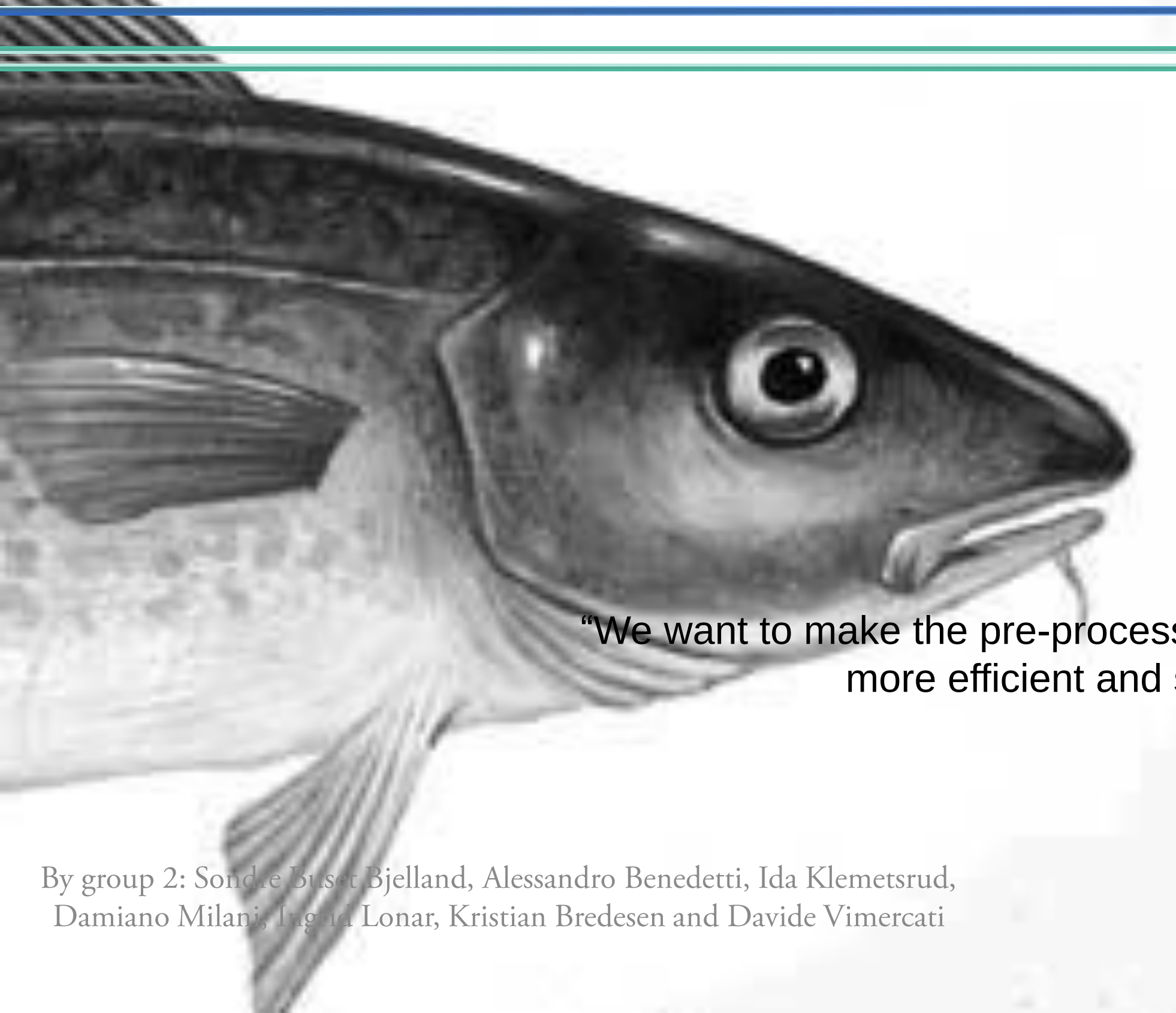


# Improve fishing at sea

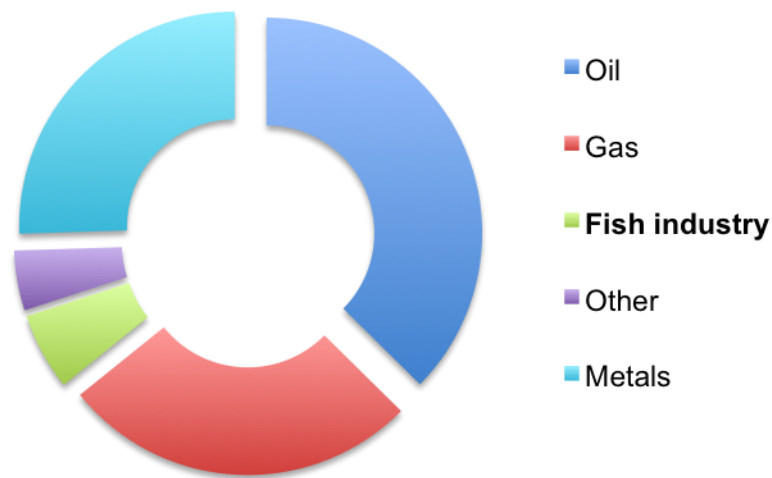
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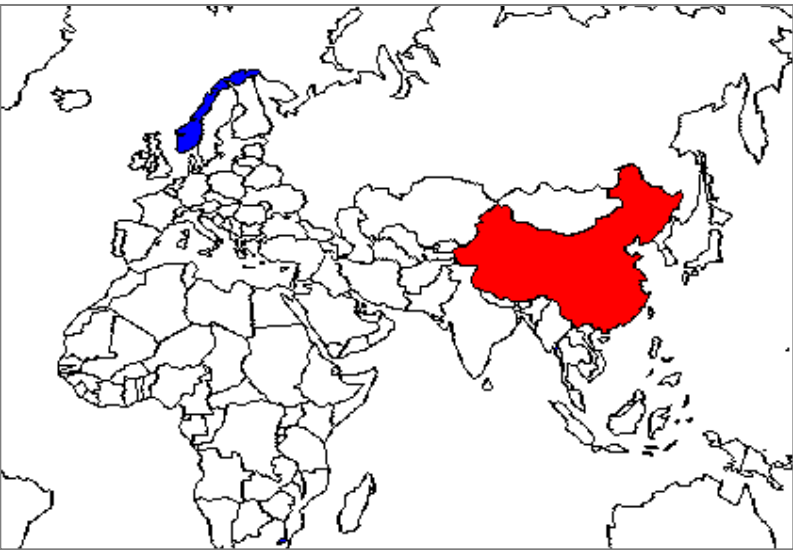
“We want to make the pre-processing of fish off shore more efficient and safe”

By group 2: Sondre Buset Bjelland, Alessandro Benedetti, Ida Klemetsrud, Damiano Milani, Ingrid Lonar, Kristian Bredesen and Davide Vimercati

NORWEGIAN EXPORTS 2009



The seafood industry in Norway contributes a significant amount to the country's economy. Fish and fish products is 4% of Norway's total exports revenue and is one of the most important exports after oil, gas and metals. It has a value of 39,1 billion NOK and makes Norway the second largest export nation of the world, after China.



Fish industry in Norway

To be one of the largest fish exports in the world the final product must be competitive, both in quality and price. Every process from aquaculture and catch to filés in the store must be at its best, and with continuous improvement.



Aquaculture and Wild fish catch



Pre-process:  
- Stunning  
- Killing  
Finalizing process  
- Cleaning and trimming



Finished product for sale and export.

Process for catching wild fish at sea

To achieve required fish-quality some of the fish processing is done right after catch. Which process that is performed at sea vary from capacity of the fish vessel. As an example on today's solution we look at “snurrevadfartøyet” M/S “Olagutt”:



M/S Olagutt:  
-30 m long  
-Crew of 6  
-1-2 days trip  
- 6-20 ton fish/day



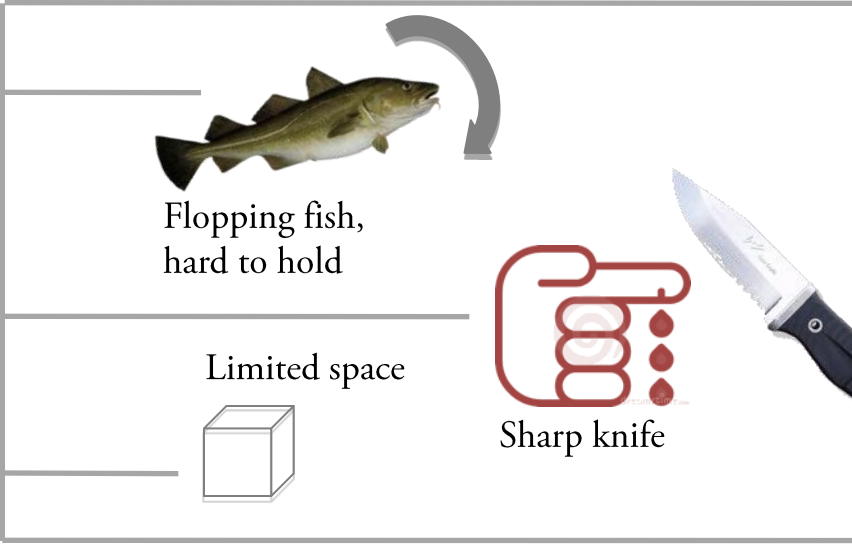
Process:  
Stunning and killing is done manually.



The quality depends on:  
-If the fish gets stressed  
-Time after catch till killing  
-The killing must not damage the filet.

Problems for the user while stunning and killing fish





Flopping fish, hard to hold

Limited space

Sharp knife



Rough sea under process

Automatic and no risk on shore



| User demand specification |                                           |      |        |
|---------------------------|-------------------------------------------|------|--------|
| User:                     | Wants:                                    | Must | Should |
| Owner:                    | Affordable                                | X    |        |
|                           | High reliability/low maintenance costs    | X    |        |
|                           | High efficiency/high rate of production   | X    |        |
|                           | Profitable                                | X    |        |
|                           | Short payback time                        |      | X      |
|                           | Easy to install on existing boats         | X    |        |
| Captain:                  | Few operators required                    |      | X      |
|                           | Compact/lightweight                       | X    |        |
|                           | Low power consumption                     | X    |        |
|                           | Silent                                    |      | X      |
|                           | Low vibrations                            |      | X      |
| Operator:                 | Not altering the boat to much (stability) |      | X      |
|                           | Safe and easy to use                      | X    |        |
|                           | Silent                                    | X    |        |
|                           | Comfortable environment                   | X    |        |
|                           | Rewarding to work with/not boring         |      | X      |
| Maintenance:              | Reliable                                  |      | X      |
|                           | Easy to install                           |      | X      |
|                           | Easy to service/repair                    | X    |        |
| Cleaning staff:           | Reliable                                  |      | X      |
|                           | Easy access                               |      | X      |
|                           | Easy washable surfaces                    | X    |        |
|                           | Safe                                      | X    |        |
|                           | Waterproof/permits use of water hose      | X    |        |
| End customer:             | High pressure washer not needed           |      | X      |
|                           | Clean cut.                                | X    |        |
|                           | Short time from catch to end product      |      | X      |
|                           | Prime quality fish for less money         | X    |        |

Users



**Bjørn** is 38 years old and works as a **deckhand at a fishing vessel**. He has been working as a deckhand on various fishing vessels for over 20 years and has seen the technology develop in the fishing industry, but automated stunning and killing of the fish is new for him. When asked about this kind of technology, Bjørn's first thought was that this sounded like a good idea. Bjørn has no official education, but he has acquired a great deal of knowledge and experience over the years. He has been able to adapt to new technologies before and thinks of himself as having no problems learning how to use the new machine. He thinks it would prove effective and make his job more comfortable.

Bjørn wants the machine to be versatile and adaptable to different vessels so that he can recognize the machine on the different boats he works on. He also wants the machine to be a safe alternative to manual labor considering the fact that the boat usually is rocking in the high waters of the North Sea. The worst thing Bjørn can think of is not being able to do his work because of faulty equipment, so he really thinks that the new machine must be reliable. He also loves his job because he finds it rewarding. He is hoping the new machine can make his job equally or more satisfactory. He would not like just to be sitting next to the machine looking at it. But then Bjørn becomes suspicious about the security of his job. Will he be out of work as the fishing vessels becomes more and more automated?



Captain



Maintenance

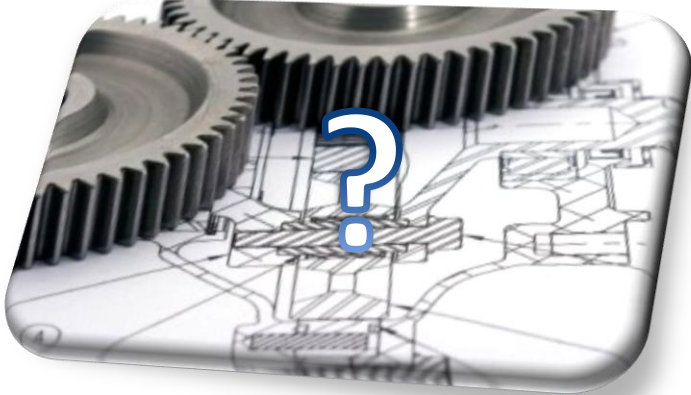


End costumer



Owner

How do we go from fetching fish to ready for filet process, by using mechatronics?



| PRODUCT REQUIREMENT SPECIFICATION        |                                   |                         |
|------------------------------------------|-----------------------------------|-------------------------|
|                                          | Units                             | Value                   |
| MACHINE                                  |                                   |                         |
| Physical dimension (LxWxH)               | mm                                | 3000x3000               |
| Total mass                               | kg                                | < today's equipment     |
| Materials corrosion                      | type                              | AlMg, plastic           |
| Food-compatible materials                | type                              | Inert material          |
| Stunning-killing rate                    | Fish/min                          | > 20/30                 |
| Electrical power                         |                                   |                         |
| Operators                                | Amount                            | < 3                     |
| FISH                                     |                                   |                         |
| Stunning                                 | Requirements                      | No harm, head first     |
| Killing                                  | Requirements                      | Stunned before.         |
| Time from catch till stunned and killed  | min                               | < 30-60                 |
| Flexible design for different fish types | Type                              | Torsk, skrei, hyse, sei |
| Flexible design for different fish sizes | mm                                |                         |
| QI score                                 | Score                             | 0                       |
| SHIP                                     |                                   |                         |
| Stability [xyz acceleration]             | With low weight                   |                         |
| Flexible design for different boats      | Length on boat, feet              | 50-130                  |
| Space for machine                        | mm                                | 3000x3000               |
| Maximum weight                           | Kg                                | -                       |
| Logistic                                 | Same as today's solution          |                         |
| Operators                                | Amount                            | < 7-8                   |
| STANDARDS                                |                                   |                         |
| Industrial standards                     | Approved by                       | "Mattilsynet"           |
| Safety standards                         | Not able to stun or stab operator | -                       |
| Environmental standards                  | Amount pollution                  | none                    |
| SAFETY                                   |                                   |                         |
| Electricity and water                    | -                                 |                         |
| Safety course                            | Needed or not                     | Needed                  |
| Moving parts                             | amount                            | 0                       |
| ECONOMICAL                               |                                   |                         |
| Maximum investment budget                | \$                                | -                       |
| Maintenance cost                         | \$                                | -                       |
| Availability                             | %                                 | 100                     |

Hold and transport of fish

- Conveyor belt with nails
- Slides with support walls
- Rubber surface
- Mobile bars (springs, dampers)



Killing

- Water jet
- Laser
- "Bløtting"



Stunning

- Electricity
- Paralyze with CO2
- Scanvacc Aqui-S (chemical)



Available technology

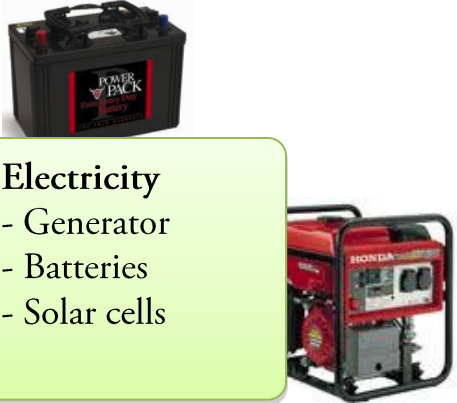
Mechanical

- Engines (hydraulic/electric)
- Gears
- Belts
- Hands



Electricity

- Generator
- Batteries
- Solar cells



Orientation of equipment

- Sensors
- X-ray
- Line scanner
- 3D camera
- Photocell
- Laser
- Software



Evaluation matrix of different function

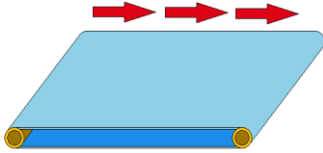
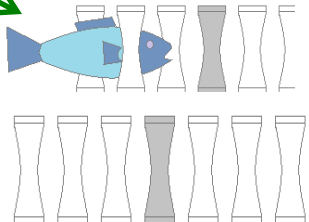
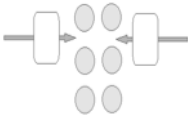
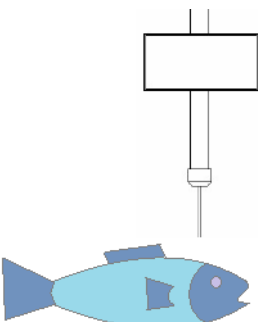
| Function  | Solution      | Exist | Low |   | Easy |   | HMD |    | Size | Pro | Eff | Total | Total % | Score |
|-----------|---------------|-------|-----|---|------|---|-----|----|------|-----|-----|-------|---------|-------|
|           |               |       | 5   | 5 | 8    | 7 | 20  | 20 |      |     |     |       |         |       |
| Hold      | Robot hand    | x     | 2   | 5 | 4    | 4 | 5   | 5  | 2    | 3   | 3   | 3,9   | 65,0    |       |
|           | Suction       | x     | 3   | 5 | 3    | 4 | 5   | 3  | 4    | 4   | 4   | 3,9   | 65,3    |       |
|           | Human hand    | x     | 6   | 1 | 6    | 5 | 2   | 5  | 2    | 6   | 5   | 4,1   | 68,8    |       |
|           | Hook          | x     | 6   | 4 | 3    | 3 | 2   | 1  | 5    | 4   | 2   | 2,8   | 45,8    |       |
|           | Clamp         | x     | 4   | 5 | 4    | 5 | 6   | 5  | 4    | 5   | 5   | 5,0   | 82,8    |       |
| Transport | Conveyor belt | x     | 5   | 5 | 5    | 6 | 6   | 5  | 4    | 5   | 5   | 5,2   | 86,2    |       |
|           | Track         | x     | 6   | 6 | 5    | 5 | 5   | 4  | 4    | 6   | 6   | 5,1   | 84,2    |       |
|           | Gravitiy      | x     | 6   | 6 | 5    | 5 | 4   | 4  | 3    | 1   | 6   | 4,3   | 70,8    |       |
|           | Rolling       | x     | 5   | 5 | 5    | 4 | 4   | 3  | 3    | 5   | 5   | 4,1   | 68,8    |       |
|           | Robot arm     | x     | 1   | 6 | 3    | 4 | 3   | 3  | 2    | 3   | 5   | 3,3   | 55,3    |       |
|           | Wire          | x     | 4   | 5 | 5    | 5 | 3   | 4  | 5    | 3   | 4   | 4,0   | 66,7    |       |
| Stun      | Electric      | x     | 5   | 5 | 6    | 5 | 3   | 4  | 5    | 6   | 6   | 4,7   | 78,8    |       |
|           | Gas           | x     | 5   | 2 | 5    | 3 | 2   | 3  | 4    | 3   | 2   | 3,0   | 49,3    |       |
|           | Chemicals     |       | 4   | 3 | 3    | 3 | 2   | 2  | 3    | 3   | 2   | 2,5   | 41,7    |       |
|           | Stroke        | x     | 6   | 4 | 4    | 3 | 3   | 2  | 3    | 3   | 5   | 3,4   | 56,3    |       |
| Kill      | Knife         | x     | 5   | 5 | 4    | 4 | 4   | 5  | 4    | 5   | 6   | 4,7   | 78,3    |       |
|           | Smash         | x     | 5   | 5 | 3    | 3 | 2   | 2  | 4    | 4   | 5   | 3,3   | 55,0    |       |
|           | Guillotine    | x     | 5   | 5 | 3    | 2 | 1   | 2  | 4    | 4   | 5   | 3,0   | 50,5    |       |
|           | Water jet     | x     | 4   | 5 | 5    | 4 | 5   | 5  | 3    | 4   | 6   | 4,7   | 78,8    |       |
|           | Laser         | x     | 1   | 2 | 4    | 2 | 3   | 5  | 5    | 1   | 6   | 3,7   | 61,8    |       |
|           | Gun           | x     | 4   | 4 | 3    | 3 | 1   | 1  | 3    | 2   | 5   | 2,5   | 41,7    |       |

How to weight the demands

The costumer expects and require high quality of the fish. That is why HMS and not damaging the fish is important values. Probability of realization and efficiency is also important factors to considered.

Green marks

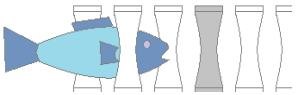
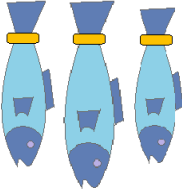
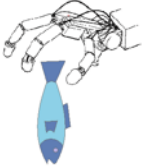
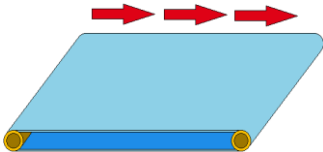
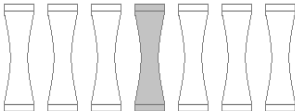
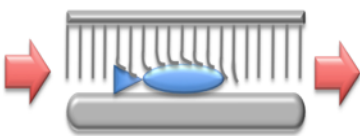
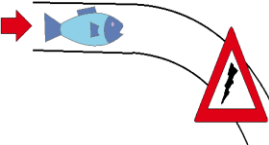
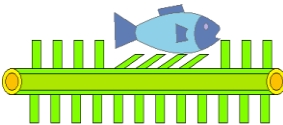
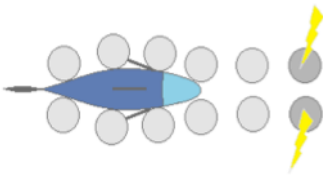
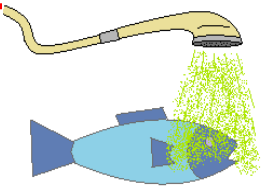
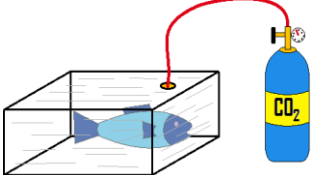
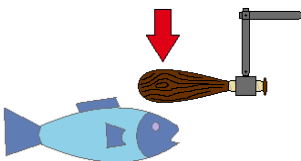
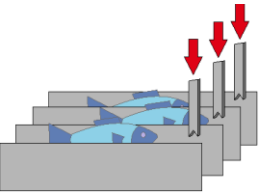
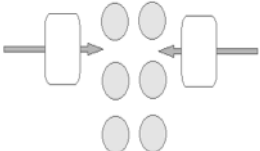
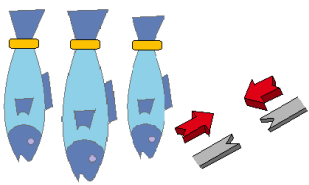
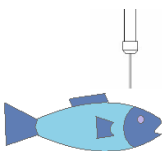
We marked the function who got the highest total % score and evaluated with pros and con.

|                                                                                                              |                                            |                            |
|--------------------------------------------------------------------------------------------------------------|--------------------------------------------|----------------------------|
| <div>Clamp</div>          | PROs                                       | CONS                       |
|                                                                                                              | Simple                                     | Can damage the fish        |
|                                                                                                              | Precise                                    | It must follow the fish    |
|                                                                                                              | Can be used with conveyor belt             |                            |
|                                                                                                              | Adaptable                                  |                            |
| <div>Conveyor belt</div>  | PROs                                       | CONS                       |
|                                                                                                              | Flexible speed                             | Maintenance                |
|                                                                                                              | Large amount of fish that can be processed | Not hygienic               |
|                                                                                                              | Stable                                     | It tooks space             |
|                                                                                                              |                                            | Also need to hold the fish |
| <div>Rolling</div>       | PROs                                       | CONS                       |
|                                                                                                              | Will hold the fish at an exact place       | Might complex to install   |
|                                                                                                              | Flexible for different fish sizes          | Technical complicated      |
|                                                                                                              | Innovative                                 |                            |
|                                                                                                              | Can hold and transport fish also (clamp)   |                            |
| <div>Knife</div>        | PROs                                       | CONS                       |
|                                                                                                              | Simple                                     | Dangerous, sharp           |
|                                                                                                              | Fast                                       |                            |
|                                                                                                              | Already tested in fish processing          |                            |
| <div>Waterjet</div>     | PROs                                       | CONS                       |
|                                                                                                              | Neat cut                                   | Expensive                  |
|                                                                                                              | Hygienic                                   | Great size                 |
|                                                                                                              | Food compatible                            | High power consumption     |
|                                                                                                              | Clean                                      | Frequent maintenance       |
|                                                                                                              | Precise                                    | Low safety                 |
|                                                                                                              |                                            | Possible fish damage       |
|                                                                                                              |                                            | Nozzle wear                |
|                                                                                                              |                                            | High technology involved   |

Red marks

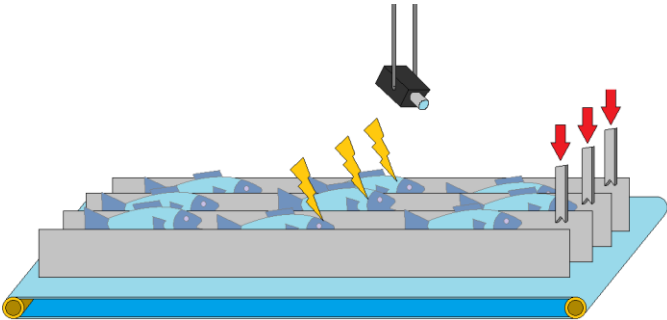
We want to create a solution that is different and innovative from current solution, but still simple and easy to use. Users demands must also be considered.

Different function and solutions

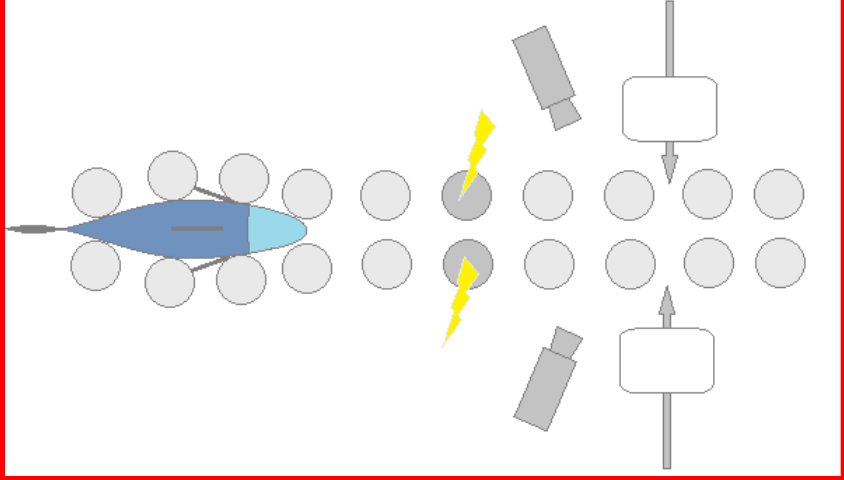
| <div>Solution</div> <div>Task</div> | 1                                                                                   | 2                                                                                    | 3                                                                                     | 4                                                                                     | 5                                                                                   |
|-------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| Hold the fish:                      |    |    |    |    |  |
| Transport fish:                     |    |    |    |    |  |
| Stunning:                           |   |   |   |   |                                                                                     |
| Killing:                            |  |  |  |  |                                                                                     |

Different total solutions

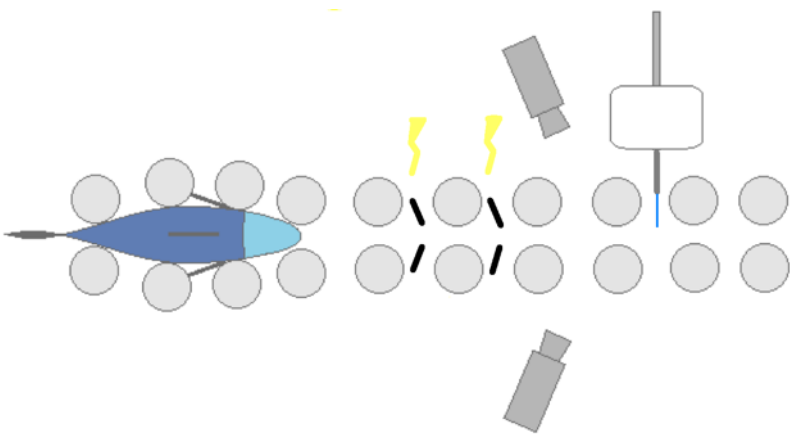
Clamp – conveyor belt – electric – knife



Clamp – rolling– electric – knife



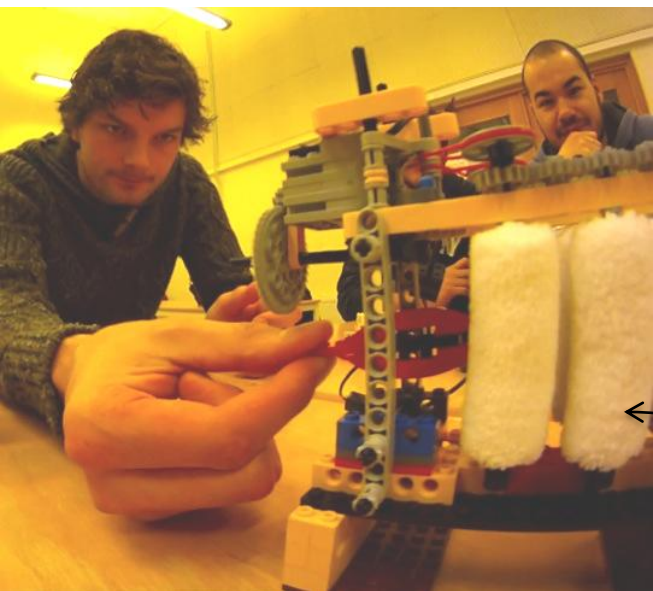
Clamp – rolling– electric – water jet



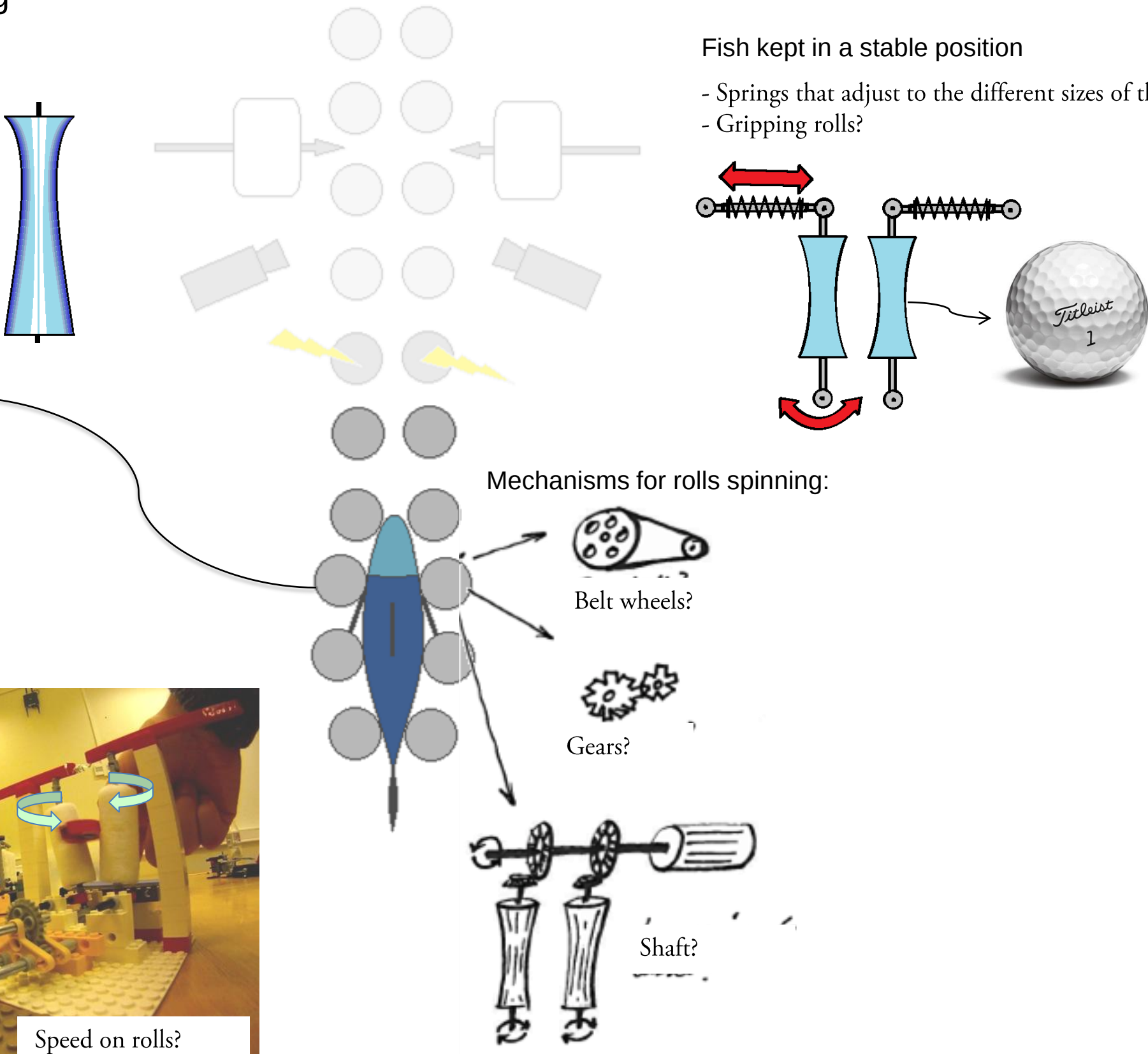
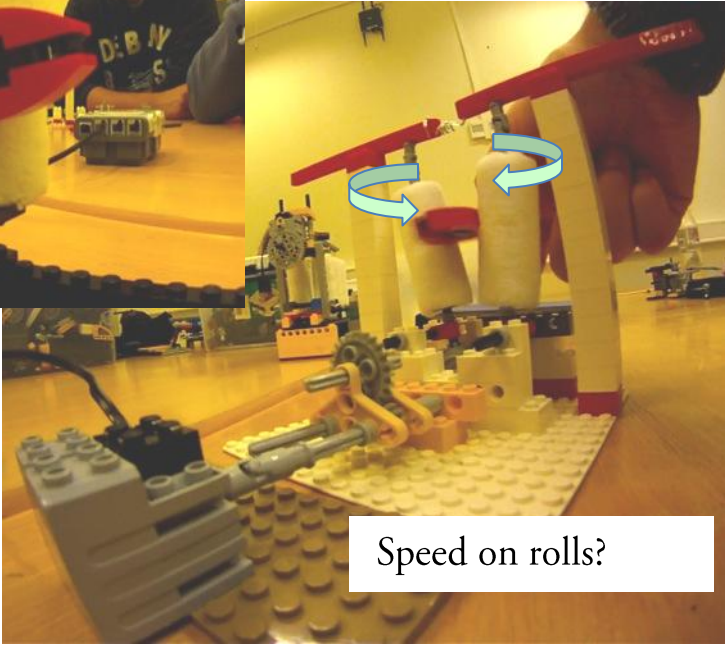
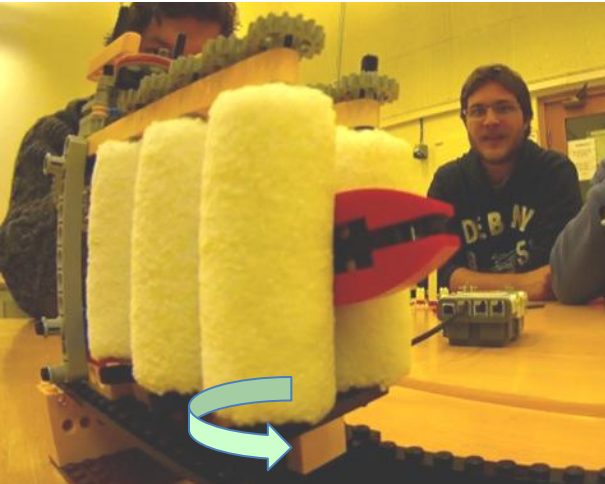
Evaluation of clamp & rolling

Design

- Asymmetric/symmetric?



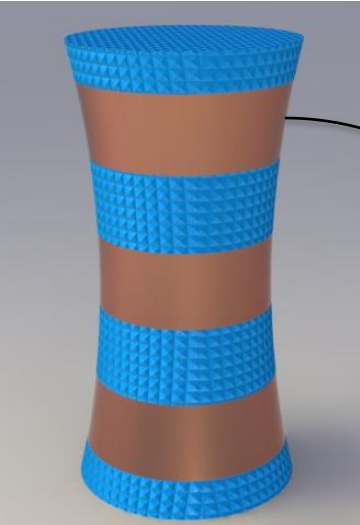
- Spinning rolls will transport the fish



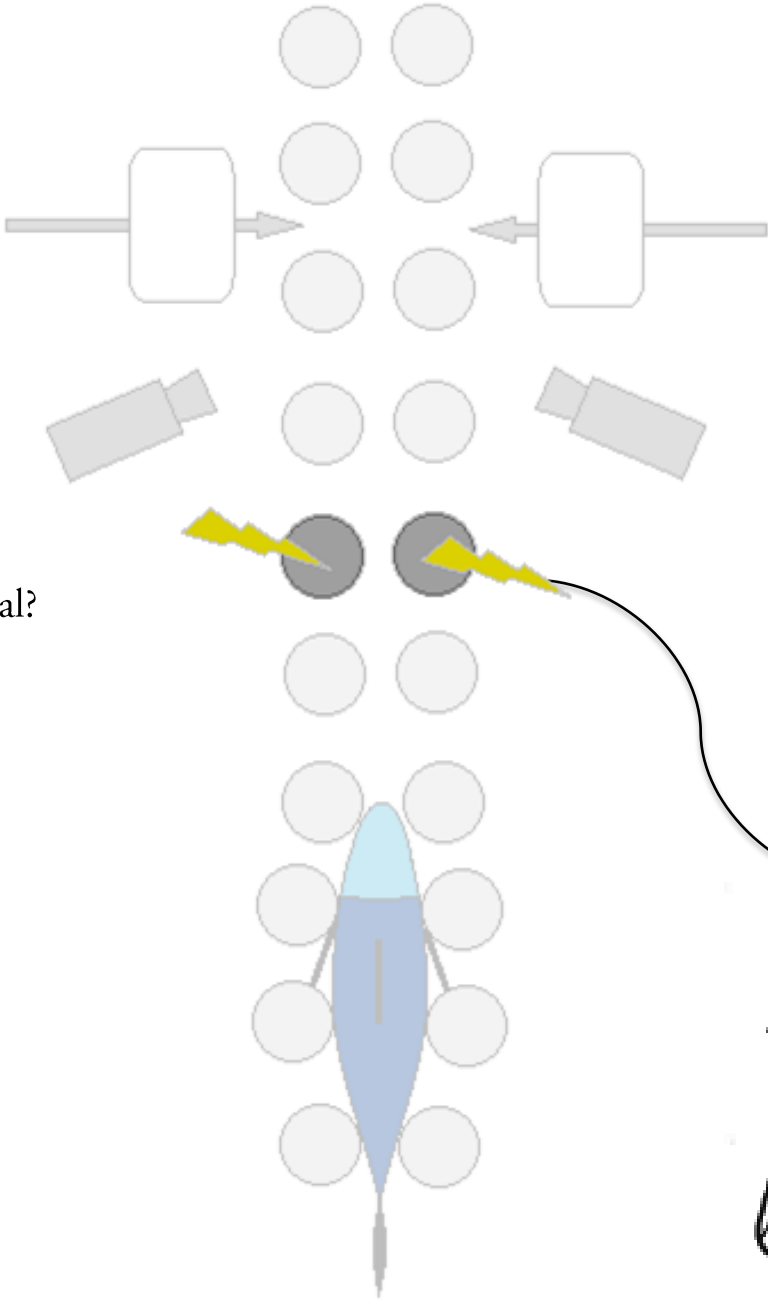
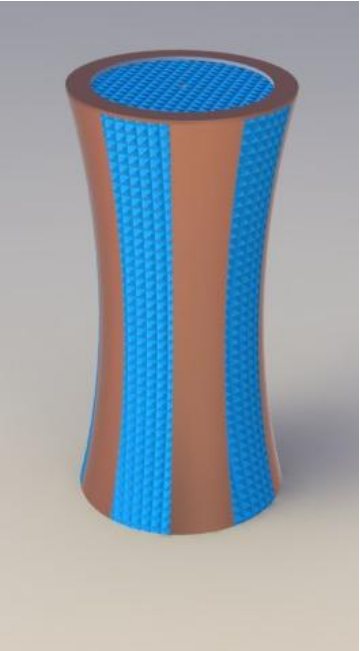
Evaluation of electric stunning

Design for electric rolls

- How do we make sure every fish will be stunned?



Electrified material?



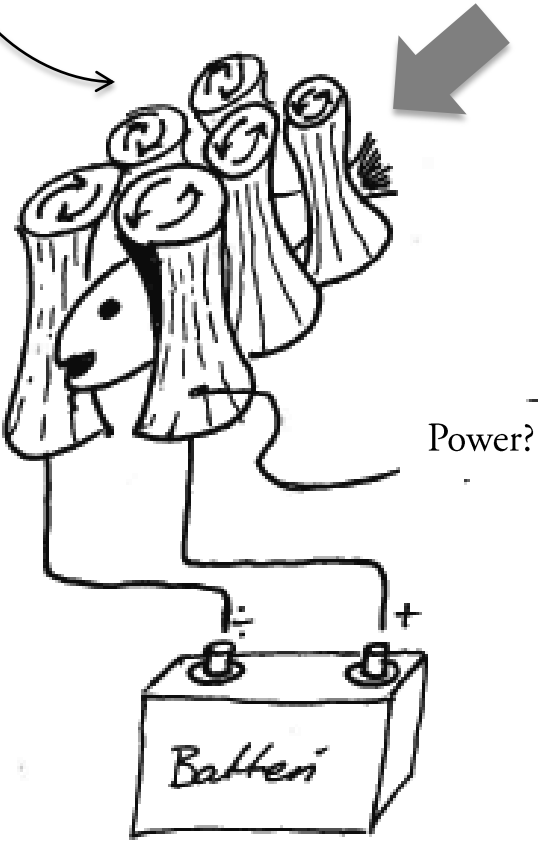
Danger!

- Not stun crew or harm the fish
- Right voltage?



Stun fish in head first

- We assume the fish will enter the rolls with head first. The head must be stunned first.

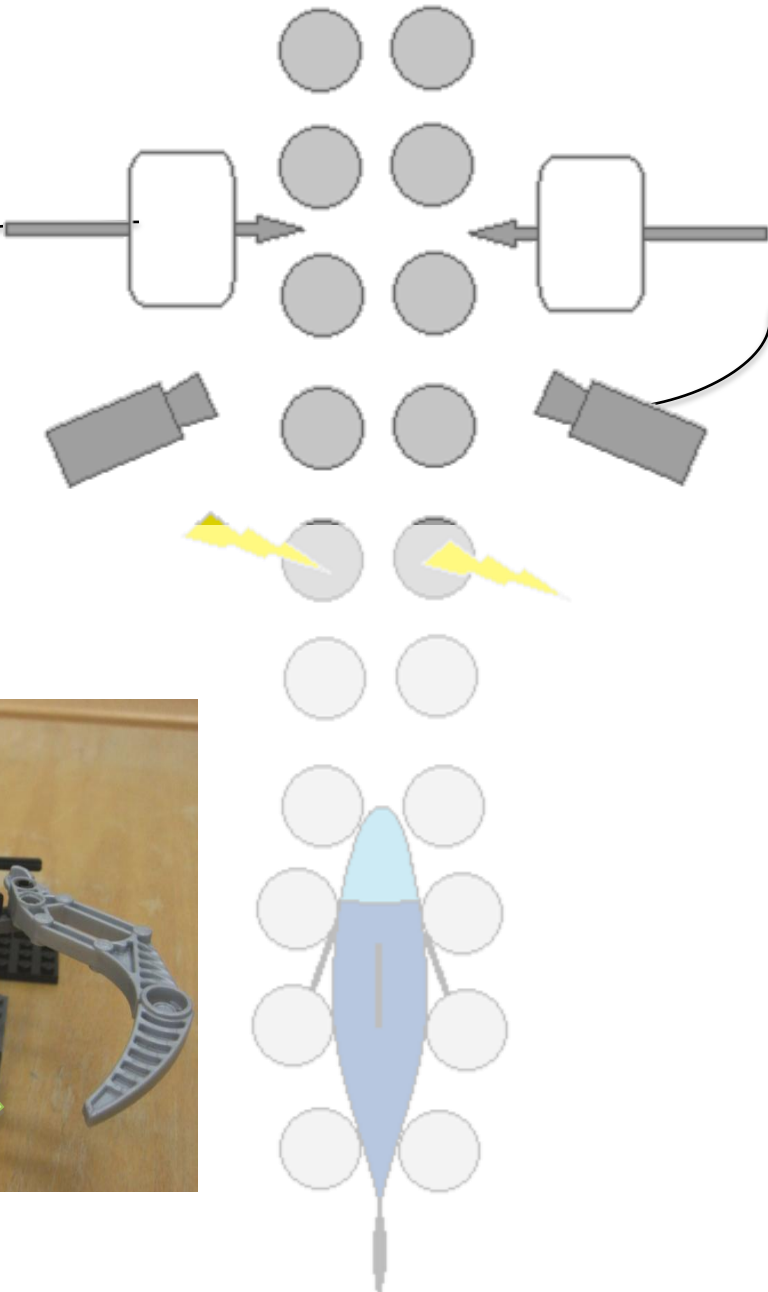
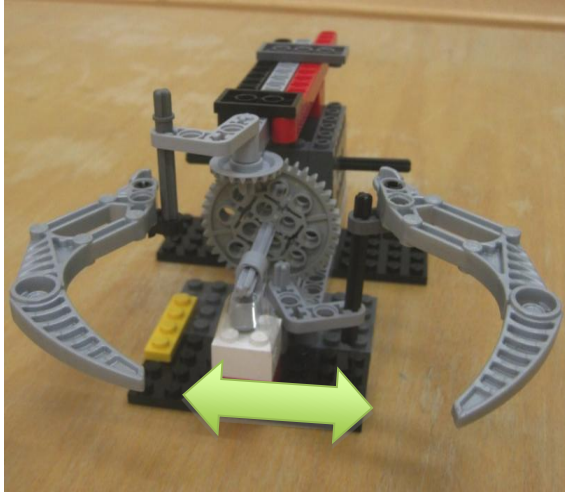
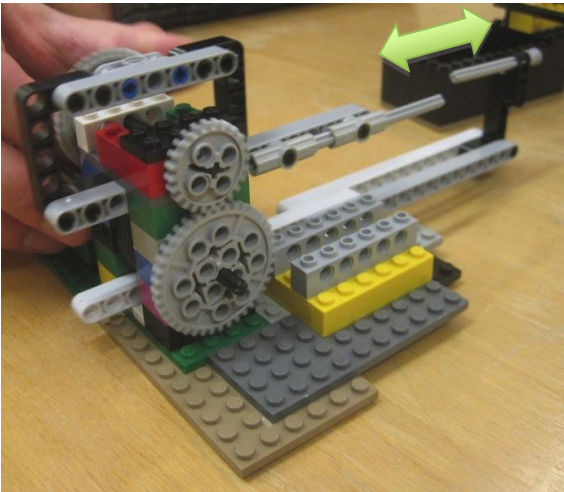
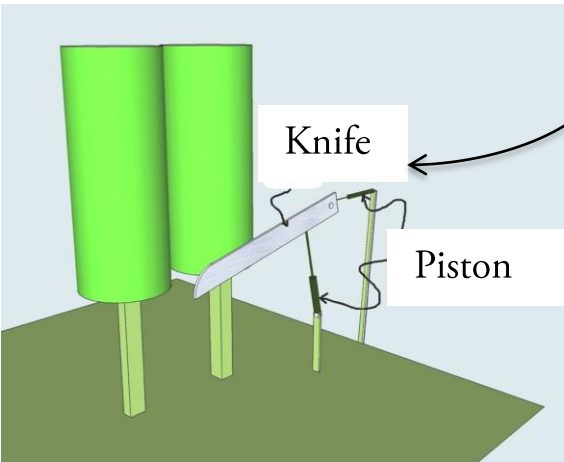


Power?

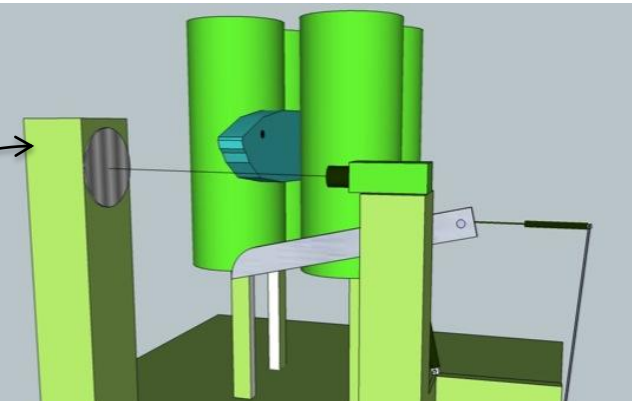
Evaluation of “Bløgging” with knife

Design “Bløgging”

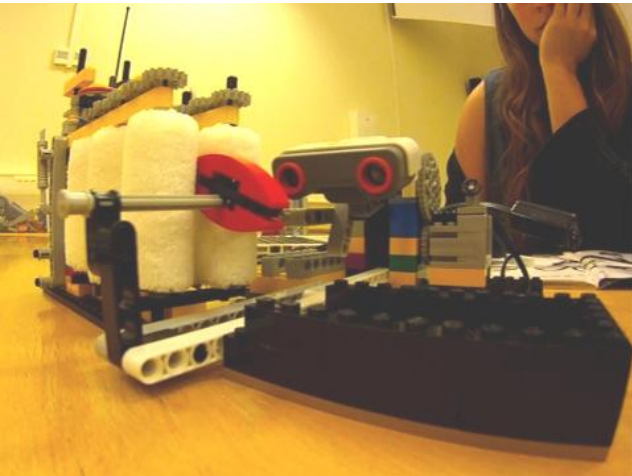
- Mechanism for correct cut?



Detect where to cut?

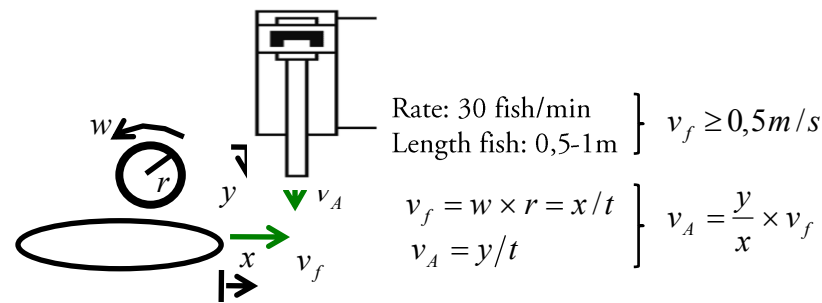


- Photo-electric sensor?
- 3D – Camera?



Speed

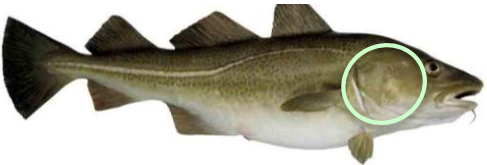
-“Bløgging” must be a fast movement, to prevent fish stopping or knife bending.



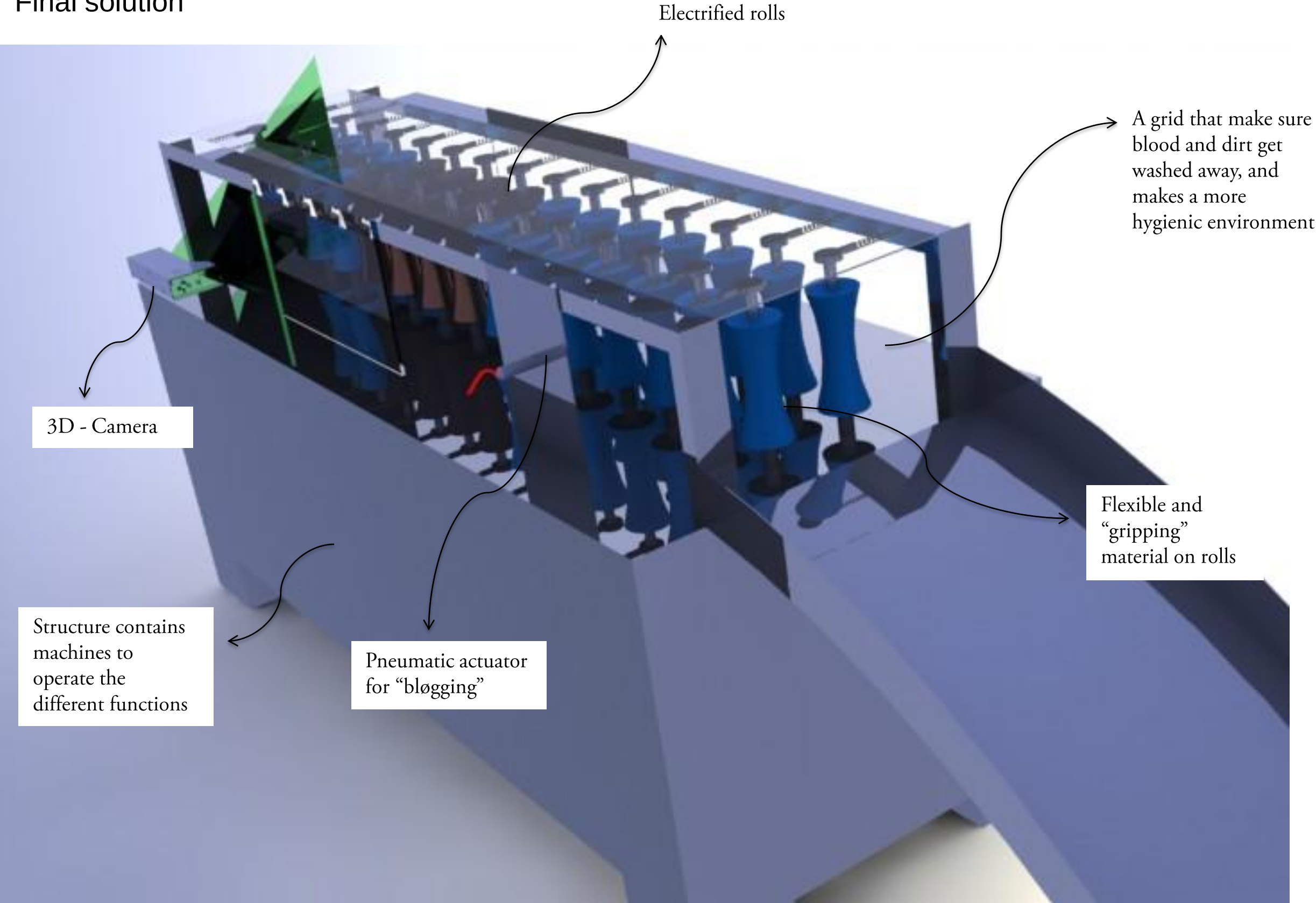
x=1mm  
y=30mm  
Speed on actuator:  
 $v_A=15m/s$

Cut

- For the fish to bleed correct the cut must hit gills
- The cut must be precise and not damage the fish filet.
- To cut through the gills we need maximum force of 400 N.



Final solution



Electrified rolls

A grid that make sure blood and dirt get washed away, and makes a more hygienic environment

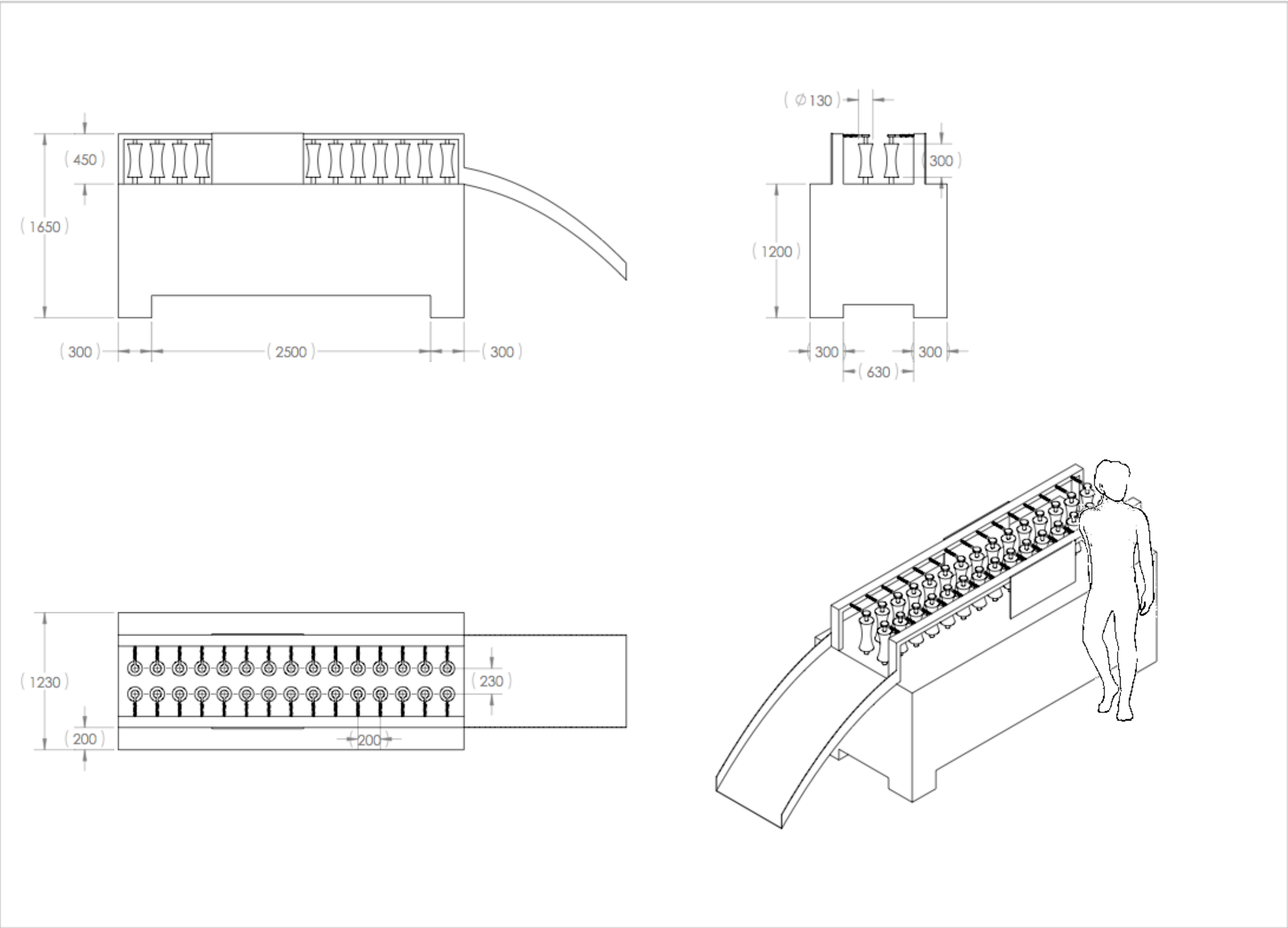
3D - Camera

Flexible and “gripping” material on rolls

Structure contains machines to operate the different functions

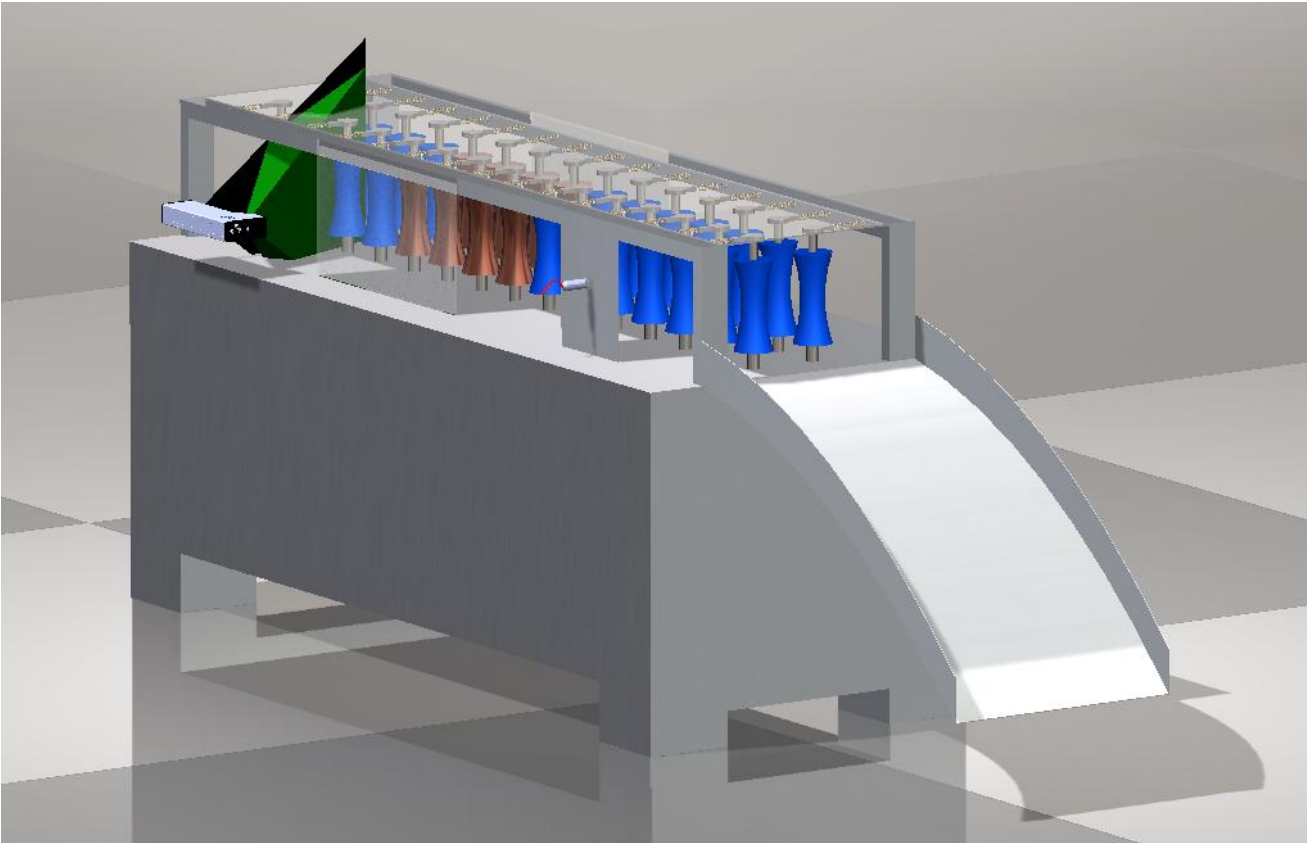
Pneumatic actuator for “bløgging”

Final solution



Process

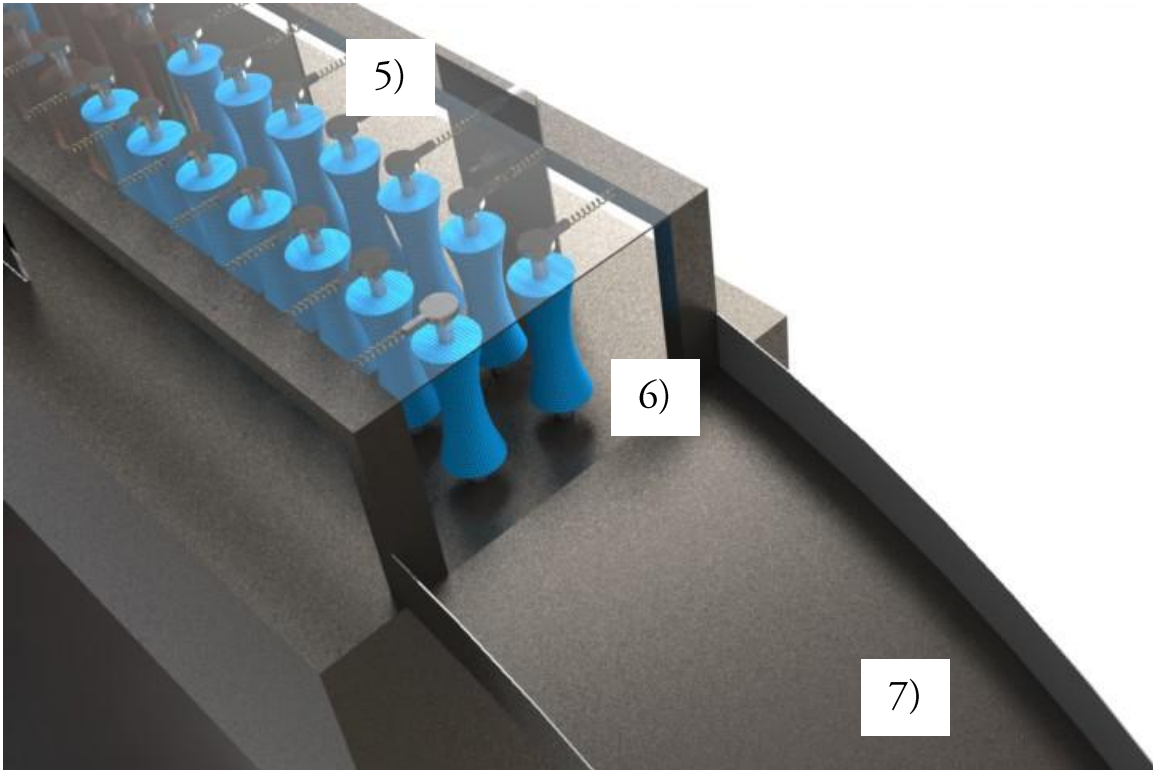
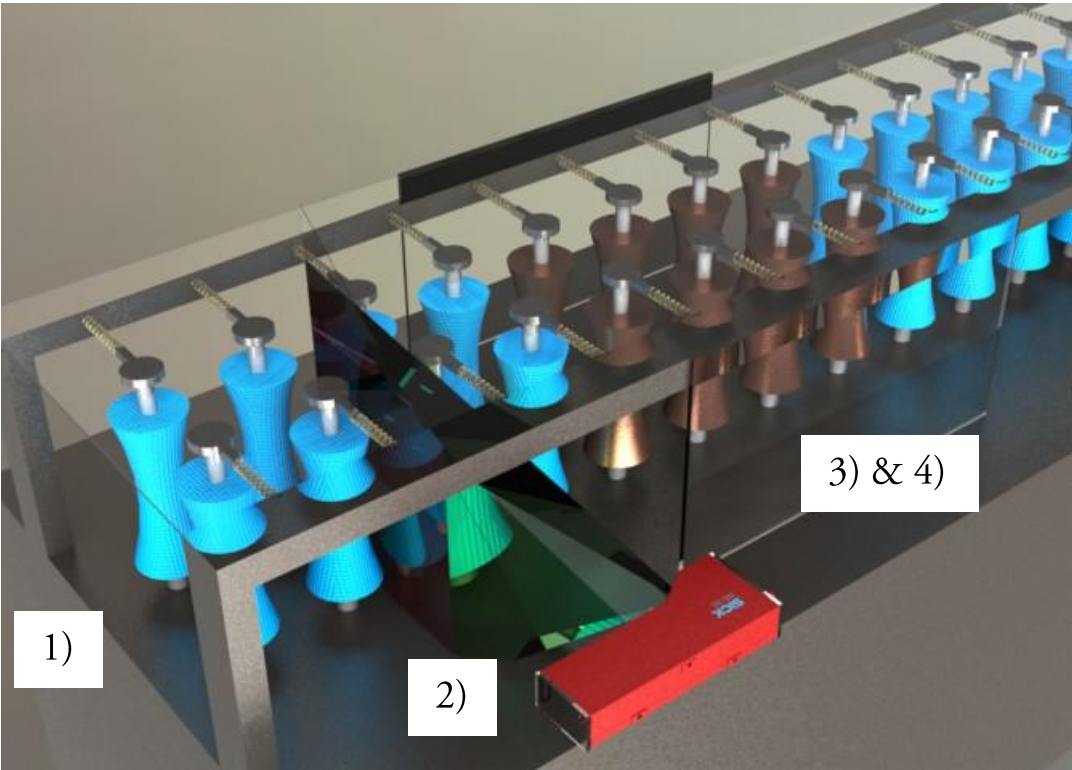
- 1) The fish enters the machine with head first, and “standing” up. The fish is so transported by the rolling rolls pushing it forward.
- 2) 3D- camera recognizes the size, k-factor and the gills where the fish must be cut.
- 3) The fish enters four rows of rolls induced with electricity of different current.
- 4) The fish is now stunned and transported further



5) The killing is preformed by a knife attached to a pneumatic actuator. Signal from 3D camera gives the right position of the fish and when to cut.

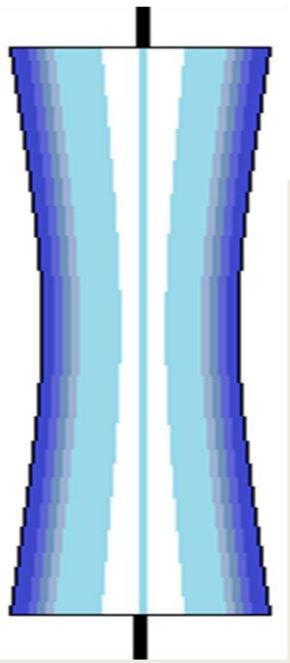
6) The fish will start bleeding out while it's transported to the tank.

7) A grid that make sure blood and dirt get washed away, and makes a more hygienic environment .



Description of solutions – The Rolls

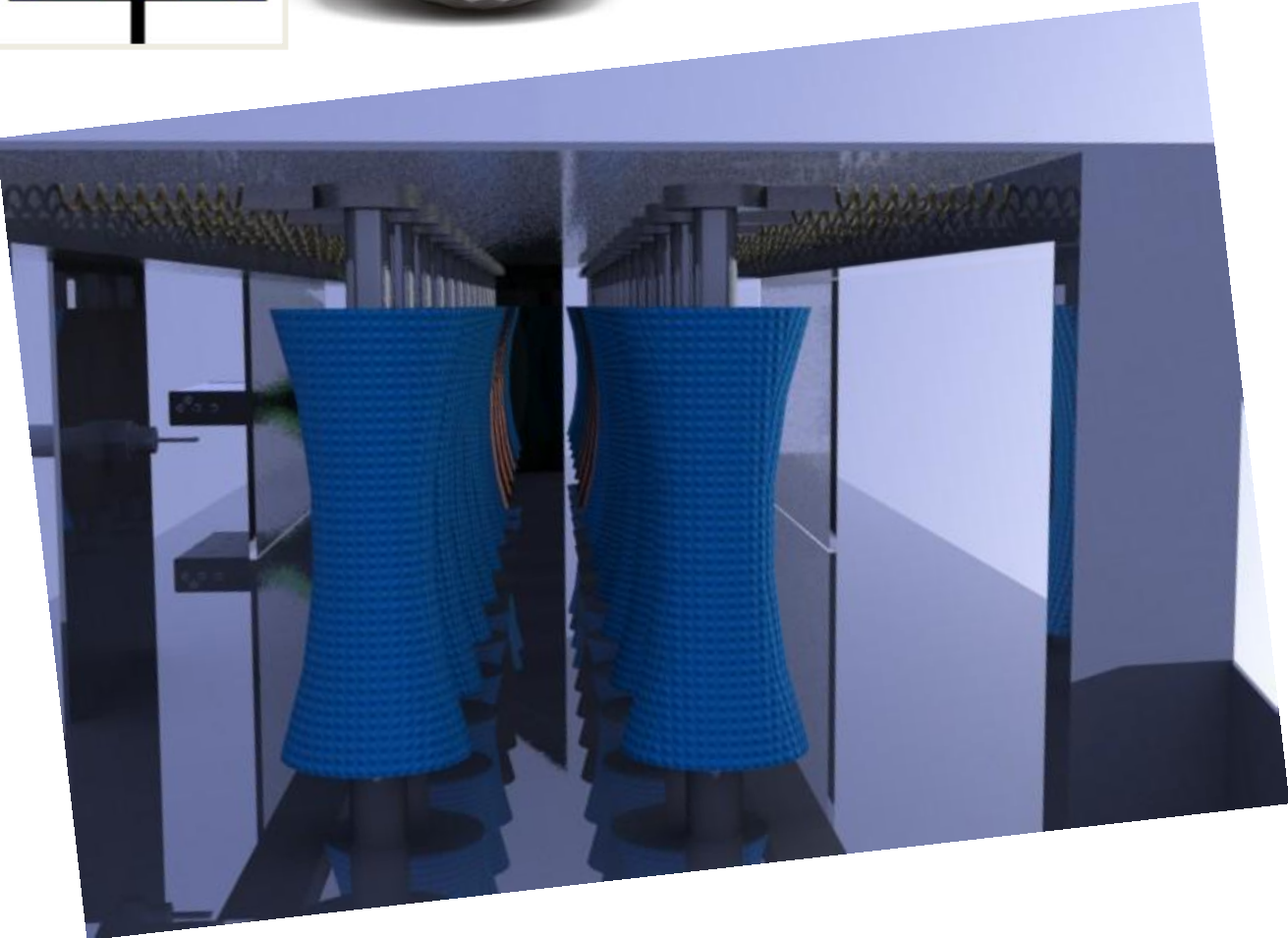
Design



Symmetrical shape (along the x- and y-axis) will always place the fish in the middle, event with variation in sizes. This will make the positioning of the blade for “bløgging” easier.



The surface of the rolls is dimpled like a golf ball for providing the necessary grip. We use **polyoxymethylene** to get the properties we need: Like high abrasion resistance, low friction, for preventing bacteria growth, and water absorption.



The Propulsion

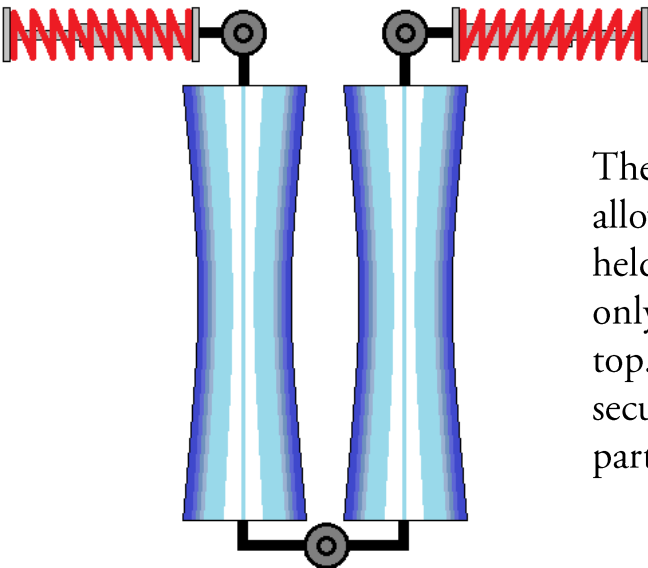


The propulsion of the rolls is provided by a stainless steel waterproof motor. The environment is wet and corrosive and the machine needs to be hosable due to the fact that we are in the food processing industry.



The propulsion is provided by single motor only, utilizing a system of rubber bands and tensioners to connect the rolls together. Much like the auxiliary belt on an internal combustion engine.

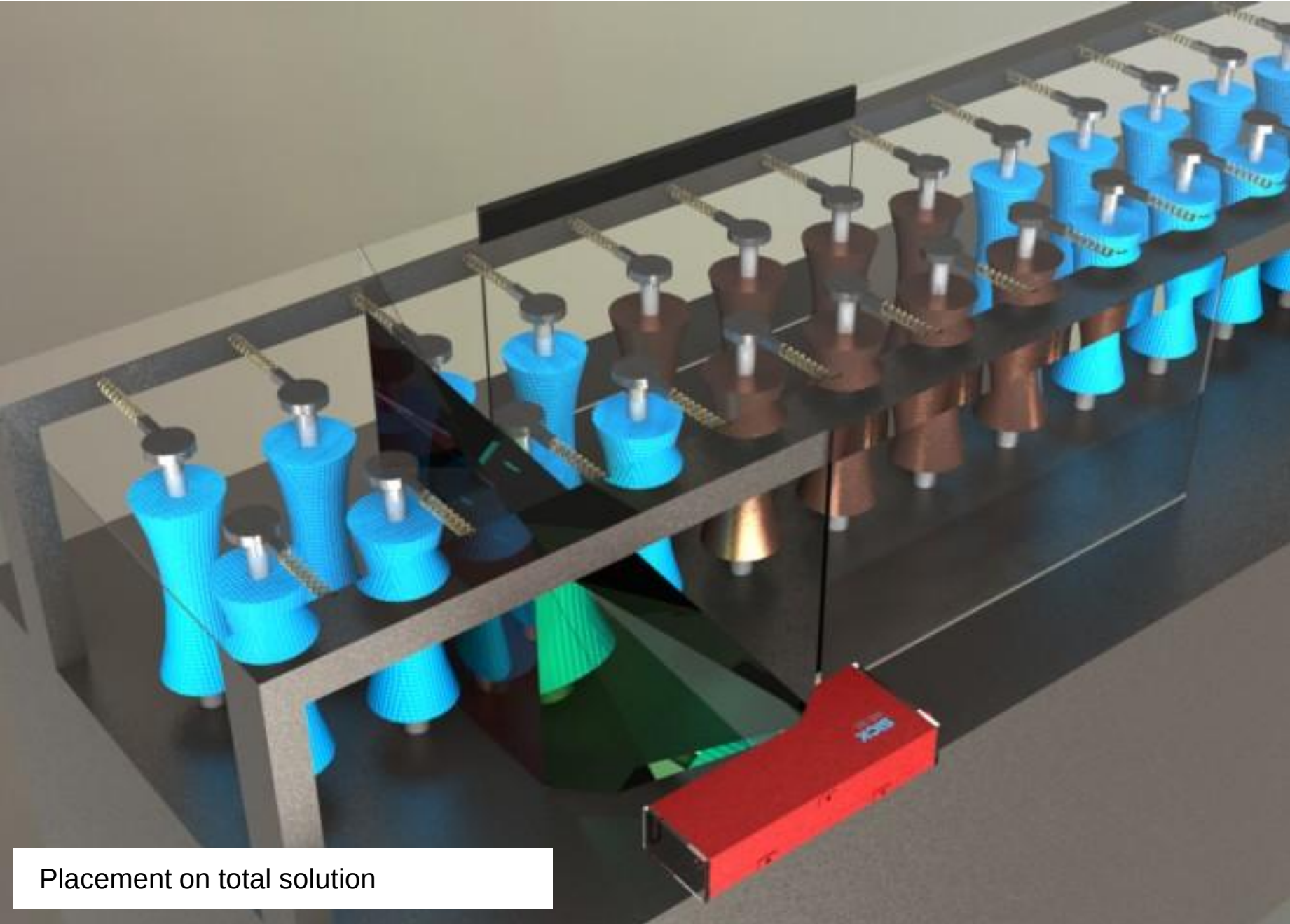
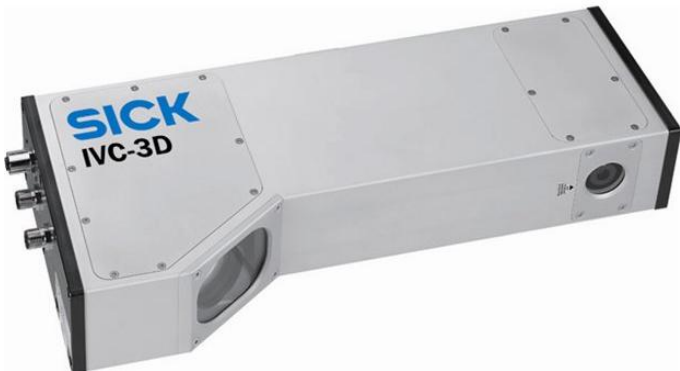
The Mounting



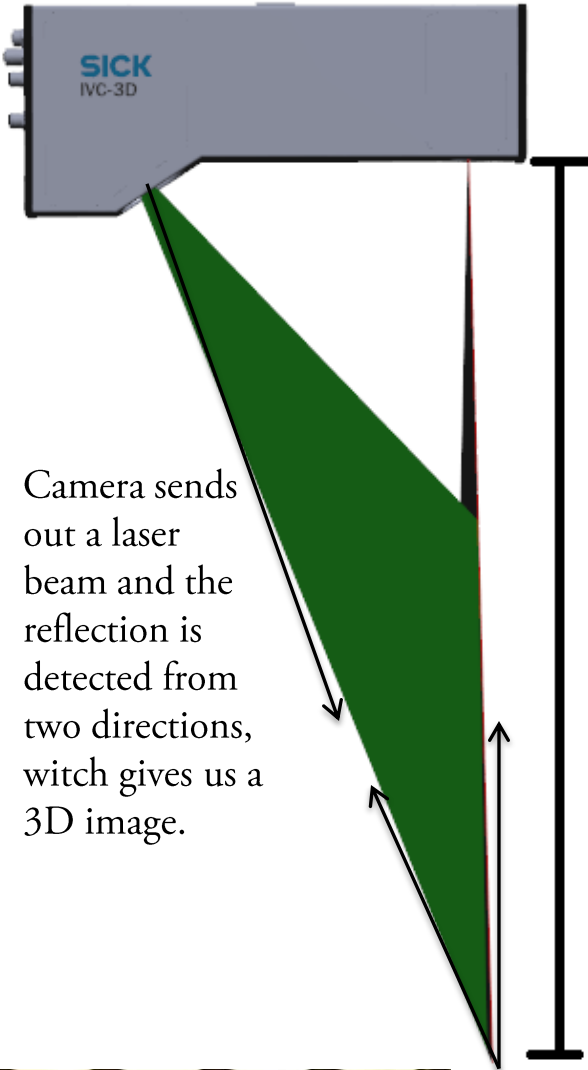
The rolls are mounted on springs allowing different sizes fish to be held in secure position. The rolls are only free to move sideways at the top. At the bottom is a pivot-point securing a tight gap at the bottom part of the rolls.

Description of solutions – Vision system

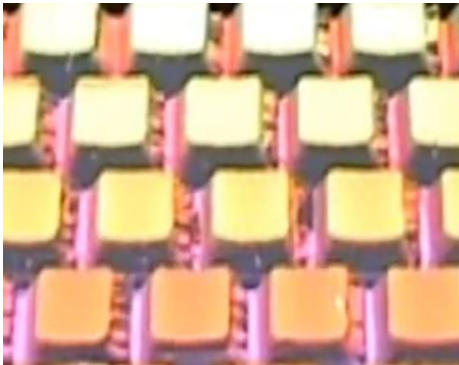
Because of very different sizes of wild fish we can't standardize the knife cut. So we need a system that could handle partly visible fish. We ended up with SICK IVC-3D 200 who uses laser technology and gives a 3D-picture. The software processes the image, finds the gills and send a signal further to the actuator for the "bløgging".



Placement on total solution

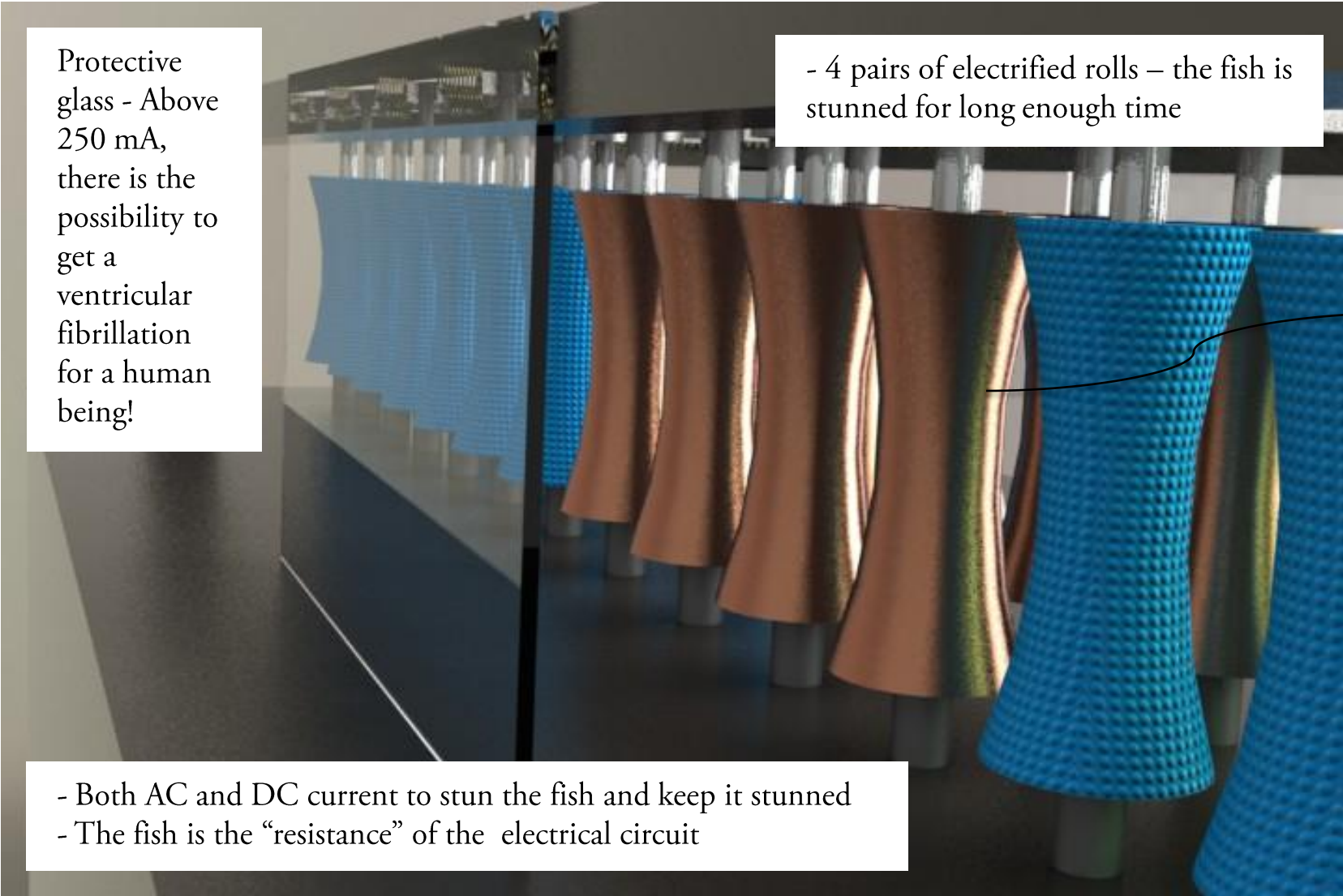


Camera sends out a laser beam and the reflection is detected from two directions, witch gives us a 3D image.

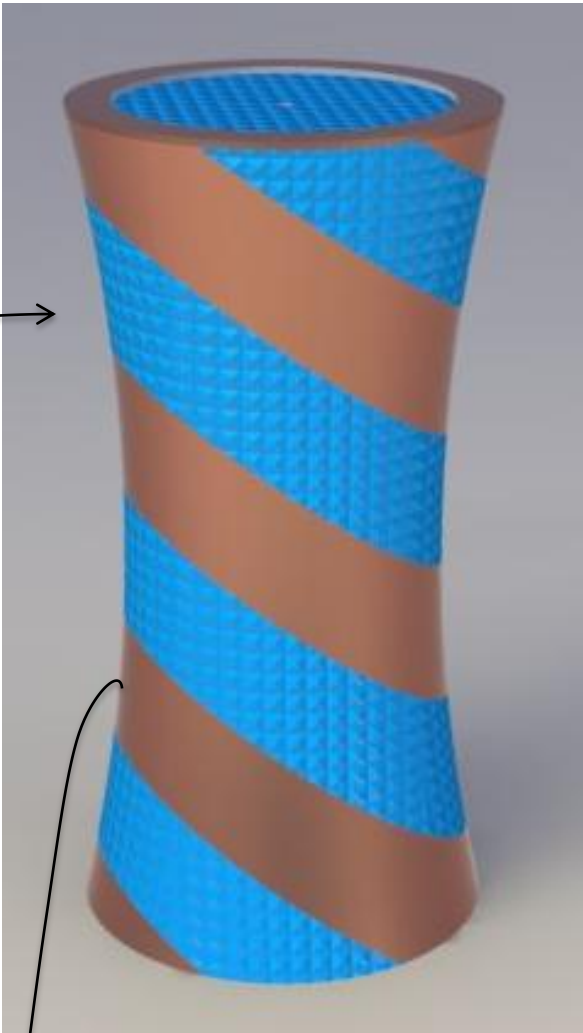


Example of 3D-picture: Keyboard

Description of solutions – Electric stunning

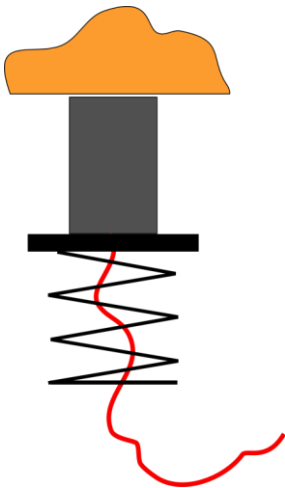


Design for electric rolls

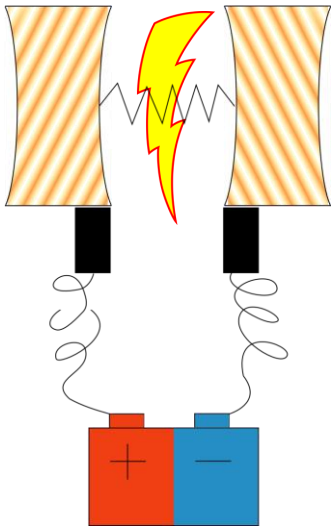


- Copper stripe layers
- Diagonal pattern to provide optimal contact with the body of the fish
- Rotating contact on the top connected to the stripes

Stunning electrical circuits



- Brushes**
- Carbon brushes
  - One for each pole
  - Loaded spring to ensure the contact



- Power supply**
- Model: TekPower TP3646A  
programmable device  
Direct and Alternate Current  
Tension: 40-60 V  
Current: 400-500 mA  
Stunning time: 1-2 s

- Material: CuNi10Fe1Mn**
- Ni-Cu alloy plating
- Corrosion resistant (seawater)
  - Food compatible
  - Good conductivity
  - Easy to clean

**NOTE!**

The exact value of the current depends on the impedance of all the structure: it requires tests!

Description of solutions – “Bløgging”

Pneumatic actuator

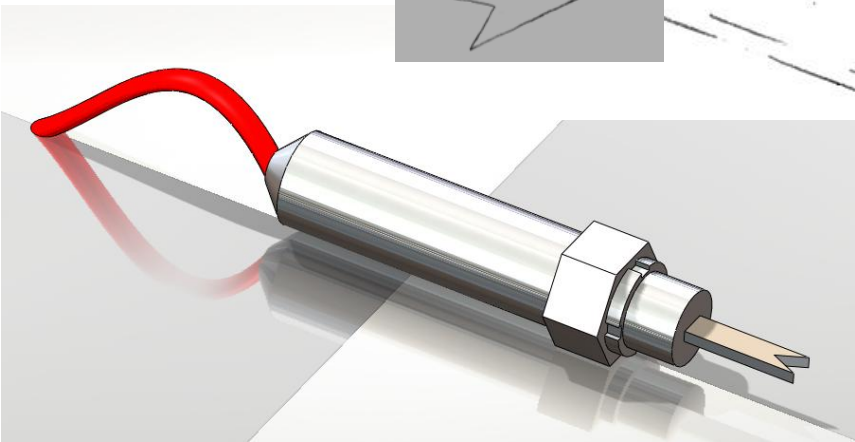
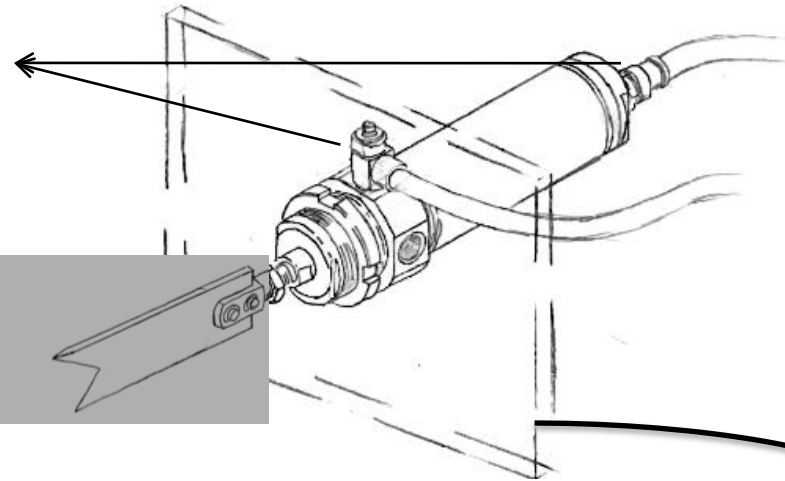
By using a pneumatic actuator we compress air to produce a linear movement. This is a good option because there is available pressured air on the boat and will leave no oil spill that can reduce quality of the fish. With a double-acting compressor motion we can get a fast actuator working in both directions.

FESTO CRDG Ø32

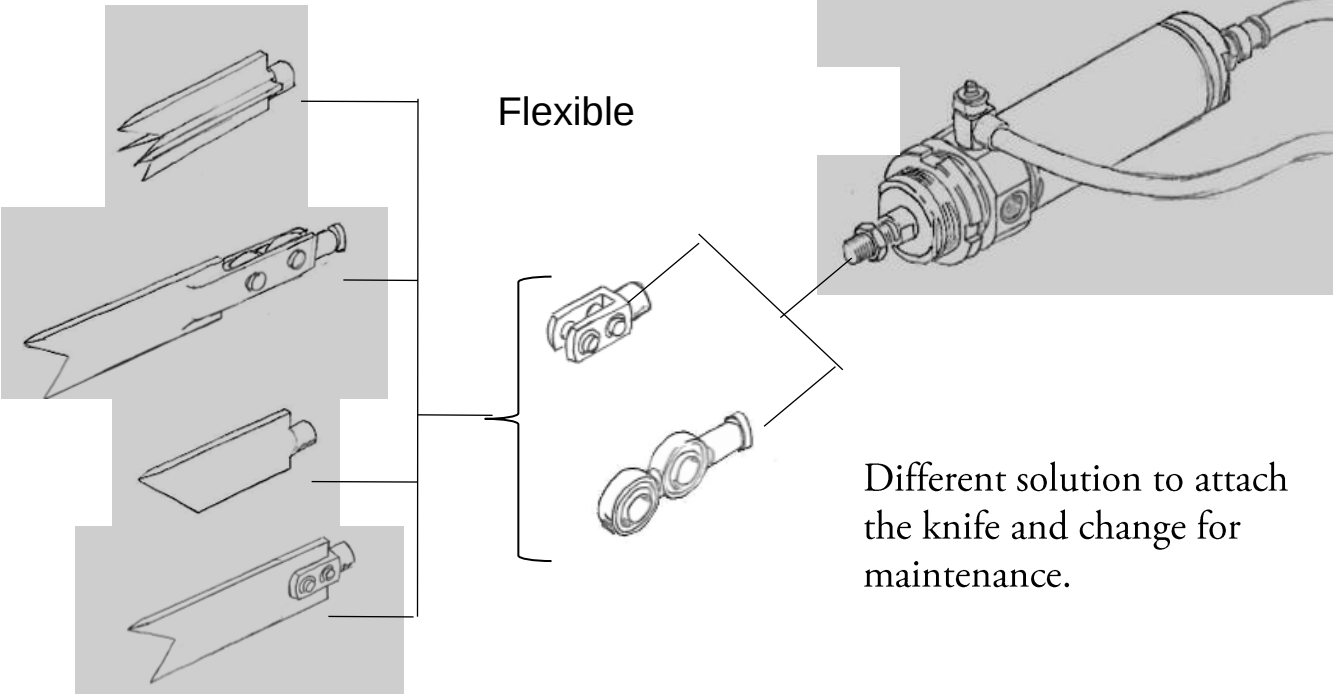


|                            |              |
|----------------------------|--------------|
| Force                      | 483 N        |
| Weight                     | 560 g        |
| Operating at               | 1 ... 10 bar |
| Corrosion resistant class  | 4            |
| Stroke                     | 1 ... 500 mm |
| Cross-section area A       | 804,247 mm²  |
| Workin pressure at 483 N   | 0,6005 MPa   |
| Needed flow rate for 15m/s | 0,01206 m³/s |

Air pressure in

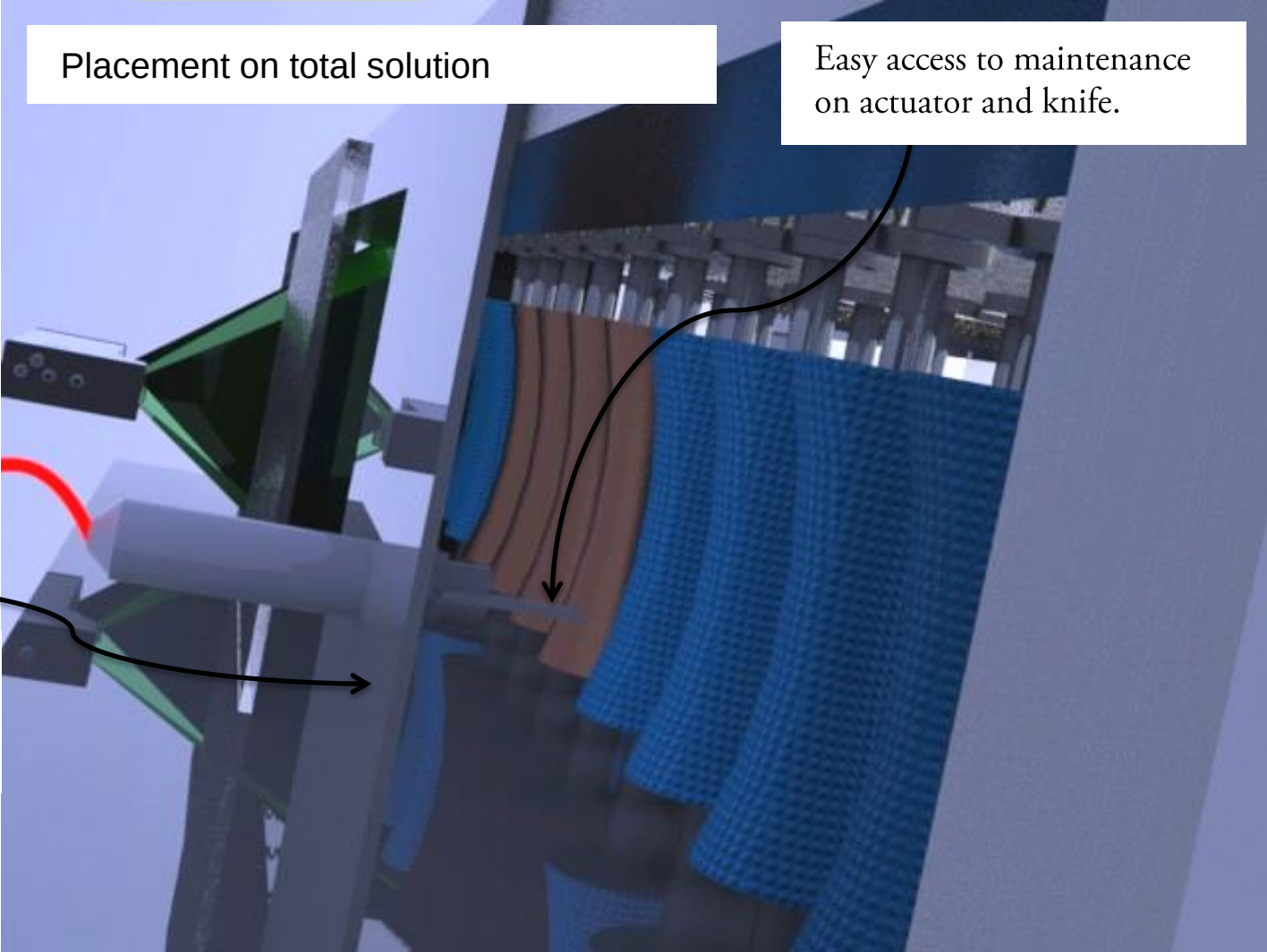


Attached to operate with enough power



Placement on total solution

Easy access to maintenance on actuator and knife.



# Probability of realization

## Available technology

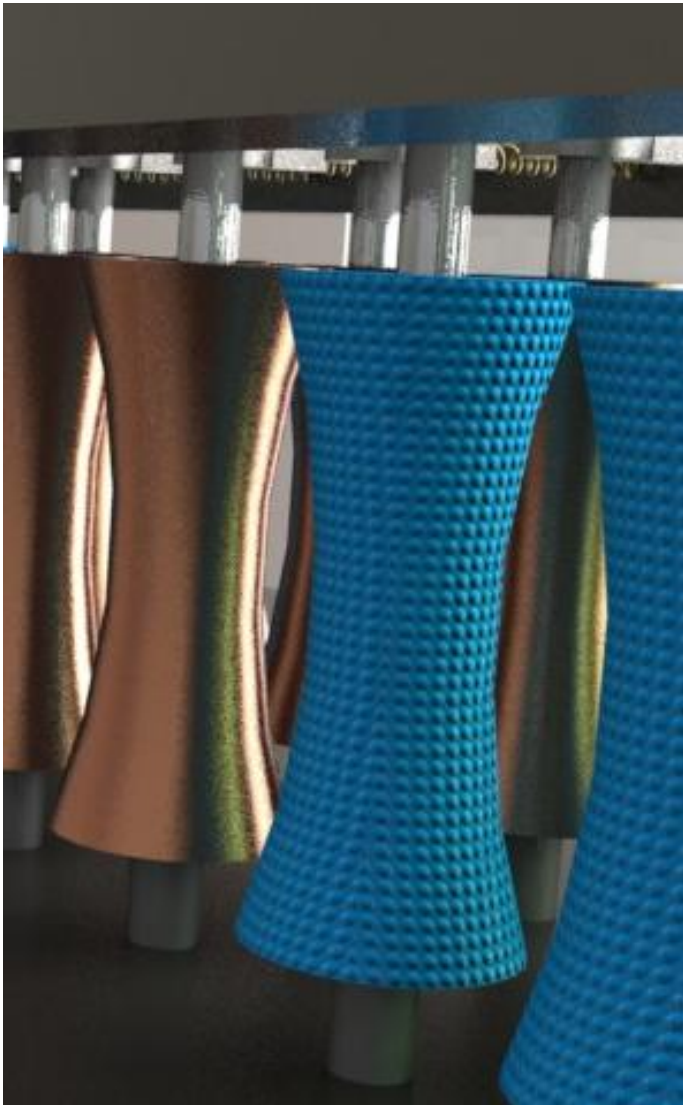
Every part and material we need to assemble and manufacture the machine is already available. The key point is the design of the machine. An affordable and simple machine for aftermarket installation on existing fishing vessels is what we have achieved.

## Investments

The machine itself is made up of available and affordable parts except for the rolls, the focal part of our concept and have only been tested with a simple demo version. Therefore the development and production of the rolls will be an important factor for the probability of realization. The rolls are made of simple solutions so we believe that ...

## Product and material cost

| What                            | Amount   | Cost [NOK]       |
|---------------------------------|----------|------------------|
| Hydraulic actuator              | 1        | 15.000,-         |
| 3D - Camera                     | 1        | 85.000,-         |
| Rolls                           | 30       | 30.000,-*        |
| Drivers, belt wheels            | -        | 5.000,-          |
| Main structure, stainless steel | 100 kg   | 5.000,-          |
| Computer and program            | -        | 20.000,-*        |
| Electrical equipment            | -        | 3.000,-          |
| Knives                          | 2        | 4.000,-          |
| Production cost                 | 30 hours | 45.000,-         |
| Investment                      |          |                  |
| <b>TOTAL</b>                    |          | <b>210.000,-</b> |



We believe that the overall size, weight and price makes our product a strong competitor to the more elaborate land-based processing equipment. This is because our product is designed with the purpose of being installed on a boat in mind. Everything the machine needs to function properly (i.e. pressurized air, electrical power) is available on the boat and can easily be hooked up to the machine.

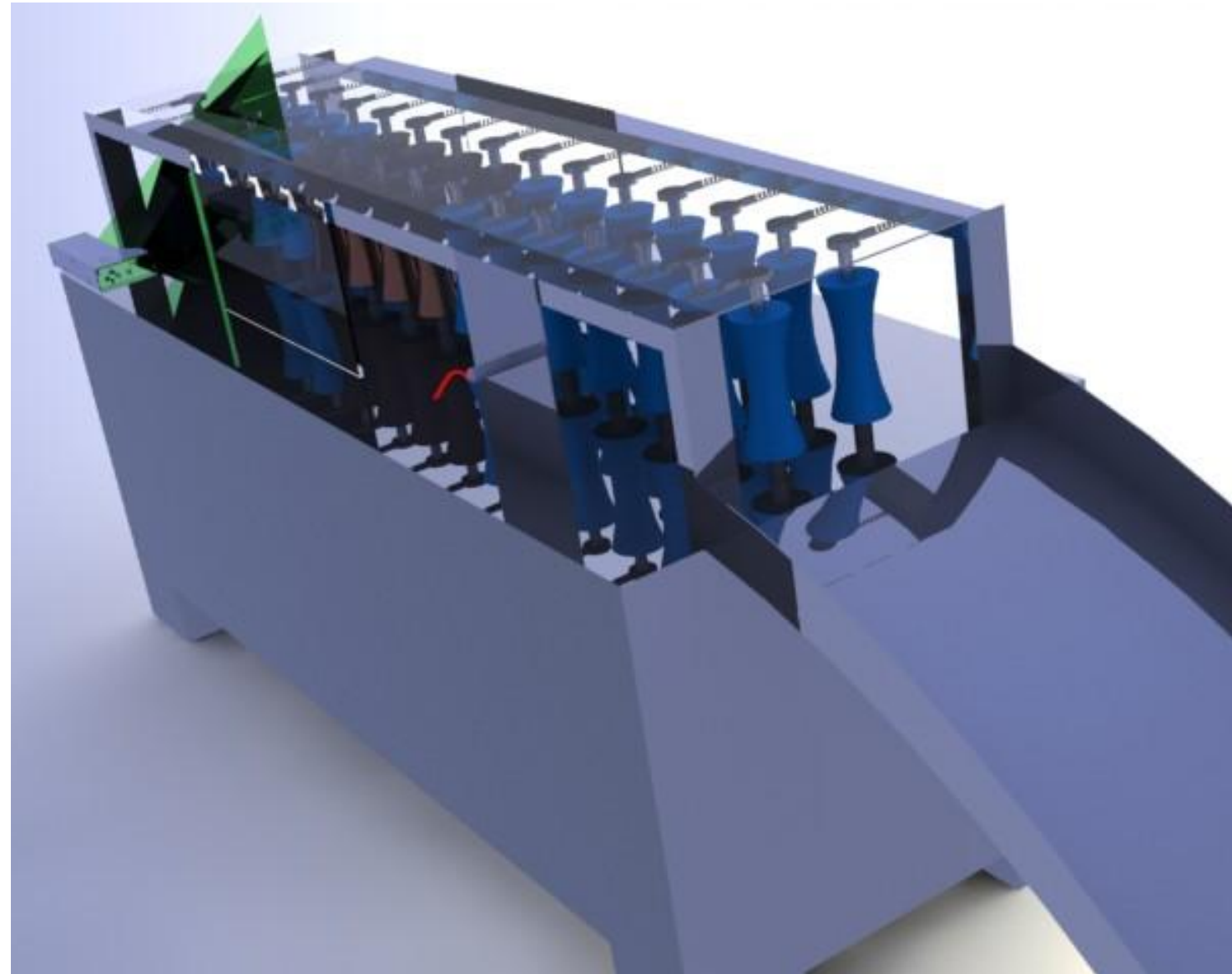
## Conclusion

Trough our process, with evaluation possible solution, we believe our final design will improve fishing at sea.

Our design will make the pre-process of shore more efficient and safe. And all this while keeping the quality of the fish.

We can conclude that our system dramatically improves safety/HSE and overall efficiency:

- I. As soon as the fish is caught the machine is ready to stun and “bløgge” the fish. No need for restructuring of the crew on boat and the physical amount is reduced.
- II. The rolls will hold the fish in any weather conditions.
- III. The rolls enables us to incorporate several functions necessary for the function of the machine like electrical stunning, fixation and positioning of the fish. Many function in a limited space.
- IV. The killing process, is more efficient than manual counterparts and eliminates the high risk for the crew. The killing is precise and happens immediately after the stunning, providing a good final quality.
- V. The use of 3D-scanning technology allows us to estimate factors, as weight, that valuable for the customer.



### Comment on cooperation of the group:

As a group, we have functioned well together. Despite some initial language barriers between the Norwegian part and the Italian part of the group, we soon found out who was best suited for the different tasks. In the start of the semester, we met up on a weekly basis expanding our meetings to a bi-weekly frequency as the deadline approached. Seeing that everyone has attended almost every meeting and done their fair share of work, we cannot see any reasons for the group members to receive any grade different from the rest of the group. The final hand-in is produced by the group as a whole. Alas, the sketches and drawings in our portfolio is not always marked properly with the authors name.

In short we believe our machine will provide a real value for both the crew on the boat and the owner as well as the shareholders experiencing increased efficiency and therefore increased profitability.

We would like to thank the following for contributing to this project:

- |                                             |                                |
|---------------------------------------------|--------------------------------|
| - Bendik Toldnes, Sintef Fiskeri og Havbruk | - Bjarte Holmgard, NTNU IPM    |
| - Jan Magnus Granheim Farstad, NTNU IPM     | - Knut Einar Aasland, NTNU IPM |