Construction of a new shrimp fishing vessel for the North Sea Wadden Sea area.

EUDP Project no 67014-05152 Rejekutter

Final Report

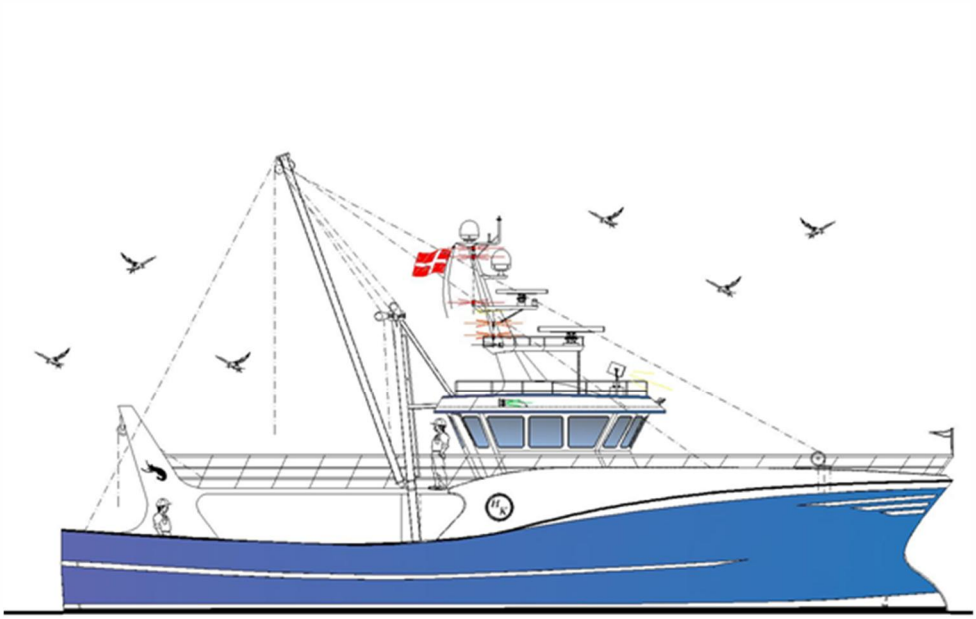

Table of content

Sammenfatning og konklusion

- **Projektets formål**
  Det var projektets formål at konstruere og bygge et nyt rejefartøj med et energiforbrug på det halve af det nuværende fartøj (referencefartøjet). Formålet skulle opnås gennem en række tiltag vedr. skrogets design, fremdrivningsudstyr og nye redskaber. Der blev regnet på en del forskellige tiltag. Nedenfor gennemgås de som indgår i det endelige design.

  Desværre ønskede fiskerne ikke at gennemføre projektet da det endelige design forelå. Vi kan derfor ikke fremvise et færdigt skib; men dog et færdigt projekt med de energi-beregninger som er foretaget.

- **Projektets resultater mht. fartøjsdesign.**
  Vestværftet tegnede i udgangspunktet et skitseprojekt for et fartøj på 24 m. Derefter blev det vedtaget at der skulle tages hensyn til følgende forhold:
  - Steaming til/fra havn 1 time resten af tiden fisker
  - Bølgehøjde op til 2 m
  - Maksimalt pæletræk med 300 HK maskine
  - To store skruer i stedet for 1

  På grundlag heraf gennemførte Force instituttet to sæt beregninger som dannede grund-Lag for det endelige design. Hundested propeller foretog beregninger af skruestørrelse og pæletræk som herefter indgik i den del af skrogdesignet.

- **Projektets resultater mht fremdrivningssystemet**.
  Der blev overvejet forskellige løsninger men besluttet at det langt mest rentable ville være diesel/elektrisk drift dvs en hovemotor som ved optimalt omdrejningstal driver to små elmotorer som igen driver hver sin skrue. Herved opnås – i kombination med de store skruer et næsten fordoblet pæletræk og i alt en reduktion af energiforbruget fra skrogform og fremdrivningssystem på godt 30 %.

- **Projektets resultater vedr. redskaber**.
  Redskaber kunne konstrueres og afprøves på referencefartøjet. Resultaterne kunne så-ledes sammenlignes med det tidligere redskab. Det viste en besparelse på ca 20 %

- **Samlet energibesparelse som beregnet**.
  Det fremgår således at den samlede energibesparelse kan beregnes til godt 50 %.
  Efter sagens natur kan det ikke gennemprøves empirisk ; men det er en ringe usikkerhed på de foretagne beregninger

Summary and Conclusions

1. Introduction

This report reflects all the considerations that was done and those which were selected and were included in the final offer to the fishers. The fishers did not, however, accept the offer to build the vessels despite the fact that the estimated results are in line with the expectations set out in the application to EUDP.

The energy consumption of the vessel is thus theoretical as calculated by Force Technology. As far as the gear is concerned new gear was calculated, produced and used and the actual results (from the reference vessel) are contained in the report.

1.1 Background

There is a fleet of about 450 shrimp vessels in the Wadden Sea. Most of these are old and due for replacement in the course of a few years. Energy consumption is the biggest single cost item which normally accounts for 20 % of the vessels turnover and for the eldest vessels more.

It was therefore interesting to design a new vessel and new gear in order to reduce energy consumption.

1.2. Scope and content

The scope of the project was to reduce energy consumption of the vessel to half. A number of measures were analyzed, but four features were retained as essential. Those were the following:

- The hull of the vessel was designed with a view to use two big propellers instead of one small. The scope of this feature is a very substantial energy reduction.

- The hull was designed to be ideal for the working conditions for the vessel. Very low steaming time compared to fishing time, and an ability to fish in waves up to two meters high. The ability to fish in two-meter waves will increase the number of fishing days by 10 -20 % and hence increase annual profits.

- The propulsion system was changed from diesel to diesel/electric propulsion. This ensures a constant number of revolutions. The combination of two big propellers,

a constant number of revolutions of the engine gives a higher bollard pull than the present vessels and a lower energy consumption than the present vessels.

- A second objective was to construct gear in dyneema instead of nylon with a view to reduce the twine area of the trawls and hence the drag in order to reduce energy consumption.

Several other elements intended to reduce the energy consumption were investigated but discarded. These were hydrogen generator, use of heat exchanger to produce cheap chilled air for the holds and cheap heating for the shrimp boilers on board.

The scope also included the change of the very heavy beams with a wing, but this was not done at the abortion of the project.

The scope of the project was to reduce the energy consumption of the vessel to half compared with the reference vessel.

1.3. Main activities in the project

The main activities of the project were the following:

- Establish baseline performance of the reference vessel
- Establish data for the energy consumption of the existing gear
- Design the new vessel after having optimized the parameters (i.e. hull shape, propeller size etc).

It was then the intention to build the vessel, but as mentioned the fishers decided to bail out of the project.

2. Project Results

2.1. Market evaluation

Our investigation of the market confirms that there is a large scope for replacing the North Sea shrimp fleet in the course of the coming 10 years.

During the project, one fundamental parameter has changed much to the detriment of building such vessels in Denmark. That parameter is the price of tonnage. Denmark has a limited number of gross registered tons (GRT) for fishing. GRT is transferable and

subject to market prices. For many years there was a nominal price of GRT, but during the latest years there has been hectic new building activity with an increased tonnage as a result.

In consequence tonnage price increased from 1000 DKK/GRT to 20.000 DKK/GRT from 2016 to 2018. That adds 3 million to the cost of the project and has played a role for the decision of the Fishers.

This is not relevant for most of the other markets for such vessels, as there is no real constraint on GRT in the other countries.

Shrimp vessels are subject to a number of regulations that are designed to limit their capacity. First the number of HP is limited to 300 HP, Second the length of the beams is limited to 10 m. each for two beams.

That blocks the way to increase capacity to fish more and to transform a higher bollard pull to more efficient fishing and to transform more energy efficient gear to higher catch. The scope in this project is therefore limited to the pure effect of the reduced energy consumption.

But the results are as relevant – and even more relevant– for other types of vessels. If you can guarantee an increase in the catch of 20-30 per cent without added fuel consumption or other additional costs that is equivalent to eliminating the fuel cost all together.

2.2. *Analysis of technical possibilities, selection and explanation of choice*

In our application the following possibilities should be tested and evaluated:

- Propulsion system
- Shape of hull
- Materials and design of gear
- Alternative design of beam
- Current registration of catch
- Hydrogen generator
- Recycling of surplus heat from engine for boiling water for shrimp boilers
- Recycling and converting heat to cool the cold storage holds of the vessel
- Use of LED light and electric wire drums.

It was clear from the outset that the major savings of energy should be found in the shape of the hull, the propulsion system and the material of the gear. The other elements were less known and could imply additional savings.

Propulsion system

Several options were considered. Purely electrical propulsion is out of the question because of the price of batteries, but partly electrical with a smaller battery pack was considered but was also discarded because of the price of the batteries.

LNG was briefly considered but was discarded because of the lengths of the trips combined with the size of the vessel and the absence of infrastructure for LNG in the relevant ports.

A study visit in Holland to a vessel that fished plaice and had been converted from beam trawler to traditional trawler (i.e. a bigger trawl without beams but spread with doors) provided the inspiration for a good solution. (See annex 1 for report from study visit to Holland).

The vessel was fishing in the North and could therefore have one very big propeller as it did not need to fish in shallow waters with limited draught.

It was equipped with a diesel/electric propulsion system where the engine was always running at a constant optimal number of revolutions. The power was partly used to power the propulsion of the vessel partly for all the other uses of energy. Propulsion was driven by a small electric engine which allows for gearless increase in speed and for transforming very high power and very few revolutions. This translates into an increase of the bollard pull compared to the engine size (fuel consumption) and this is exactly what a fishing vessel needs.

It our case it would however be necessary with two propellers and two parallel electrical engines (both connected to the diesel engine) to drive the vessel forward.

Hundested propeller provided calculations of the bollard pull we could obtain by this solution compared to a traditional propeller.

The bollard pull was increased by 70 % as compared to one traditional propeller.

Shape of hull.
The vessel should be able to fish in shallow waters and should have a draught of no more than 2,5 m. It was therefore chosen to design a hull with 2 big propellers. That would allow for a very low number of revolutions of the propellers and a substantial increase in bollard pull. That, together with the design of the hull, would assure that the vessel would be able to increase the number of fishing days as it could fish in more rough sea as lack of thrust is the most common reason for loosing speed in high seas. It was estimated that the number of fishing days could be increased by between 10 and 20 %.

Other considerations of the shape of the Hull was the working routines of the vessel i.e.

how much steaming time compared to fishing time and in what wave heights the vessel should be able to fish.

After dialogue with Force Technology and after studying the fishing pattern and wave heights common in the relevant area of the North Sea it was decided to use the following inputs in the design of the vessel.

- Steaming 1 hour out and one hour in.
- Fishing 3-5 days
- Wave heights up to 2 m

On this basis Vestvaerftet designed a hull for Force Technology to optimize on.

The calculations from Force Technology appear in Annexes 3 and 4.

The result is part of the final design of the vessel but depends on final flume tank test at Force technology. But the differences will be of minor importance.

The estimation is that this would reduce energy costs of the vessels with at least 30 %.

The final design of the new vessel and the offer from Vestværftet to the fishers is included as annex 5.

Material and design of gear.
The shrimp trawls are generally constructed in nylon twine. Nylon is a very good material with a number of desired properties such as a high tensile strength and a substantial elongation.

Experience from other fisheries have shown, however, that a relatively new material (Dyneema) that has a four to five times higher tensile strength can apply. This will reduce twine size to half and reduce draft very considerably.

We therefore designed trawls that was built in dyneema rather than nylon and measured their performance relative to the old trawl.

We installed a fuel consumption tracker in the reference vessel and logged the fuel consumption for two weeks. We the installed the new trawl and repeated the measurements.

For the reference vessel this new trawl reduced fuel consumption with 20 %.

More detailed logger results are available in annex 6.

Alternative design of beam

It is not assumed to be important for the fishing result that the trawl is very hard on the bottom. We therefore performed a literature study on which alternatives were tried in similar fisheries in different parts of the world.

In the Netherlands different beams with electric pulse is used. This is not allowed in Denmark and could therefore not be used. It turned out the it did not work well on shrimp vessels contrary to plaice trawlers. Most likely this is due to the limited size of the shrimps compared to plaice because the tension drop over the organism is much smaller.

In Florida as the rest of the Gulf of Mexico there is a substantial shrimp fishery (all though much bigger shrimp). They use either traditional doors or an aluminum wing that hold close to the bottom during fishing.

It was therefore the intention to develop such wing that would be suitable for Danish waters, but it was fortunately foreseen for the latest part of the project and hence not initiated.

Current registration of catch
Monitoring the catch in real time is normally done with echo sounder or similar. The shrimps are so small, however, that they give no echo.

This information is relevant because shrimp occur in patches. As is, you only know what you caught since the trawls was set last. If there were many shrimps in the catch you have to fish the whole area over again in order to catch more from that patch.

It would be much more useful to monitor the catch on real time basis i.e. receive the catch on the vessel during fishing.

That requires a kind of pump that brings the catch from the trawl to the deck as catches take place.

Such a system is known in Norway where it is used monitor krill fisheries in the arctic. Krill are smaller than the shrimp targeted in the Wadden Sea and are caught in much higher depths. The system is way too expensive to use in the Wadden Sea, but to provide a proof of concept.

This part of the project was also postponed until the vessel was ordered.

Hydrogen generator
Hydrogen reactors are used in the US and in Australia to improve fuel utilization in diesel engines. A generator that produces hydrogen from water provide the hydrogen to be blown into the engine with the air suction.

The producers claim that the little machine could improve performance by as much as 10 %, but it turned out that only anecdotical evidence could support this claim. Further investigations showed that we could have a test performed at the Danish Technological Institute, but that none of the relevant engine suppliers would maintain their guarantee if such an appliance was installed. It was therefore given up.

Recycling of surplus heat from the engine for boiling water for shrimp boilers.

It turned out that this in principle was a simple standard exercise, but that the production of hot water required, was too small to justify the price of the equipment, and an electrical production of chilled water on the basis of surplus electricity was also foreseen. In the overall picture, however, this counts very little.

Recycling and converting heat to cool the cold storage holds of the vessel.
This could be generated from surplus electricity, but it counts little.

Use of LED light and electric wire drums.
This was done and will give a certain contribution to energysavings, but very small compared to the most important features (hull, propulsion, big propellers and gear).

There will also be an additional feature which is a "leave ship" button that switches off all dispensable use of electricity while the ship is idle in port.

2.3. Overall energy consumption as calculated.

It is on the basis of the designed vessel the expectation that the vessel and the gear combined would have given a reduction og energy consumption to at least half.

2.4 Specification for vessel. Main features

A specification of the vessel is annexed as annex 5 with a drawing of the general arrangement as well.

The designed vessel has as main features:

- A new design of the hull
- Two new propellers of 1,80 m instead of one for 1 m for the reference vessel

- Diesel/electric propulsion system
- Led lights

2.5. Specification for gear. Main features.

The gear consists of two trawls with a beam each. The regulation is on the length of the beam (and the max power on the engine at 300 HP). The maximum length of the beam allowed is 10 m.

This means that the savings on energy that can be obtained are only the direct savings. There is little or no possibility to increase the size of the gear in order to increase the catch unless you fish with an ordinary trawl instead of the beam trawl. This is not considered a good option by the fishermen because the only way to see when you have catch or not is to pull in the trawl and inspect the catch, as sonar or echo sounder does not work on invertebrates (because they have no swim bladder). It takes much longer time to set and pull an ordinary trawl than a beam trawl.

The only possibility in that case is to reduce the drag of the trawl. We made a trawl with the same design and size as the old trawl but changed material in the gear. The traditional material for this kind of trawls are Nylon or Polyethylene. In this case is was nylon.

We exchanged nylon with dyneema® in most of the trawl. Dyneema is a rather new material – and completely new for this purpose. Id is four times stronger than PE for the same diameter and therefore half diameter for the same strength. Half diameter reduce drag form the trawl to half and overall energy consumption with app 20 %. (the drag from beams and wires is not reduced).

We tested the new trawl against the old trawl on 2 weeks fishing with each trawl on the same vessel and verified the results this way.

3. Dissemination of results

The results have not been disseminated to the Industry yet. We expect that we will be able to conduct another project and demonstrate the results. This will be far more convincing than an aborted project. We will therefore wait until a new project is completed.

4. Annexes

1. Report from study tour to the Netherlands

2. Calculations of Bollard pull and propeller size

3. Report from Force Technology (model 20 condition 01)

4. Report from Force Technology. (model 10 condition 01)

5. Final vesseldesign and offer from Vestværftet

6. Logger results on baseline performance with old versus new trawls