MAREL FISH

Automated machine infeed for the white fish industry

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ADVANCING
FOOD PROCESSING

1 Summary

One of the labor-intensive roles within whitefish processing factories that has not yet been automated is the infeed of different whole fish machines. Examples of such processes can be whole-fish graders, de-heading machines, and filleting machines. A solution that meets the requirements of those process would need to be able to deliver a single fish at a time with correct orientation. The correct orientation depends on the subsequent process, but it covers in which direction the head is turning as well as on which side the fish is laying (if the belly is to the left or right side).

A first test was conducted as a part of a cooperation between Valka AS and FHF (Valka was acquired by Marel in 2021). The test was successful in presenting the capabilities of a singulation system. However, software and hardware optimizations are needed to make the solution suited for industrial environment. Additionally, integrating the solution into already established factories would be a challenge since the footprint (the floor space the solution requires) is substantial.

Even though the singulation problem can be solved, there are multiple other aspects that need to be considered, where the actual singulation is only one of them. If the solution cannot be integrated into modern factories, there is no limited value.

Oppsummering

En av de mest arbeidskrevende oppgavene i hvitfisknæringa som enda i liten grad er automatisert er innmating til ulike prosesser og maskiner. Et eksempel er helfisk gradere, hodekappere og filetmaskiner. En løsning som tilfredsstiller møter kravene vil måtte være i stand til å levere singulert fisk med rett orientering. Rett orientering er avhengig av den påfølgende prosessen, men det innebærer at hodet har rett orientering og det samme med buk og rygg (om buk ligger til venstre eller høyre).

En innledende test ble utført som en del av samarbeidet mellom Valka og FHF. Testen var en suksess vedrørende når det gjelder å vise egenskapene til et singuleringssystem. For å ha en egnet løsning for industrielt bruk er det behøvelig med både mekaniske-og programvaretilpasninger. Å tilpasse løsningen til industrielt bruk vil også medføre utfordringer i forhold til plassbruk, da fotavtrykket er betydelig.

Selv om singulering absolutt kan løses, er det flere aspekter som må drøftes, hvorav singuleringen i seg selv er kun ett av dem. Dersom løsningen ikke kan integreres i dagens fabrikker har den liten faktisk nytte.

2 Introduction

This project is a grant project in cooperation with FHF, with project number 901699 and a project homepage. The aim of the project is to automate the infeed of white-fish processing machines.

One of the labor-intensive roles within whitefish processing factories that has not yet been automated is the infeed of different whole fish machines. Examples of such processes can be whole-fish graders (Figure 1), de-heading machines, and filleting machines. A solution that meets the requirements of those process would need to be able to deliver a single fish at a time with correct orientation. The correct orientation depends on the subsequent process, but it covers in which direction the head is turning as well as on which side the fish is laying (if the belly is to the left or right side). In the first reference group meeting (dated 15.09.2021), it was discussed that the solution could be approached in a scalable way as different processes require different level of automation.

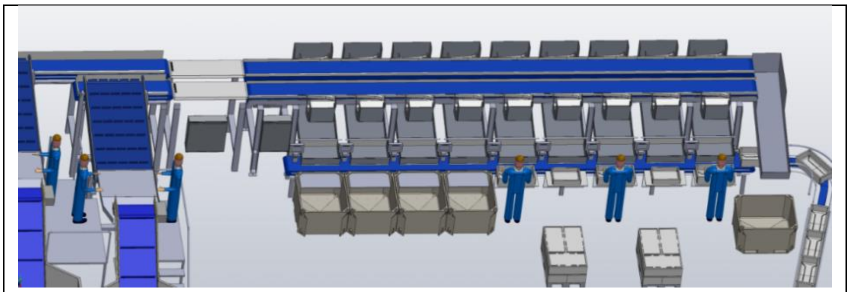

Figure 1: Whole fish grader with manual infeed.

For example, a sub-system of the whole solution would be sufficient for the whole fish grader, where the belly left/right and the head front/back is not as important. However, singulation would be necessary. There, the possibilities would be do replace manual sorting and singulation, as shown in Figure 2. Furthermore, the whole solution, for de-heading and filleting machines, would be highly dependent on the manufacturer and fish species but to be able to advance with the increased automation, it is required that the fish is delivered one at a time with the correct orientation. The final step of feeding the machine (put on a saddle for example) must be solved in the future to make the most out of this solution.

Figure 2: Manual infeed to a whole fish grader.

In the initial discussion of the project, it was decided to simplify the approach to some extent and focus on a solution for the whole fish grader, i.e., delivering fish one at a time.
The initial timeline, presented in Figure 3, has undergone significant changes due to two main reasons. First, COVID19 had a drastic effect on the supply chain, where most of the high-tech equipment such as cameras and computers were unavailable for a substantial amount time. Second, Marel’s acquisition on Valka had an

adverse effect on the operation of Valka, since there was a prolonged uncertainty period, and, to some extent, a reorganization was needed. Therefore, the project had significant delays.

	2021						2022												2023					
	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Fase 1 - Conceptual design					M1			M2																
Overall system requirements	X	X																						
From bulk to a single stream		X	X	X	X																			
Regulated flow		X	X	X	X																			
Quality evaluation			X	X	X																			
Unnaturally shaped post-rigour whitefish			X	X	X																			
Fase 2 - Design																								
Mechanical design					X		X	X						X	X	X								
Electrical design							X	X						X	X	X								
Fase 3 - Software development											M3													
Identify the need for high level software					X	X	X																	
Design a vision system							X	X	X	X	X													
Develop a quality evaluation system								X	X	X	X	X												
Design, produc and test a prototype unit for the vision system										X	X	X	X											
Fase 4 - Proof of concept																M4	M5-7				M8			
Prototype: Bulk to single stream					X	X						X	X	X	X									
Prototype: Reagulated flow					X	X						X	X	X	X	X								
Prototyp: Solution to unnaturally shaped post-rigour white fish					X	X									X	X	X							
Test and error correction of the complete system prototype at Valka																		X	X	X	X			
Fase 5 - Test and error correction of prototyp in production																								M9
Test and error correction in production																					X	X	X	X

Figure 3: Original time schedule.

3 System description and project execution

In this chapter, the system setup and functionality is presented, additionally, key components are described and discussed.

3.1 Setup

A general overview of the singulation unit is presented in Figure 4 and Figure 5, showing a top view and a side view of the unit, respectively. The dimensions of the unit are: length=9.7m, width=0.967m, and height=3.0m. Additionally, the height offset for the chute is 0.6m.

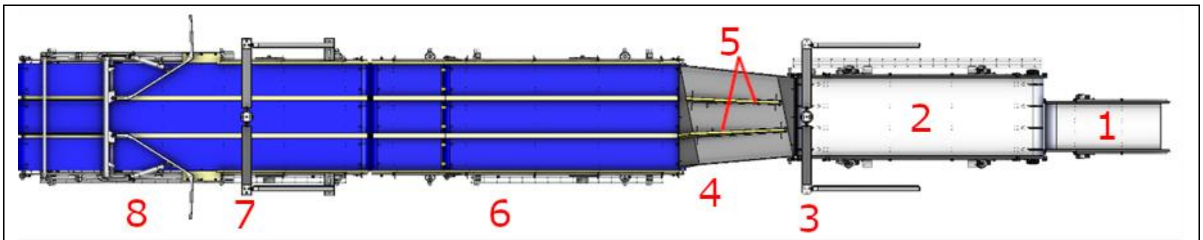

Figure 4: Top view of the unit, length = 9.7m and width 0.967m.

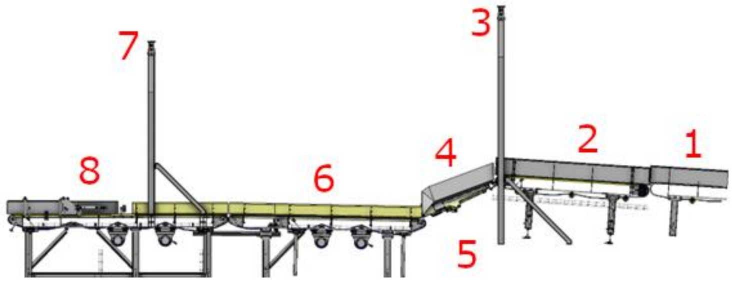

Figure 5: Side view of the unit. Note the height difference over the chute (0.6m).

In Table 1, the components from the singulation unit are defined and linked to the numbers shown in Figure 4 and Figure 5. The narrow infeed conveyor (1) receives fish from upstream process steps. The conveyor is narrow to limit the number of fish delivered to the system to avoid overflooding. The subsequent conveyor (2) is wider than (1) and has a higher speed. The wider conveyor belt is to spread the fish across the conveyor belt as much as possible and the higher speed is to spread the fish out in the longitudinal direction. A camera system (3), located above the conveyors, is monitoring the conveyor belt (2), the chute (4) and the three-line conveyor system (6). The information from the camera system is used to feed a CPU with data to control the singulation system. The chute (4) is built with a downward slope to get the fish to slide through it. Within the chute there are two deflectors (5) that can be pushed up through slots on the chute's surface. The deflectors are controlled by the CPU to deflect the fish into one of the three lines in the conveyor system downstream (6). The conveyor system (6) has three lanes and receives fish from the chute, where it serves as a buffer and a merging mechanism from three lanes into one. The merge is optimized with two pushers (8) on the two side conveyors. The second camera system (7) controls the merging process, i.e., the conveyor system (6) and the pushers (8).

Table 1: Components presented in Figure 4 and Figure 5.

Description	Number
Narrow infeed conveyor	1
Wide conveyor with higher speed compared to 1	2
Camera unit	3
Chute	4
Deflectors	5
Three lane conveyors	6
Camera system	7
Pushers	8

As discussed before, a part of the project was to develop mechanism and methods to rotate the fish with the respect to in which direction the head is turning and to flip the fish with respect to in which side the fish is laying. However, as mentioned earlier, the project was simplified to exclude the orientation mechanism (head/tail and belly/back), and only focus on the singulation aspect with a whole fish grader in mind.

3.2 Functionality

The functionality and performance of the singulation unit is based on an Artificial Intelligence (AI) computer algorithm, a logical computer program (composed in a CPU), and a camera system. By using an AI, the computer can be taught to identify if there is a fish on the conveyor belt and where it is located, where the fish is identified by the head. Other parts of the fish could be used but it should be kept in mind that the choice of the body parts to identify must reflect which part is most likely to be visible for every fish.

The CPU and the camera system collect data about size, and location of each fish to control downstream components.

4 Results (Proof of concept)

The test was conducted on 12th of January 2023 in the Marel test facility at Austurhraun 7, Iceland. The raw material was ten gutted cods, with approximately 4kg average weight and 10 gutted haddock, with approximately 1.5kg average weight. The fish was caught the day before and stored in polystyrene boxes with ice during the night. Due to the long exposure to ice, the fish was relatively stiff when the test began, but became softer throughout.

This was the first-time white fish was processed in this singulation device. So far, only salmon had been tested. There were eight runs executed in total, four with 10 cod and four with 10 haddock were processed with the singulation device. The results were very positive, but not without errors. For example, the CPU was not properly defined, and the cameras were disturbed by the strong light reflection on the conveyor belts, resulting in the wrong execution in some cases. Additionally, the camera settings had been optimized for salmon sized fish, resulting in incorrect reactions when the small haddock was processed. Figure 6 presents examples of when the fish was separated successfully, even though the fish upstream of the chute in Figure a) should have ended in the mid lane of the downstream conveyor in Figure b). This is an example on when the CPU did not function as intended. Figures c) and d) present how the device manages to separate two parallel fish upstream of the chute into two lanes downstream of the chute.

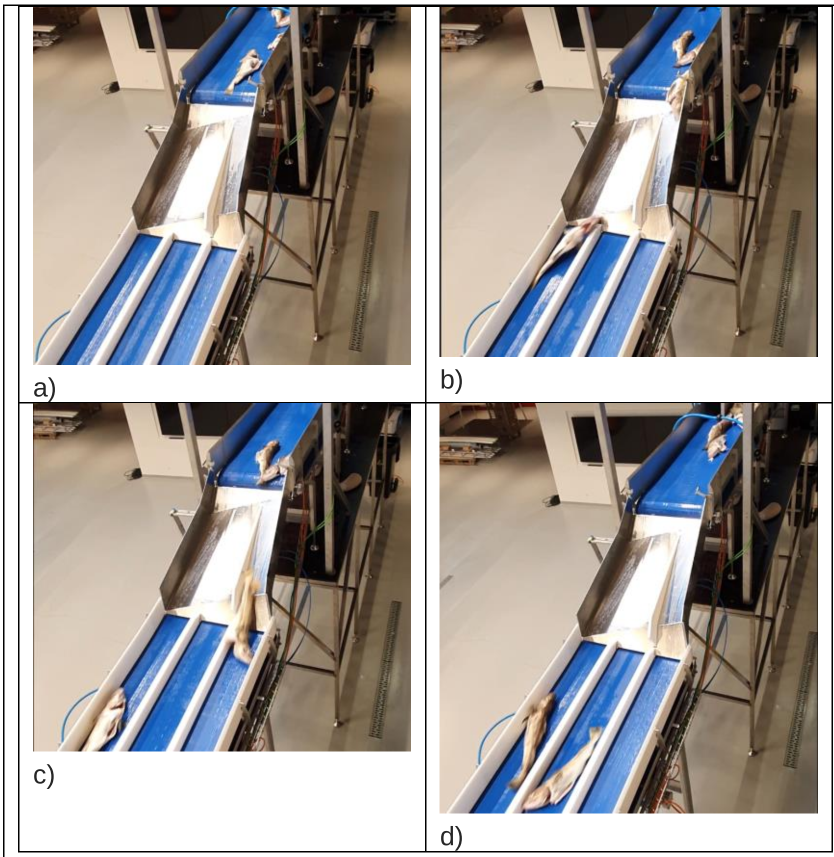

Figure 6: Successful separation.

Figure 7 presents two examples of unsuccessful separation. In the first case, Figures a) and b), the flap is, again, not correctly engaged, resulting in the two individual fish ending up too close to each other in the same lane. Additionally, two fish upstream of the chute in Figure b) are not activating the right flap in Figure c), resulting in the two fish being next to each other in the same lane in Figure d). Both cases were caused by incorrect control of the flaps. This was not realized until after the unit was dissembled and therefore it was not possible to repeat the test.

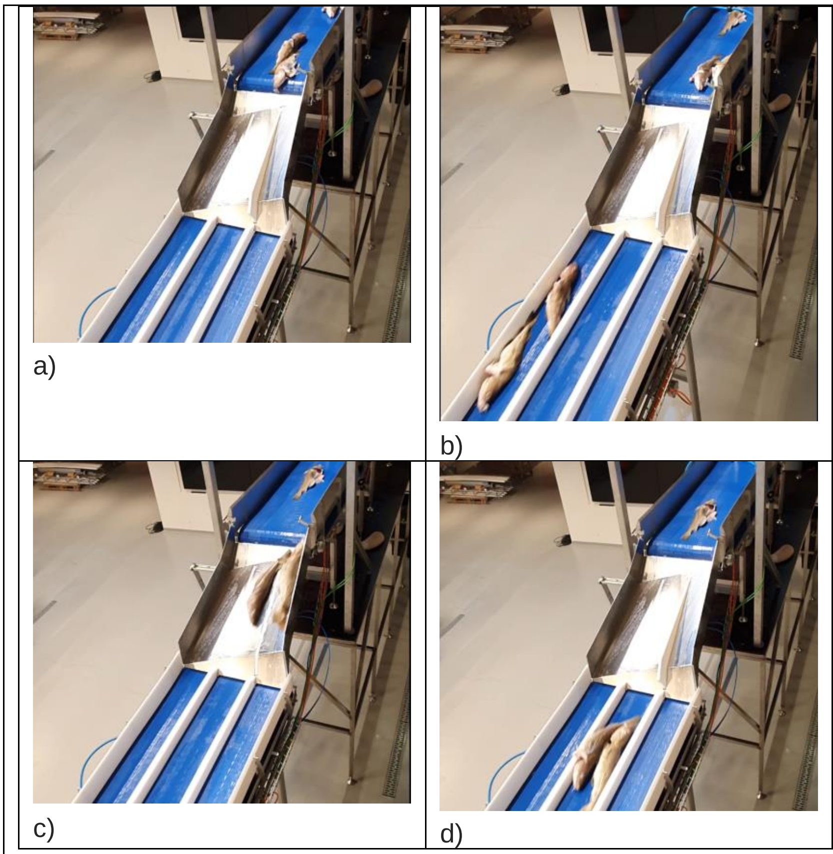

Figure 7: Unsuccessful separation.

In Figure 8 the functionality of the merging mechanism is shown. In Figure a), a single fish is approaching the merge location on one of the side conveyors within three lane conveyor system (6). The side conveyor is halted until the CPU deems that it is safe to push the fish into the middle lane. Then the corresponding side conveyor is started and at the same time the pusher is engaged to assist the fish through the merging process (Figure b)). In Figure c) the pusher has been retracted, and the fish has merged into the middle lane.

Figure 8: Merging mechanism using the push lever arm.

5 Conclusion
A cooperation project was initiated between Valka and FHF through a grant project, with the objective to increase the automation level for the infeed of whole fish into different processing machines. With that support, a proof-of-concept test unit was adjusted from an already started development for salmon. With the test unit, the fish was singulated, which is the first vital step to match the requirements for the downstream processing machine or steps. An example of such machines or steps can be whole fish graders, de heading machines or filleting machines.

The development of the device was divided into several steps, where the first step was to develop a unit that delivers the fish one by one. Such device would be able to feed a whole fish grader and should be the first approach within this project. During testing, and in the post-review of the test, several challenges were identified that should guide future developments:
- **Size of fish** – software was initially written for a more uniform distribution found in a salmon factory
- **Fish identification** – Currently, the heads are used but if the fish is de-headed some other fish part must be used.
- **Bent fish** - Gutted cod can be significantly bent, resulting in jams. For example, at the converging location when unifying the 3 lanes into 1 in conveyor system (6). Could it be treated with a camera identification unit and a reactive mechanical measure to fix/release the fish? However, as the problem was not approached during this project, there is a question if a completely new concept is needed.
- **Conveyor belt reflection** due to water. This is important to be able to define a background value for an empty conveyor belt.

One of the main questions that arises after reviewing the project is if the industry is willing to commit to the solution. Within the white fish industry, it is usual that the factories are in already built, with limited space to implement a solution like the one presented here.

5.1 Future work
The next steps would be to review the test and make appropriate changes to optimize the performance when processing white fish. Additionally, a discussion must be initiated with the industry to reflect if they consider this approach acceptable.

6 Main findings
The main findings from the project
- It is possible to singulate fish
- The main challenge is to decrease the current footprint
- Cameras can replace optical sensors
- Fish that has an abnormal shape (U-shaped fish for example) remains a challenge.

Hovedfunn
- Det er mulig å singulerer fisk
- Hovedutfordringen er å minimere fotavtrykket til løsningen
- Kamera kan erstatte optiske sensorer
- Fisk med avvikende form («bananfisk») forblir en utfordring.

7 Deliverables

To receive whole fish in bulk and deliver each fish one-by-one at the correct rate, e.g. 30 fishes/minute, and with the correct orientation where that is needed, to a machine. Originally the plan is a feeding system for graders and gutting machines. The project deliverables are presented in Table 2 with the status of each deliverable when the project was terminated.

Table 2: Deliverables.

M	Description	Status
M1	Conceptual design for the complete system. Product from phase 1, where the system requirements and conceptual solutions are identified.	**Finished**
M2	A first iteration for the complete system design. Mechanical and electrical design.	**Finished**
M3	Vision system. The camera system must be developed and designed to recognize the location and orientation of the fish. This is necessary to know which actions are required later in the process.	**Finished**
M4	Solution to treat unnaturally shaped post-rigor fish as in extreme cases the fish can have a U-shape	**Not started**
M5	Prototype: A prototype that receives fish in bulk and delivers a single stream.	**Finished**
M6	Prototype: A prototype that ensures a regulated flow of fish, i.e., the fish is delivered at a constant rate.	**Finished**
M7	Prototype: A mechanism that ensures the head or tail first with the belly left or right. The final orientation depends on the whole system requirements and is flexible.	**Not started**
M8	Complete system prototype: Test and error correction of the whole system at Valka	**Stopped**
M9	Test and error correction of a prototype in a production	**Not started**