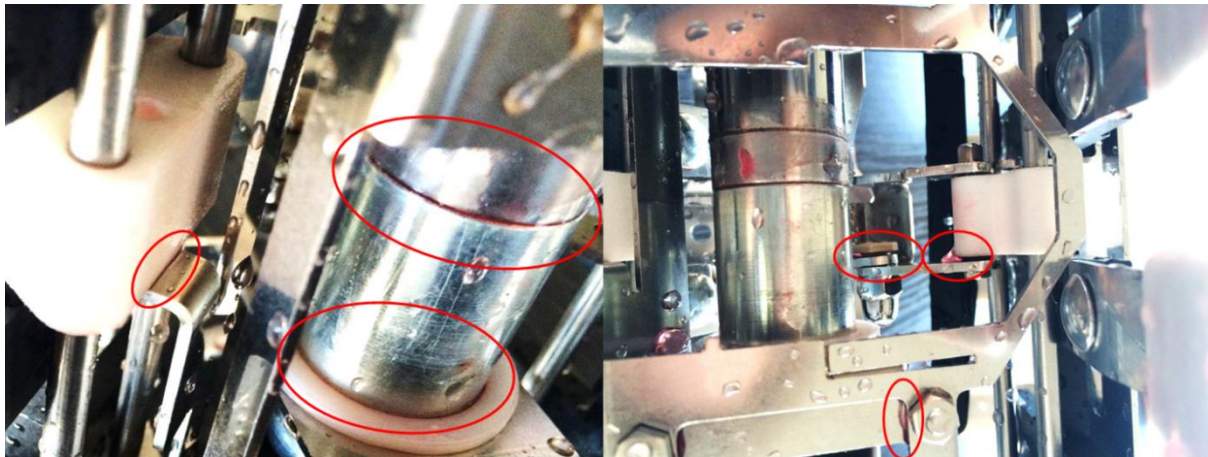


Fig. 14: Tomato Gripper after Cleaning: – Critical parts: Crevices (left), small gaps (right).

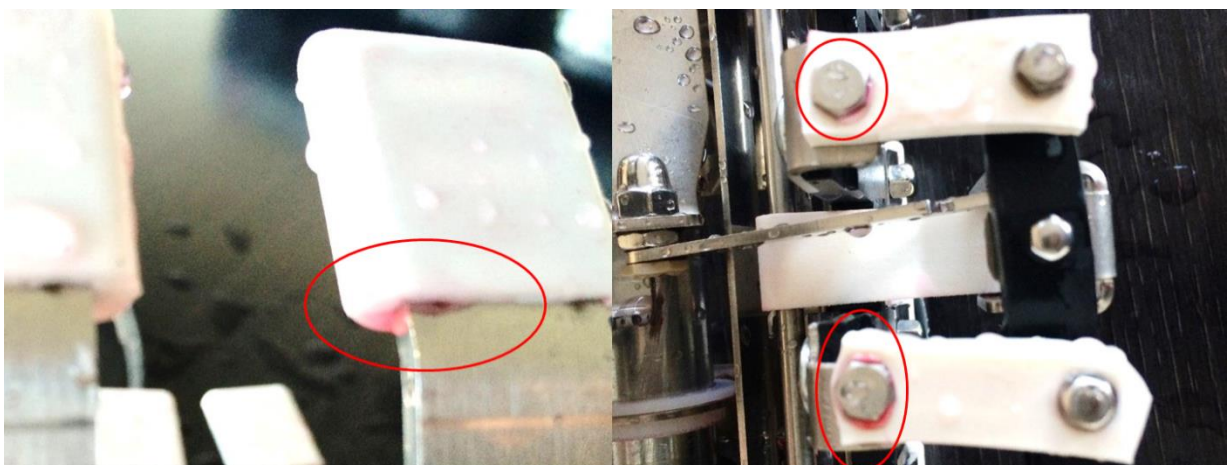


Fig. 15: Tomato Gripper after Cleaning – Critical parts: Crevices, sharp edges.

For both grippers could be shown, that it is possible to reach all open surfaces within the cleaning procedure in a washing machine. All of those surfaces get at least wetted, so that the RET medium

could be removed. But there were also a lot of critical spots on both grippers which were not cleanable at all. Those were especially:

- Crevices and small gaps,
- Sharp edges,
- Rough surfaces,
- And metal-to-metal-contacts.

These critical areas have to be redesigned because soil can easily accumulate there so that it can serve for germs as breeding ground. Improvement measures are listed in chapter 3.

2.2.3 Assessment of critical areas (hard to clean)

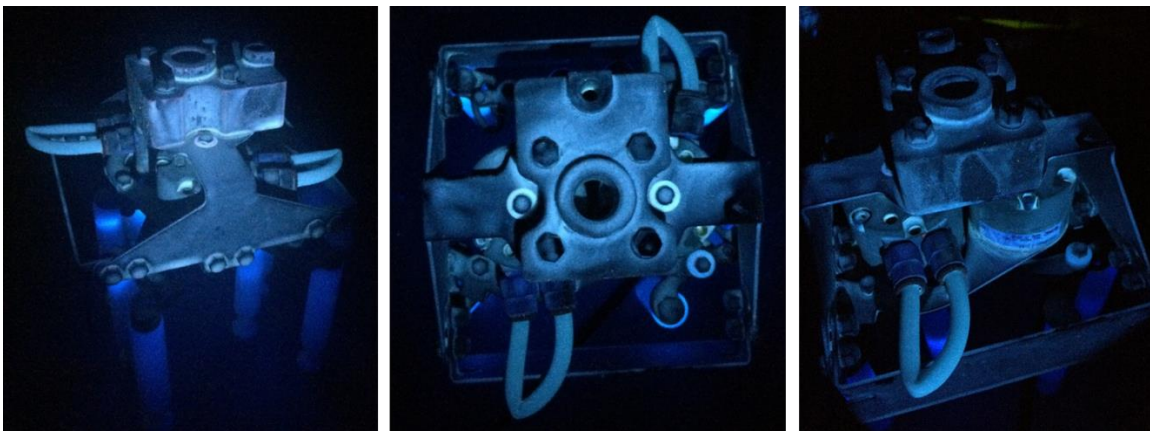


Fig. 16: Chicken Gripper soiled with custard before cleaning.

Fig. 16 shows the soiled Chicken Gripper before cleaning. It has to be considered that some parts (like white plastic or the pneumatic hoses) are also fluorescent even if not soiled. Fig. 17 to Fig. 21 show the Chicken gripper after 3 minutes of cleaning and reveal spots which not cleanable with reasonable effort.

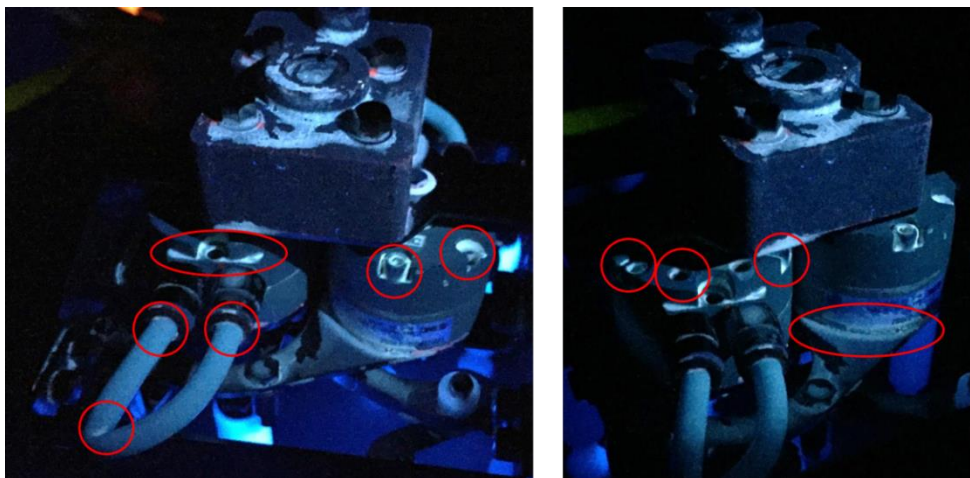


Fig. 17: Chicken gripper after 3 minutes of cleaning – Critical parts: Small gaps, crevices.

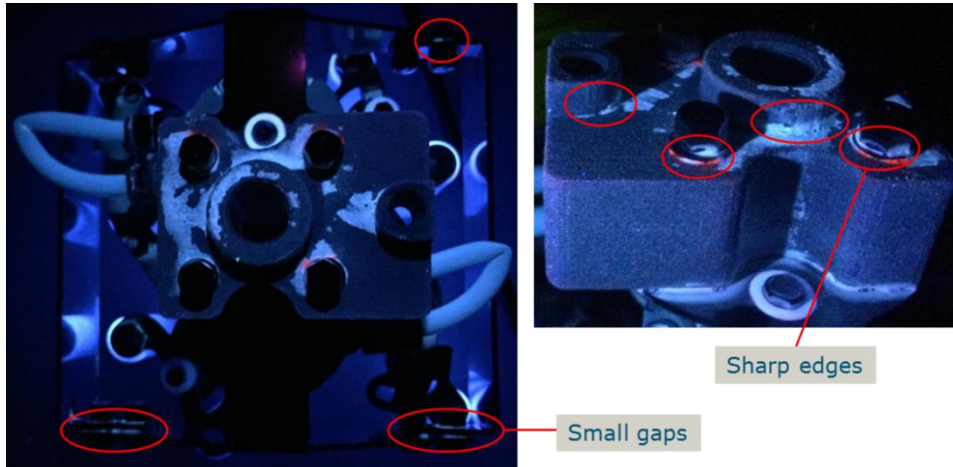


Fig. 18: Chicken gripper after 3 minutes of cleaning – Critical parts: Crevices, sharp edges.

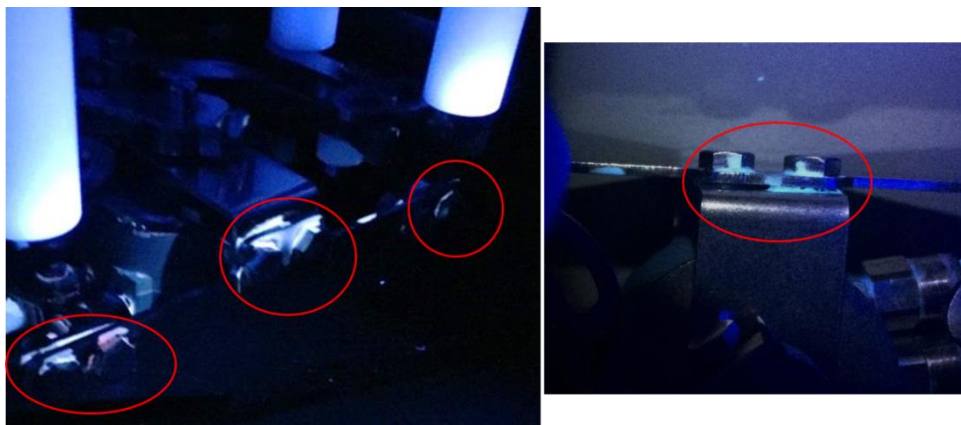


Fig. 19: Chicken gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections on hexagon bolts.

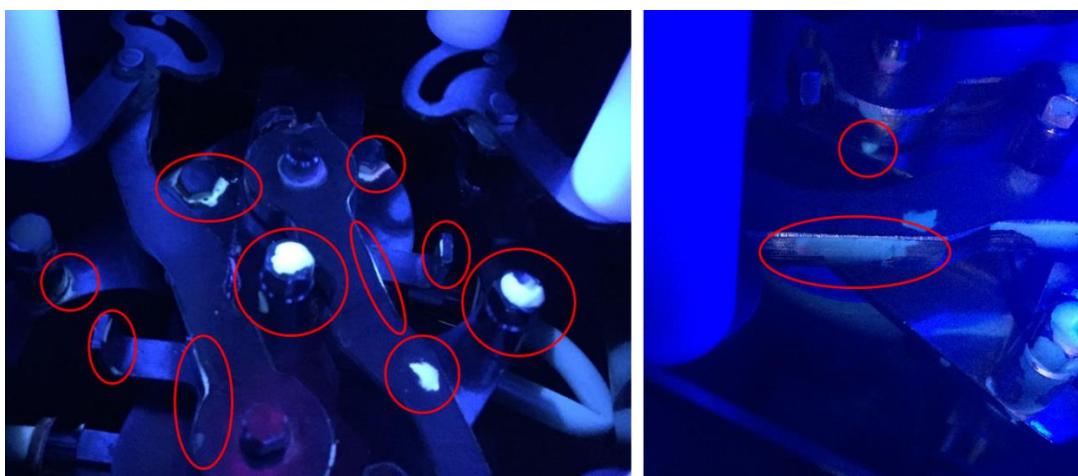


Fig. 20: Chicken gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections, spray shadow areas.

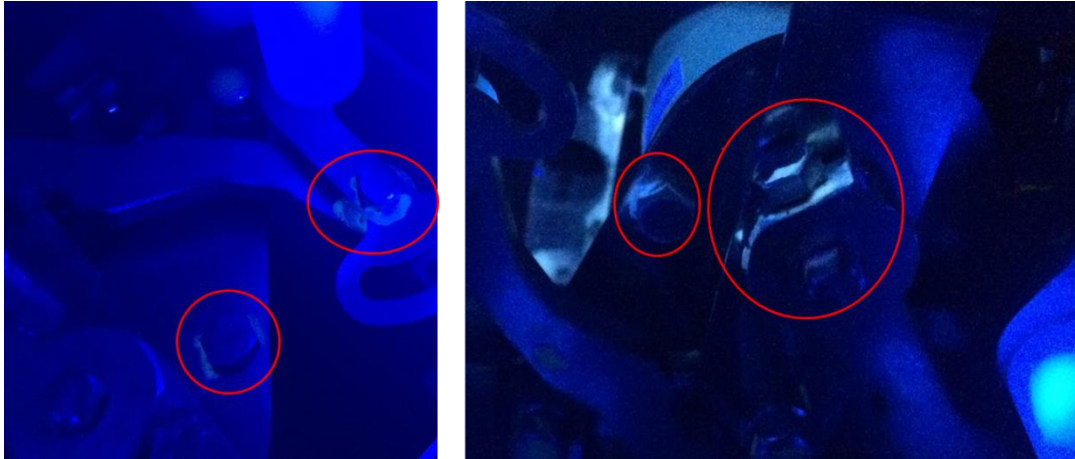


Fig. 21: Chicken gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections.

Fig. 22 to Fig. 24 reveal that there are critical spots even after a very long cleaning time of 30 minutes.



Fig. 22: Chicken gripper after 30 minutes of cleaning – Critical parts: Crevices.

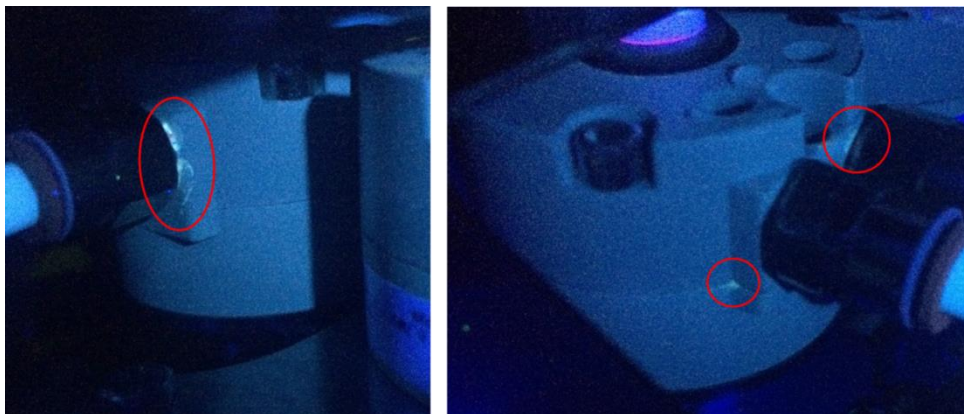


Fig. 23: Chicken gripper after 30 minutes of cleaning – Critical parts: Crevices.



Fig. 24: Chicken gripper after 30 minutes of cleaning – Critical parts: Crevices.

Fig. 25 shows the soiled Tomato Gripper before cleaning.

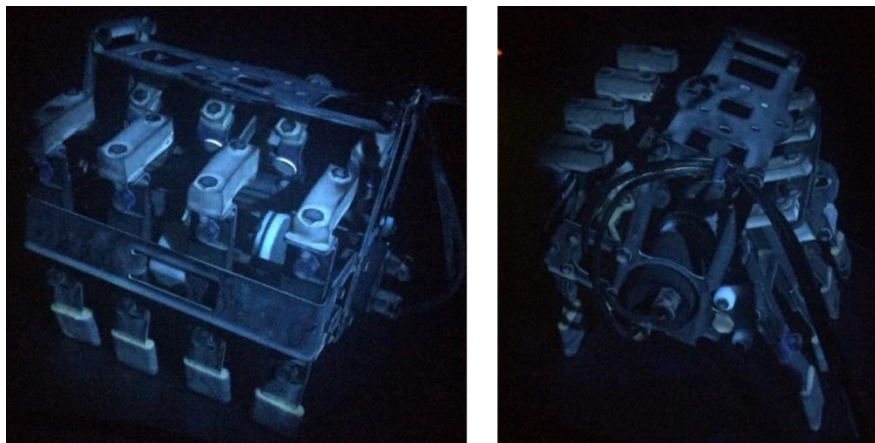


Fig. 25: Soiled Tomato Gripper before Cleaning.

Fig. 26 to Fig. 35 show the Tomato Gripper after the 3 minute cleaning procedure marking its critical areas.

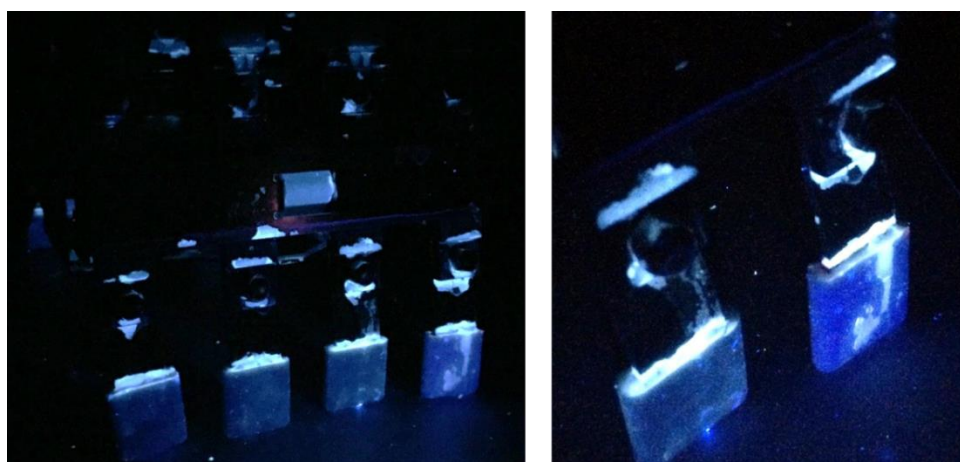


Fig. 26: Tomato Gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections, crevices, sharp edges.

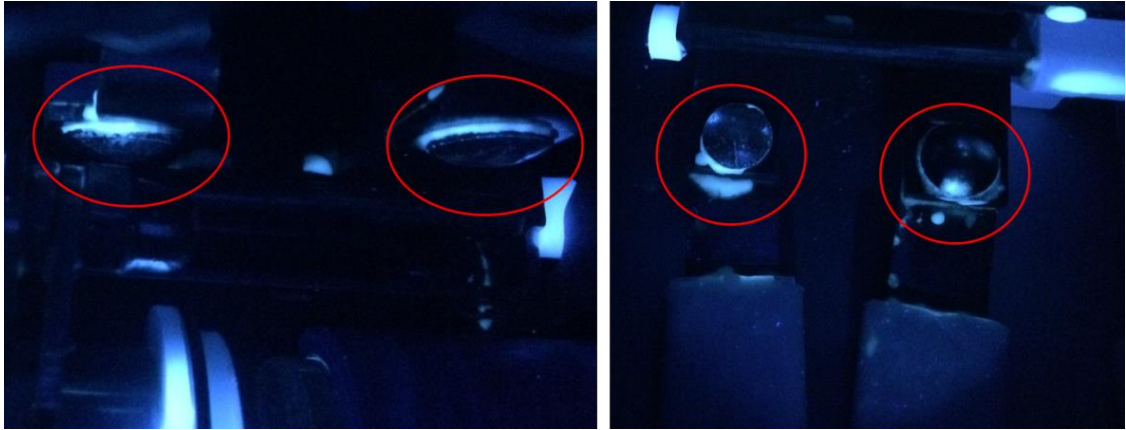


Fig. 27: Tomato Gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections.

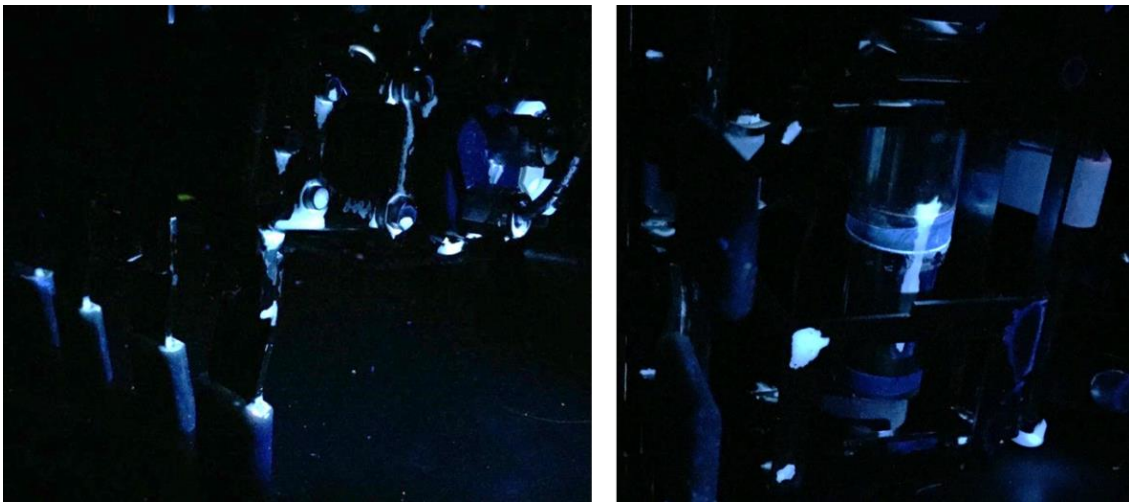


Fig. 28: Tomato Gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections, spray shadow areas, crevices.

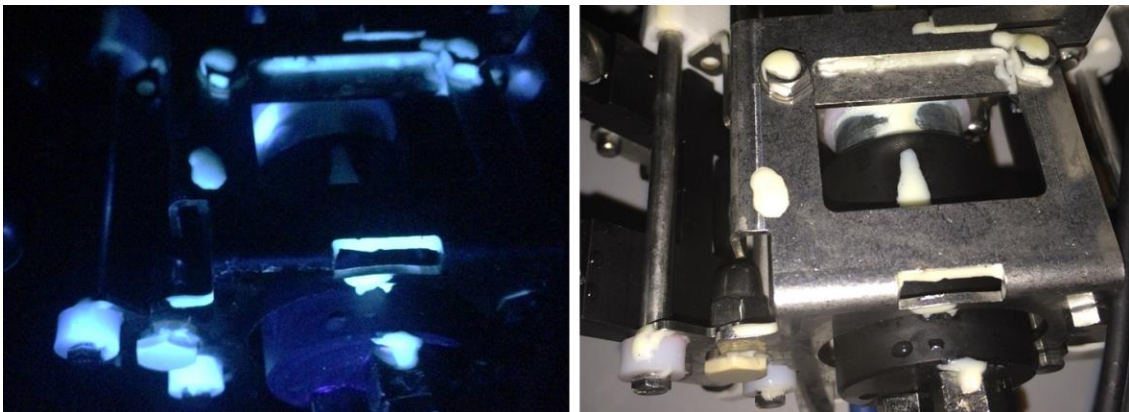


Fig. 29: Tomato Gripper after 3 minutes of cleaning – Critical parts: Crevices, spray shadow areas.

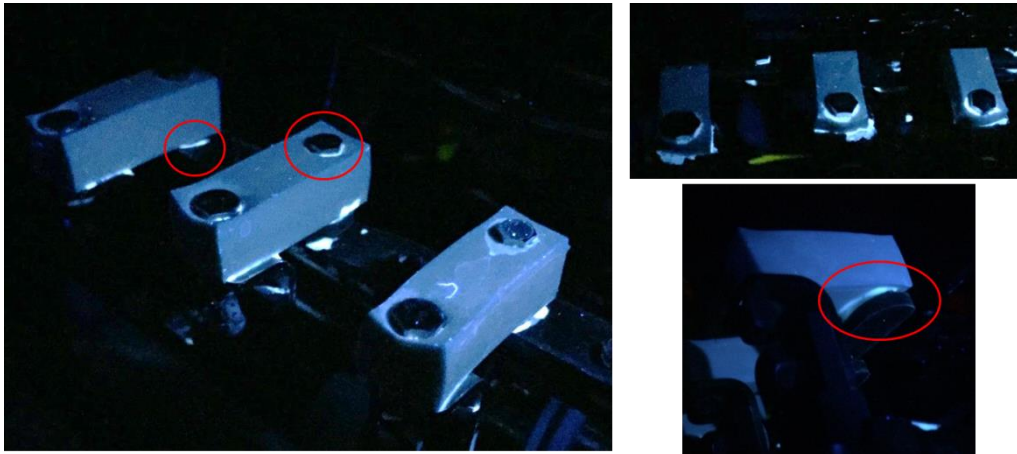


Fig. 30: Tomato Gripper after 3 minutes of cleaning – Critical parts: Crevices (plastic parts are self-fluorescent!).

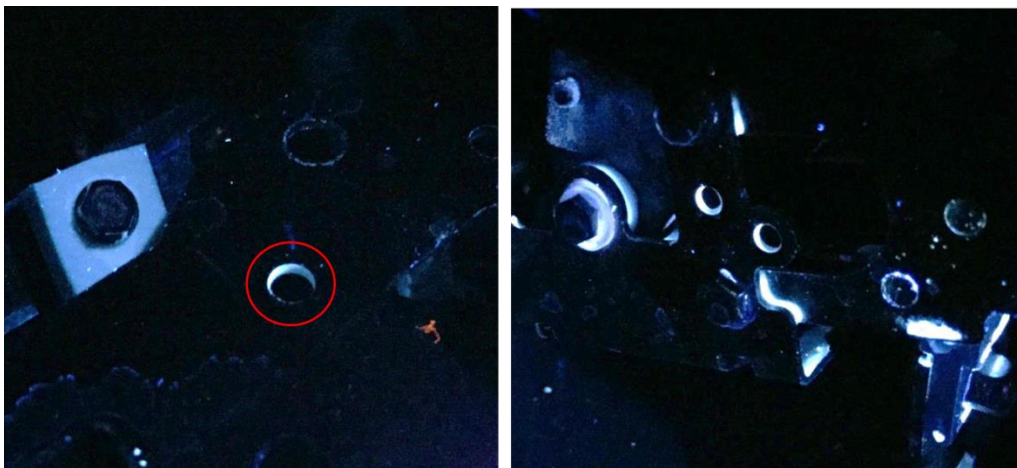


Fig. 31: Tomato Gripper after 3 minutes of cleaning – Critical parts: Spray shadow areas.

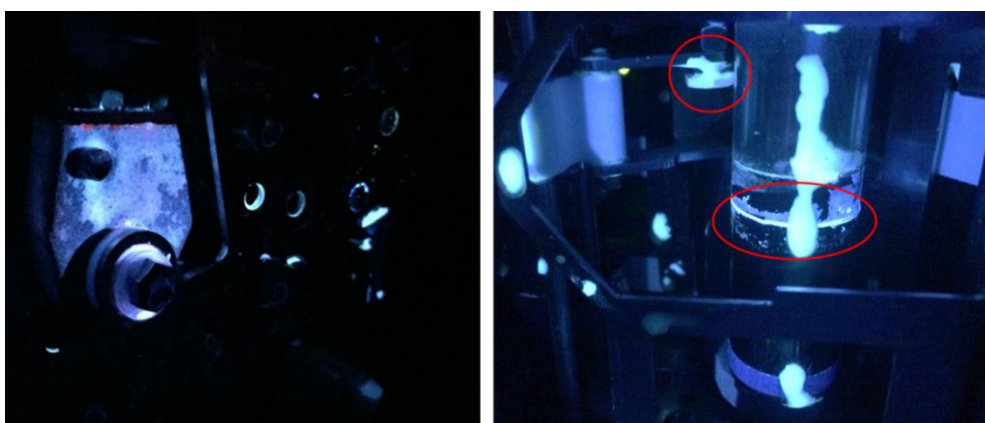


Fig. 32: Tomato Gripper after 3 minutes of cleaning – Critical parts: Crevices, small gaps, Spray shadow areas.



Fig. 33: Tomato Gripper after 3 minutes of cleaning – Critical parts: Non-hygienic cable fixers and cable glands.

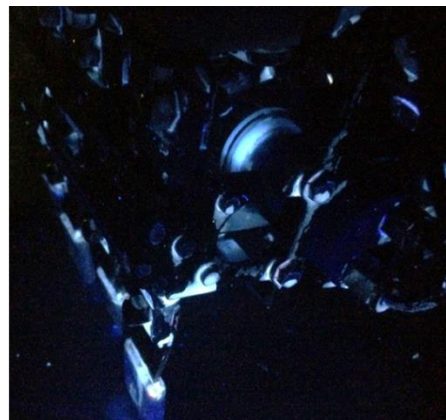
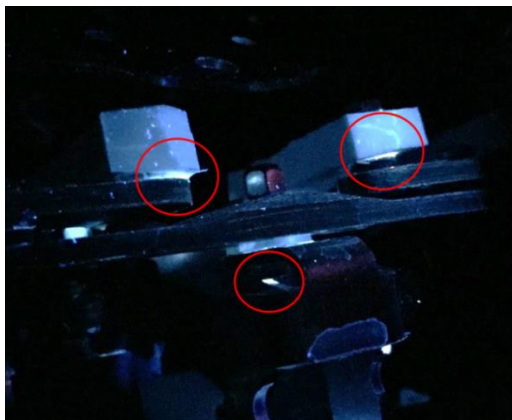


Fig. 34: Tomato Gripper after 3 minutes of cleaning – Critical parts: Small gaps (left), Metal-to-metal-connections, crevices, spray shadow areas (right).

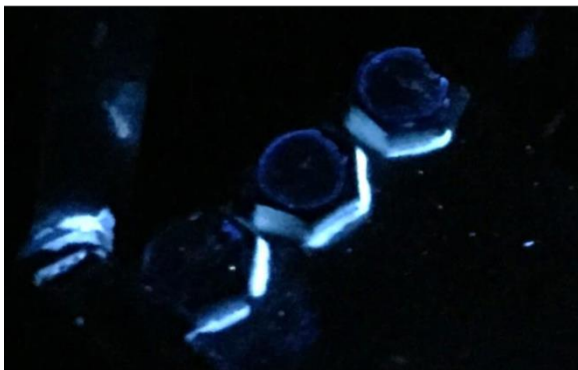


Fig. 35: Tomato Gripper after 3 minutes of cleaning – Critical parts: Metal-to-metal-connections.

Fig. 36 to Fig. 38 show the Tomato Gripper after 30 minutes of cleaning.

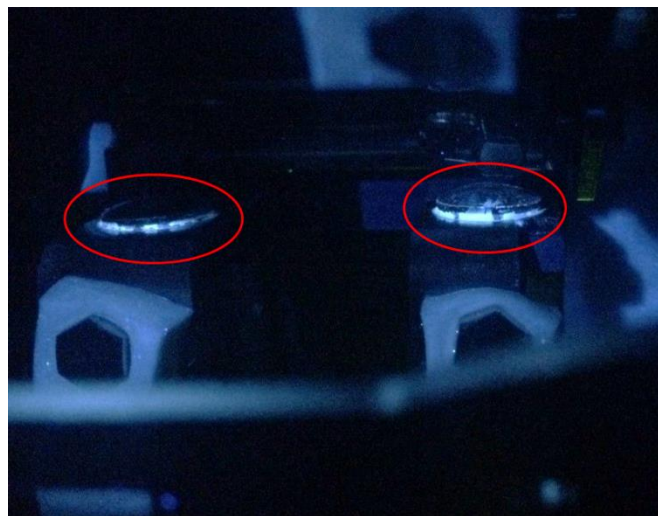


Fig. 36: Tomato Gripper after 30 minutes of cleaning – Critical parts: Metal-to-metal-connections.



Fig. 37: Tomato Gripper after 30 minutes of cleaning – Critical parts: Metal-to-metal-connections.



Fig. 38: Tomato Gripper after 30 minutes of cleaning – Critical parts: Spray shadow areas.

For both grippers it could be shown that their complex geometries lead to several areas which are very hard to clean. Due to non-hygienic design features in those areas the cleaning effect is pretty poor. After the short cleaning procedure of 3 minutes widespread soil remains in areas which are hard to reach for the cleaning fluid. After the long cleaning procedure soil still remains on critical, complex areas, which are similar to the ones which were detected within the tests with the RET medium. The marked areas should be redesigned according to hygienic design criteria. Parts should be reduced on both grippers to make all areas better accessible for the cleaning fluid. Particularly critical are the high number of metal-to-metal contacts and the resulting crevices and small gaps which have to be sealed. In addition there are a lot of sharp edges which need to be removed.

In the current state it would be a high risk to use the grippers in direct contact with the product in a food production line, because there are too many spaces where soil can accumulate and germs can grow.

2.3 Cleanability Tests with the Delta Robot

2.3.1 Cleaning System for the Delta Robot

The Delta Robot itself is not in direct contact with the product. It only holds the gripper which does the picking and placing. Nevertheless, it is likely to be contaminated by product splashes. If these food residues cannot be removed, they are providing a breeding ground for germs or can fall back into the product stream. Therefore, it has to be ensured that all relevant parts can be reached by the cleaning fluid. Two different cleaning concepts have been chosen for the Delta Robot. The first strategy is to clean it with fixed nozzles. The other concept is to clean it with a Mobile Cleaning Device which moves through the whole line. Both concepts will be implemented in the line to compare them towards effectiveness and efficiency.

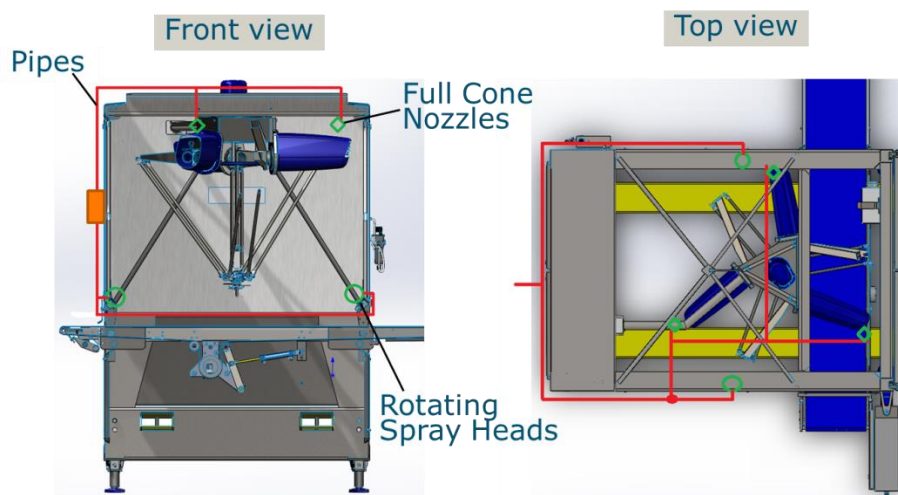


Fig. 39: Cleaning System with fixed nozzles on the Delta Robot.

The fixed nozzle system consists of two rotating spray heads in the bottom part which do the main part of the cleaning and three full cone nozzles in the top area which support the cleaning in spray shadow areas (Fig. 39). These positions were determined by means of spray shadow simulation. The

Mobile Cleaning Device carries several nozzles. For the Cleaning of the Delta Robot only one Rotating Spray Head is activated. The full cone nozzles from the fixed nozzle system can also support the Mobile Cleaning Device.

2.3.2 Test Method

Cleanability tests have been performed to find critical areas within the Delta Robot and to compare the both cleaning concepts. As model soil the RET medium was used. Since it is easily removable, it can be used perfectly for finding out spray shadow areas in an open cleaning system. It can be also used very good to compare the cleanability of a module with different cleaning systems, in this case the cleaning with the fixed nozzles and the Mobile Cleaning Device.

For the cleaning with the fixed nozzle system, the robot module was completely sprayed with the RET medium. The cleaning process was started with the two rotating spray heads. After several time steps the process was paused and photos were taken of the critical areas which didn't get cleaned within this time. The time steps were 1 minute, 3 minutes, 10 minutes, 20 minutes and 30 minutes (total cleaning time). For the last cleaning step also the three full cone nozzles were used to see if they are able to clean the areas which the rotating spray heads were not able to reach.

For the cleaning with the Mobile Cleaning Device the robot was completely soiled again. For the cleaning the Mobile Cleaning Device was pulled from one side of the robot to the other and then back. The pulling was performed at different speeds. After each run the cleaning was paused and photos were taken. The cycle times were 2 minutes, 8 minutes and 10 minutes (20 minutes in total just as with the two fixed rotating spray heads).

The nozzles were supplied with the cleaning fluid by two CIP racks from Ecolab, which were provided by the University of Lincoln. The tests were performed at the National Centre for Food Manufacturing in Holbeach (UK). The CIP racks provided constant flow rates for the different cleaning fluids. The cleanability tests with the RET medium were performed with water at room temperature. The provided flow rate with water was around 150 l/min. Since the concept is to clean the PicknPack line with foam, there were also done foaming tests to see if the cleaning devices are able to reach all relevant areas with the foam and also to rinse it away properly.

2.3.3 Tests with the fixed nozzle system

The first cleanability tests were performed with the fixed nozzles on the Delta Robot. At first only the two rotating spray heads were used to see if they are able to clean the robot by themselves. Fig. 40 shows the Delta Robot soiled with RET medium.

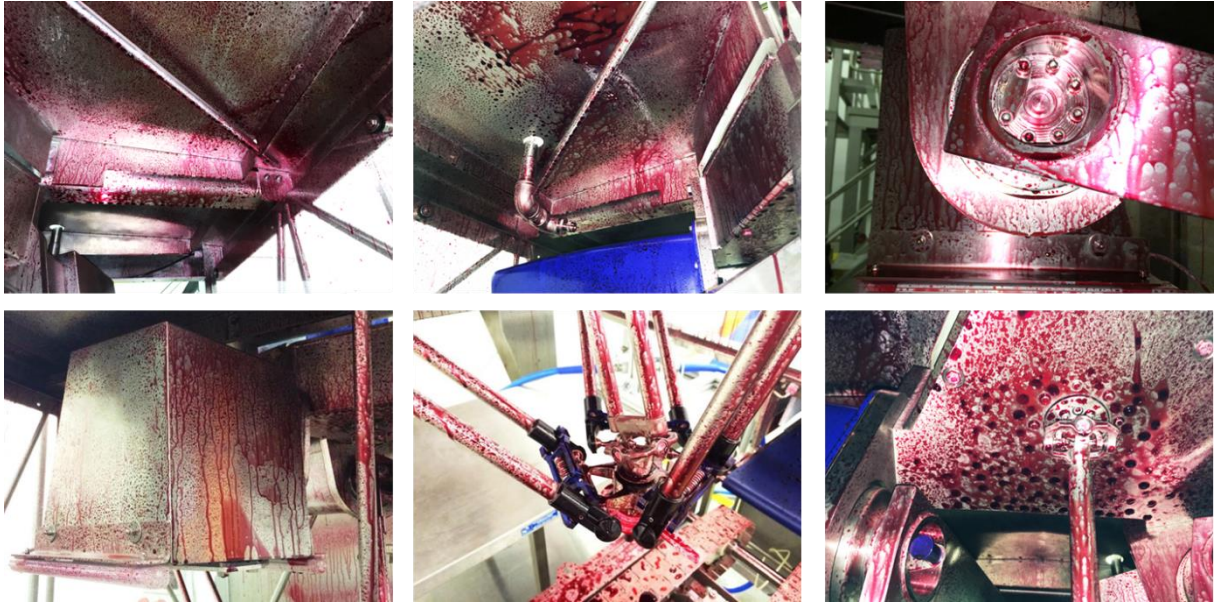


Fig. 40: Delta Robot soiled with RET medium.



Fig. 41: Delta Robot after 1 minute of cleaning with the fixed nozzles.



Fig. 42: Delta Robot after 1 minute of cleaning with the fixed nozzles.

Fig. 41 and Fig. 42 show the robot after the first minute of cleaning. It can be seen that the soil got wetted in the most parts of the robot but it was not possible to rinse it away in a lot of areas. Only in areas of high direct fluid impact near to the nozzles surfaces were already clean. Some areas also didn't get wet at all. Those were especially surfaces in the front ceiling area where spray shadows occurred due to stability geometries which were not known by Fraunhofer before the tests and before the cleaning system was designed (Fig. 41 (right), Fig. 43, Fig. 49, Fig. 50).

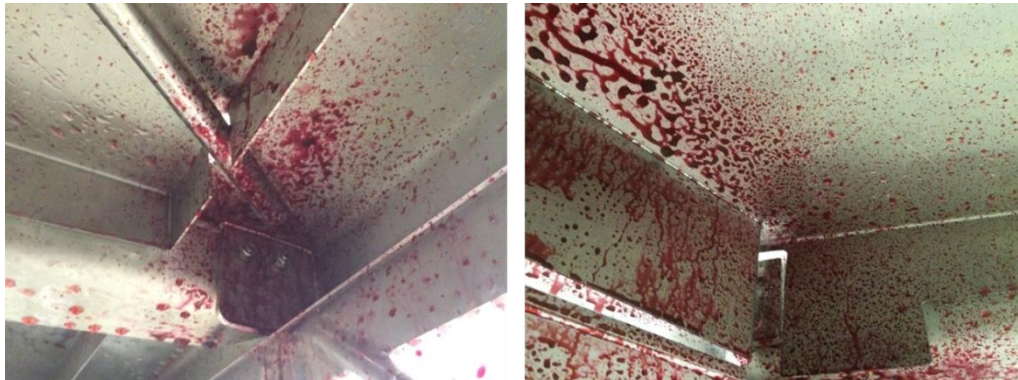


Fig. 43: Delta Robot after 3 minutes of cleaning with the fixed nozzles – spray shadow areas.

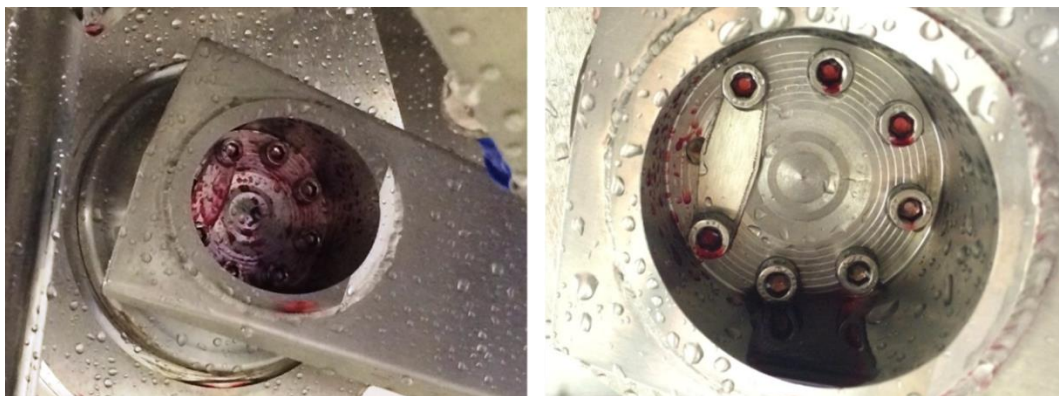


Fig. 44: Delta Robot after 10 minutes of cleaning with the fixed nozzles – spray shadow areas, metal-to-metal-connections.



Fig. 45: Delta Robot after 10 minutes of cleaning with the fixed nozzles – crevices, metal-to-metal-connections.

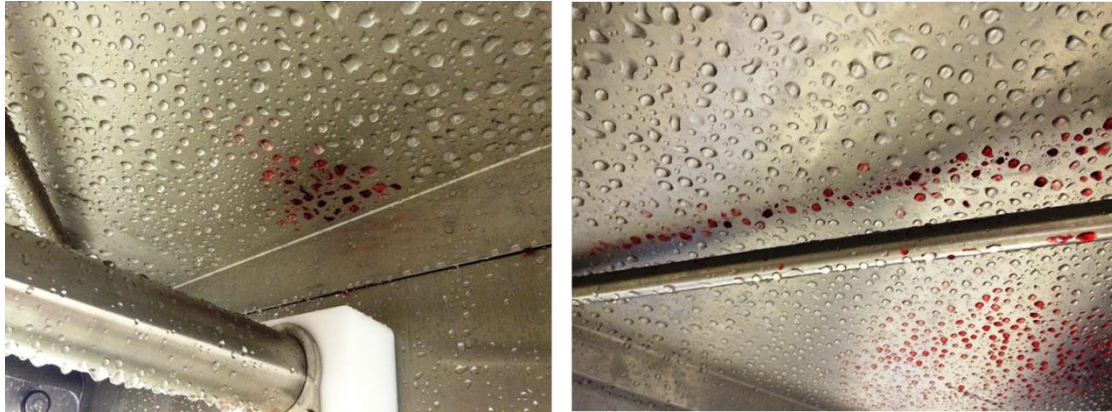


Fig. 46: Delta Robot after 10 minutes of cleaning with the fixed nozzles – spray shadows.

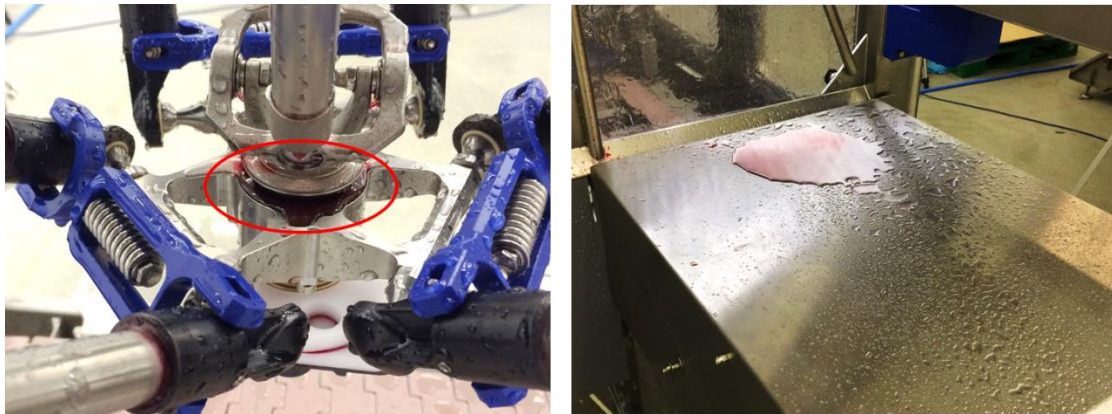


Fig. 47: Delta Robot after 10 minutes of cleaning with the fixed nozzles – complex geometries and metal-to-metal-connections (left), not drainable surfaces, robot not fully sealed (right).

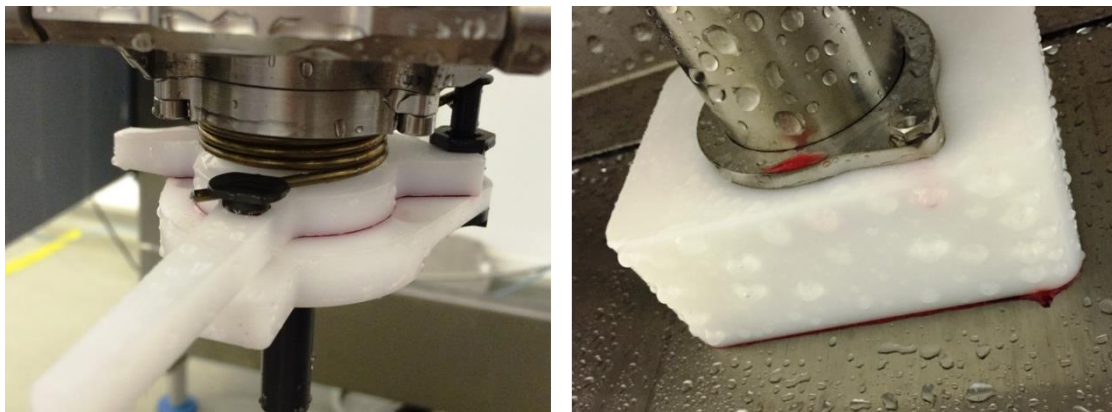


Fig. 48: Delta Robot after 20 minutes of cleaning with the fixed nozzles – crevices.

Fig. 43 to Fig. 48 show the robot after 3 minutes, 10 minutes and 20 minutes of cleaning. It can be seen that especially on complex geometries there are some areas where cleanability is poor. In the top area spray shadows can occur e.g. due to the crossbars beneath the ceiling in combination with the immobile nozzles. Also the inside of the orifices on the inner side of the motor blocks is not cleanable and critical. Unwanted stagnant water can occur on horizontal surfaces inside the robot

but also outside since the casing is not completely closed and sealed. Fig. 49 shows the most critical surfaces in the front ceiling area, which didn't get wetted at all.



Fig. 49: Delta Robot after 20 minutes of cleaning with the fixed nozzles – spray shadows.

Fig. 50 in comparison shows the same area after another 10 minutes of cleaning with the three full cone nozzles in the top area. It can be seen that they also were not able to clean this area. This means their current position is not ideal and must be optimised.



Fig. 50: Delta Robot after extra 10 minutes of cleaning with the full cone nozzles – spray shadows.

2.3.4 Tests with the Mobile Cleaning Device

Following to the tests with the fixed nozzles tests were performed with the mobile cleaning device. Regarding the Delta Robot it mainly consists of one moving rotating spray head. The results after the three cleaning steps mainly revealed the same critical areas as the tests with the fixed nozzles. Complex geometries are still hard to clean and spray shadows in the front ceiling area and inside the orifices on the motor blocks still remain since the Mobile Cleaning Device is mainly running on the path between the two fixed nozzles. But in some areas spray shadows have also been reduced due to the movement of the cleaning device. Fig. 51 shows an example for that. The surfaces behind the crossbars in the top area get cleaned significantly better due to the changing spray angle because of

the moving device. The fixed immobile nozzles had created spray shadows there so that some areas could not be cleaned.



Fig. 51: Improved cleaning behind crossbars in the top area due to the movement of the cleaning device.

So it can be stated that cleanability can be improved with the Mobile Cleaning Device in comparison to the cleaning with the fixed nozzles but it is still not possible to reach all areas of the robot. Therefore it is suggested to use the Mobile Cleaning Device in combination with optimised full cone nozzles for the spray shadow areas beneath the ceiling. Nevertheless, critical and non-cleanable areas of the Delta Robot should be redesigned as far as possible. A redesign is recommended.

2.3.5 Foaming tests

The cleanability tests have been performed with water. The cleaning demonstration within the final PicknPack line is meant to be done with foam. Therefore foaming tests were done with different rotating spray heads. The aim was so see if all relevant areas can be covered with foam by those nozzles. Afterwards it is also important that the foam can be rinsed away fast enough.



Fig. 52: Delta robot after foaming with rotating spray head.



Fig. 53: Delta robot after foaming with rotating spray head.

Fig. 52 and Fig. 53 show the robot after the foaming procedure. It could be shown that all used rotating spray heads were able to cover most of the robot with foam. Only in the front ceiling area the same spray shadows could be monitored which were also determined within the cleanability tests.

For rinsing the foam away it turned out that the slowly rotating spray heads are generating the best results. Quickly rotating spray heads are creating a lower local flow rate so that foam in bigger distances is only rinsed away very slowly. The slowly rotating spray heads in comparison are supplying a very high local flow rate so that it is possible to carry the foam away also about higher distances.

2.4 Cleanability Tests with the Shielding Tunnels

2.4.1 Covers of the Transfer Area

In the transfer area from the Delta Robot to the QAS module a tunnel is shielding the product trays from the dirt of the environment. This tunnel needs to be cleaned from the inside automatically with flat fan nozzles.

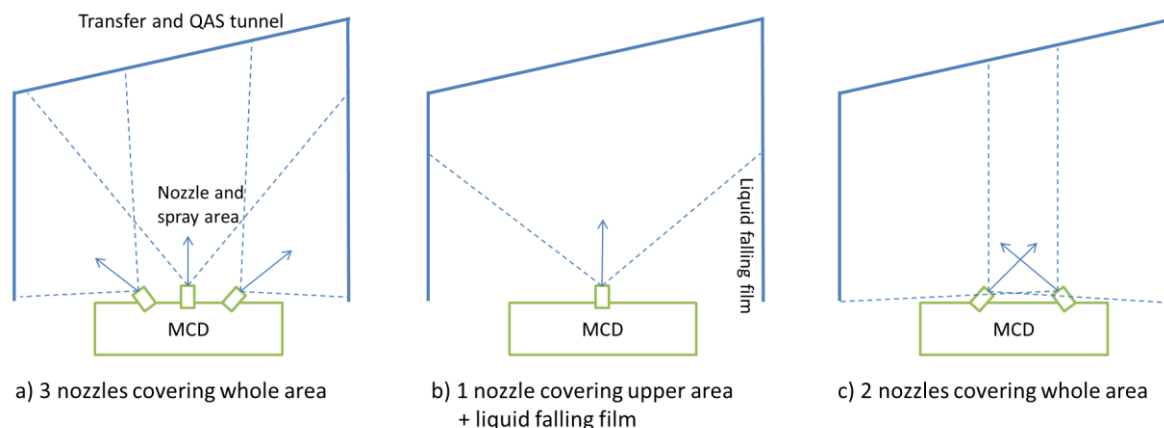


Fig. 54: Different concepts of nozzle arrangement for efficient cleaning of the inner tunnel surface.

Fig. 54 shows different possibilities of how the nozzles can be arranged on the Mobile Cleaning Device. To find out which solution is working most efficiently while guaranteeing a safe cleaning, tests have been performed on a tunnel mockup. The mockup was soiled with RET medium. Different nozzles were mounted on a frame of Item profiles which was pulled through the tunnel at different speeds. The cleaning fluid was water at room temperature.



Fig. 55: Mockup of the tunnel and mockup of Mobile Cleaning Device.

The tests showed that that one nozzle with a wide spray angle and a high flow rate can be enough for a sufficient cleaning (Fig. 54, solution b). If it is pulled slowly enough the liquid falling film is able to clean the sidewalls which are only wetted indirectly. In comparison, by using two nozzles with a lower flow rate it is possible to wet the whole inner surface (Fig. 54, solution c). Due to the direct spray impact it is possible to pull the cleaning device faster through the tunnel. This means the solution with two nozzles can be more efficient than using only one nozzle. This design will be used for further tests. The use of three nozzles for better overlapping of the spray areas is not necessary.

2.4.2 Tunnel in the QAS Module

The QAS module also contains a tunnel which separates the product stream from the sensors. It protects the product from dirt of the environment but also protects the sensors from the cleaning fluid cleaning the sectional frames. Its geometry is nearly the same as it is for the tunnel of the transfer area. Therefore, no additional tests were necessary to ensure the cleanability of the QAS tunnel.

3 Suggestions for revision and improvement of Hygienic Design

3.1 Suggestions Grippers

According to the cleanability tests with the grippers some major changes have to be made on the design to make them suitable for the use in direct food contact. The most important measures are:

- Reduce the number of parts to decrease complexity and increase accessibility.
- Reduce critical geometries:
 - o Sharp edges,
 - o Crevices and small gaps,
 - o Rough surfaces,
 - o Metal-to-metal-contacts.

On behalf of these recommendations Lacquey has already made design suggestions to improve the cleanability of the grippers, which are shown in Fig. 56 to Fig. 61. Those improvement suggestions are going to be implemented as soon as functionality tests of the grippers are finished.

Regarding the motor on the Chicken Gripper it is planned to replace it by a new FDA approved pneumatic motor made from POM by Rotomation which has no crevices.

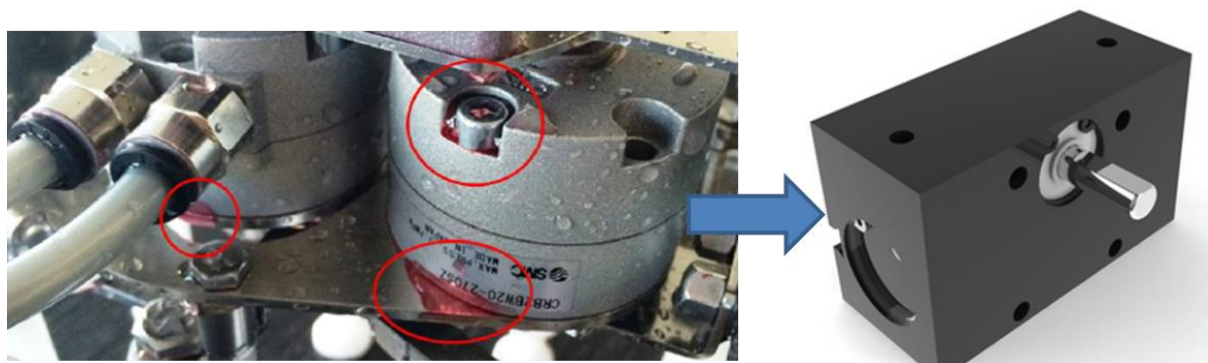


Fig. 56: Design solution with an FDA approved pneumatic motor for the Chicken Gripper.

Regarding the high number of hexagon bolts which are creating also a lot of critical crevices it is planned to use hygienic hexagon bolts which are using a seal to avoid metal-to-metal-contacts.

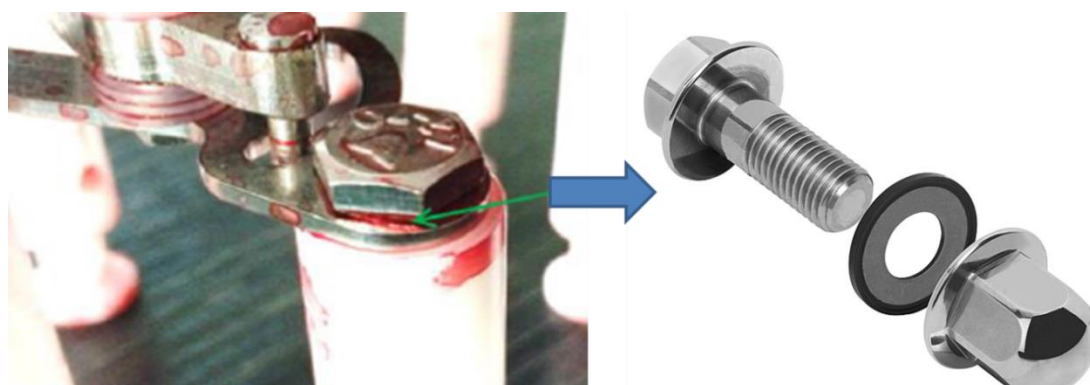


Fig. 57: Solution with sealed hexagon bolts to avoid metal-to-metal-contact.

The tested grippers were prototypes which were built with focus on functionality. Therefore some parts were not produced according to hygienic design criteria to keep the costs low when they have to be produced in different versions. One example for this are 3D printed parts which got a rough surface that is hard to clean. In the final version of the gripper those parts will be milled so that they are easily cleanable.

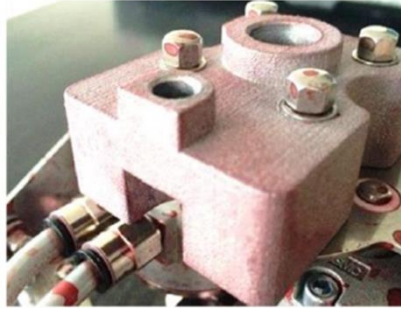


Fig. 58: Replacing 3D printed prototype parts by milled parts.

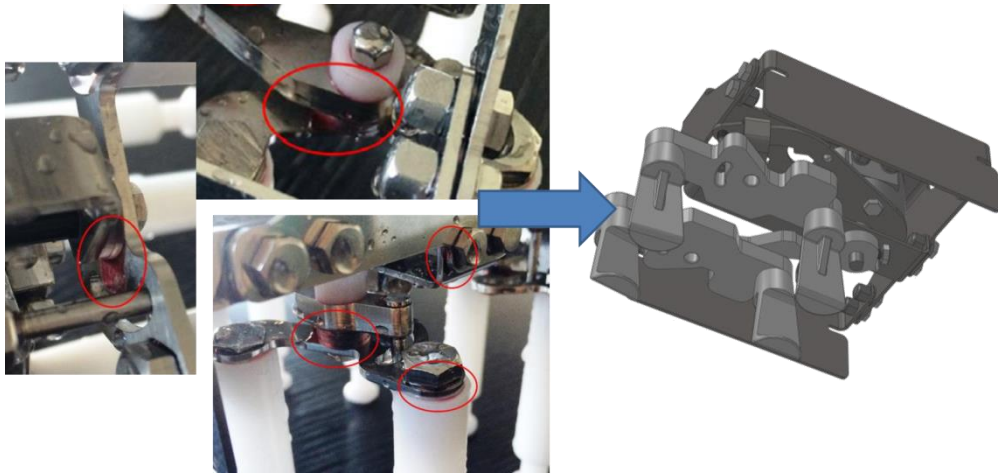


Fig. 59: Solution with decreased number of parts on the Chicken Gripper by milling it from one piece.

There were a lot of single parts in the prototype which were connected by joints because it was necessary to gain flexibility during the functionality tests. In the final design the number of parts will be reduced significantly so that several areas can be milled out of one part to reduce joints. In addition, the tests have shown that the number of fingers on the Chicken Gripper can be reduced so that complexity is decreased.

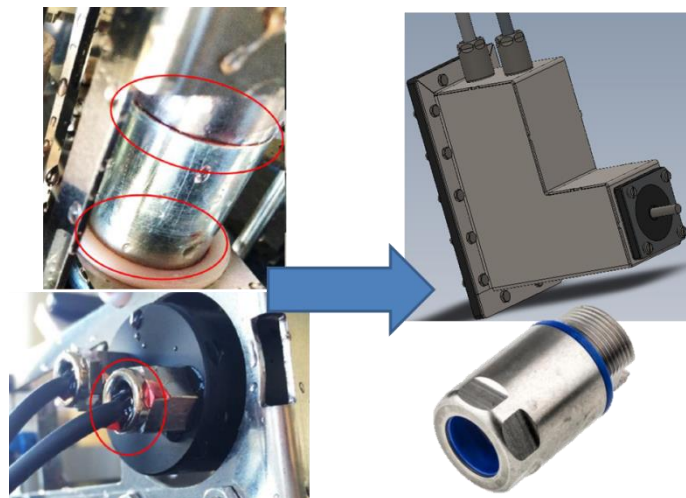


Fig. 60: Design solution for the Tomato Gripper with welded holding and hygienic IP69 cable gland.

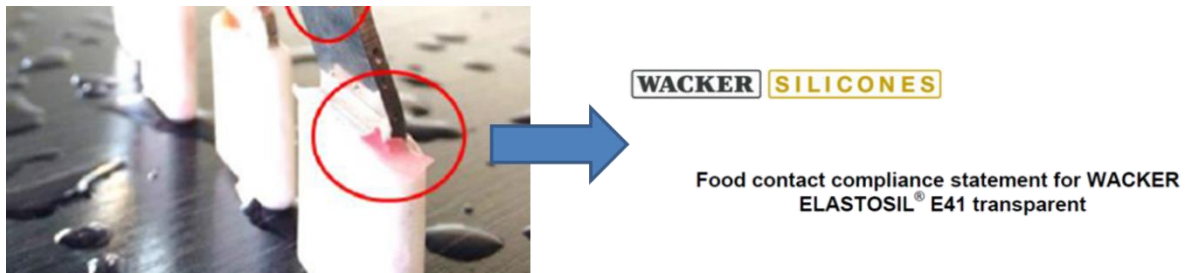


Fig. 61: New fingertip solution using FDA approved glue.

3.2 Suggestions Delta Robot

The tests with the Delta Robot also revealed some areas where cleanability is poor due to insufficient hygienic design on the one hand but also due to the wrong arrangement of some cleaning devices. Especially the full cone nozzles on the top were not placed in the ideal position because at the time when the cleaning concept was designed by Fraunhofer some structures in the ceiling area and some sensors in the front area were not mentioned in the design files of the robot.

Since major design changes on the robot itself are not possible anymore due to budget and time issues, the suggestions for improvement are mainly restricted on the cleaning system and some bigger critical areas.

An easy solution, already discussed with Marel, can be done on the fixed rotating spray heads, which are facing downwards at the moment. Thereby, water is sprayed not efficiently and spray shadows are created. The orientation should be changed in a way so that the nozzles are facing inside the robot or maybe a little bit upwards (Fig. 62).

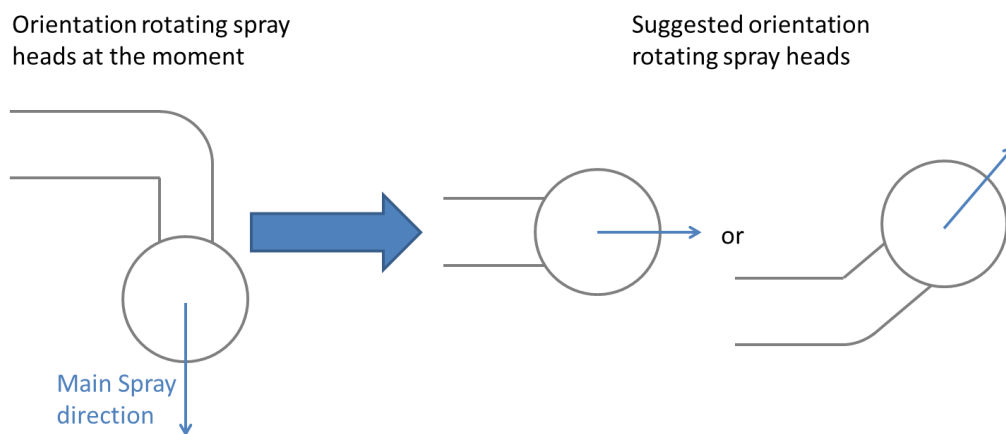
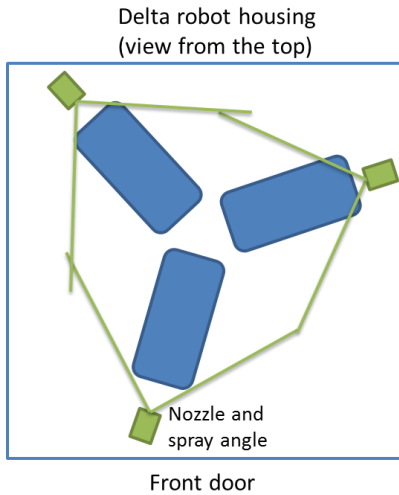


Fig. 62: Design suggestion for the arrangement of the fixed rotating spray heads.

To reduce the spray shadows in the front ceiling area the position of the full cone nozzles should be optimised. The original intention of these nozzles was to clean the upper parts of the motor blocks because spray shadows were expected there. Since in the current design most spray shadows are resulting from the new ceiling design and the additional sensors, the full cone nozzles should be shifted more towards the corners of the robot so that they can reach a wider area (Fig. 63).

Current arrangement of the full cone nozzles



Suggested arrangement of the full cone nozzles

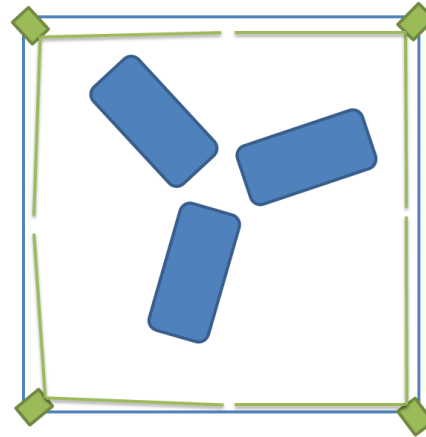


Fig. 63: Design suggestion for the full cone nozzles.

Very critical areas are also the orifices on the inside of the motor blocks (Fig. 64). There is nearly no cleaning effect possible inside of them because of hard accessibility. In addition, the cleaning fluid cannot properly drain from there. Therefore, the recommendation was given to close and seal the orifices.



Fig. 64: Not cleanable and drainable areas inside the orifices at the motor blocks.

In general, the recommendation is given to eliminate the hygienic design flaws. The mentioned ones are the most critical but also the minor critical parts which are hard to clean can lead to hygienic issues.

3.3 Suggestions Cable Robot

In the PicknPack line the Cable Robot is located at the end of the line where it is only handling sealed packages. But the ambition for the robot is also to be able to handle hygienic sensitive products.

Therefore it is also necessary that it follows hygienic design criteria. Fraunhofer constantly supported Tecnalia during the design process with advice to make the Cable Robot easily cleanable. Special attention was paid to the cables and cable drums, the moving robotic unit and the casing. Some major design changes due to this cooperation are shown in Fig. 65. Further improvements on hygienic design are shown in D5.3. The shown improvements were already implemented in the early design process.

| Old Design | New Design | Comments |
|---|---|---|
|  |  | <p>Cable robot: Closed frame design without gaps and crevices. Motor blocks outside the framework. Only rotating winches inside. No Spray shadows. Inclination for draining implemented.</p> |
|  |  | <p>Cable robot: Old Manipulator held on the top surface by air bearing made of porous material (not cleanable) leading to a risk of microbial growth. New design: Manipulator held on the top surface by vacuum suction system and drainable ball bearings.</p> |
|  |  | <p>Redesigned Cable Drums for better cleanability. Cables completely unrollable.</p> |
|  |  | <p>Industrial Cable Chains have poor cleanability → alternative solutions with better cleanability are tested.</p> |

Fig. 65: Examples for Hygienic Design changes on the Cable Robot.

Since the robot is a novel product and some parts are very complex, compromises had to be found between functionality and proper hygienic design. To verify if the critical parts can be used in a food environment cleanability tests are still necessary. With the current functional design the use in applications with hygienic sensitive products is not recommended.

3.4 Suggestions Sectional Frames

The Sectional Frames are transporting the web of packages through the whole line. Especially the upper area near to the trays as well as the shielding tunnel were determined as product contact areas which need to be easily cleanable. Fraunhofer supported the Wageningen UR and the DTI during the design process with assistance regarding hygienic design. Another aim of the PicknPack cleaning strategy is to keep the line as dry as possible. Therefore, it was decided to drain away the cleaning fluid in a defined way so that the shop floor does not get completely wet. For this purpose, drainage plates were integrated into the Sectional Frames. The final design of the Sectional Frames can be seen in Fig. 66.

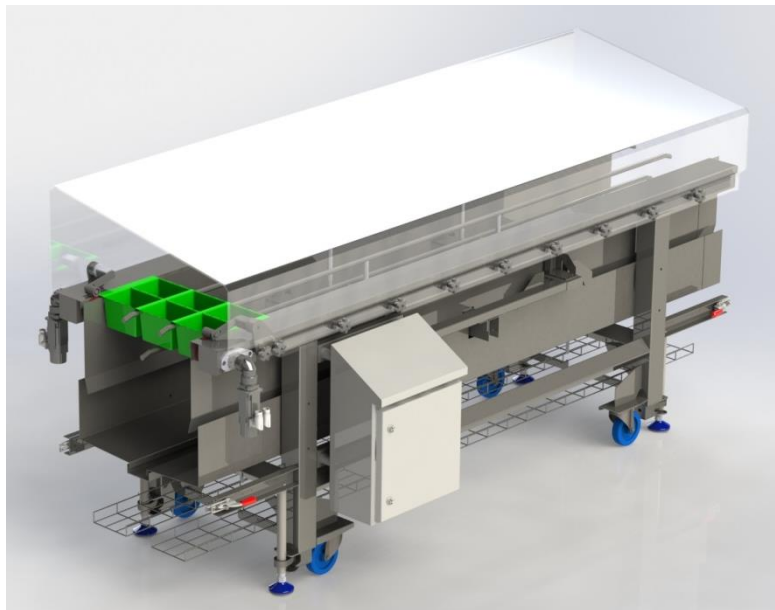


Fig. 66: Design of the Sectional Frames

4 Upcoming Cleaning Tests

Since some modules of the PicknPack line are still in the design process it was not possible yet to do cleanability tests on them. Therefore it is still planned to do further cleanability tests. Especially the parts of the Sectional Frames close to the web of packages needs to be cleanable for the Mobile Cleaning Device. Therefore the tests will be done in the upcoming month.

The Cable Robot is currently placed at the end of the line. Therefore it is not in direct food contact and hygienic design criteria do not strictly apply to it. But since the Cable Robot is also meant to be in

direct food contact in the general concept, it was decided that there will be some cleanability tests with critical parts like the cable drums as soon as their design and manipulator are ready.

In addition to the cleanability tests which only assure that all parts are generally cleanable there will also be further cleaning tests to find out ideal operating parameters for an efficient cleaning procedure.