Newsletter April 2021

Dear CoolFish participant,

Below you will find a summary of our recent accomplishments in CoolFish as well as our plans for future work.

Update on project partners

One of our industry partners, PTG has decided to participate with a larger financial contribution in the project. That means that we have fulfilled the requirement from the research council of having 20 % financing from industry partners and that we can have full focus on research activities. Thank you all for contributing.

Webinars

We plan to have several shorter webinars this year. The topics and contents are not finally in place, but here is an overview of our suggestions:

- CO_2 as a refrigerant in fishing vessels
- Thermal energy storage onboard fishing vessels
- LNG as fuel in fishing vessels
- Integration of cooling and heating onboard fishing vessels

We plan to have the webinars in English and invite participants from other projects and countries as well. If anyone has suggestions for presentations or topics, please contact us.

We will set up physical meetings when it is safe to meet again, hopefully at the end of this year or beginning of 2022.

The presentations from earlier webinars are available on the webpage of CoolFish: www.sintef.no/en/projects/coolfish

Industry cases

We are well into the work of our four industry cases:

Case 1: Energy efficiency on board fishing vessels

A research cruise was conducted last year with the purse seiner Selvåg Senior which mapped energy flows of the refrigeration system. This resulted in an increased understanding of how the fishing cruises are done and how on-board energy usage is linked to the operational mode of the vessel. This in turn has been crucial to develop a foundation for design of energy efficiency measures and provides valuable input for Case 2.

A new research cruise is currently being planned, this time on a freezer trawler belonging to project partner Bluewild. The intention is the same: to map the energy flows of the refrigeration system. A freezer trawler and a purse seiner are quite different in terms of operational profile and refrigeration systems and equipment, so the idea is to gain a similar understanding for this type of vessels which will be fruitful for exploring energy efficiency measures. The research cruise will likely be conducted during the last half of this year.

Case 2: Design concepts for cold utilization from LNG driven ships

One of the core activities of this case is to investigate how to utilize "free" cooling from LNG driven fishing vessels in the best manner on board fishing vessels. Previous work on this subject has been conducted by Muhammad Zahid Saeed, who during his master thesis explored different concepts for integration of LNG cooling with the refrigeration system. However, updated knowledge regarding fishing vessel design and how they operate has led to a necessary continuation of this work, with the aim to investigate the potential given more realistic conditions. This work will be carried out through modelling and simulation of a refrigeration system and integration of an LNG cold utilization system and is done with Modelica/Dymola. This is a great tool for creating thermodynamic energy systems and can be used to perform transient simulations.

Case 3: Freeze concentration

We have decided to change the content of case 3 from what was given in the original project description to instead include the development of technology for freeze concentration. This will be in cooperation with Bluewild and PTG. We will work with the design of new low temperature processing of fish protein hydrolysates (FPH): freeze concentration. The freeze-concentration is a gentle and energy efficient treatment for liquid protein hydrolysates, which ensure high quality of final product. The process utilises the freezing point depression phenomena to transfer free moisture into ice with its subsequent separation and cleaning, see Figure 1.

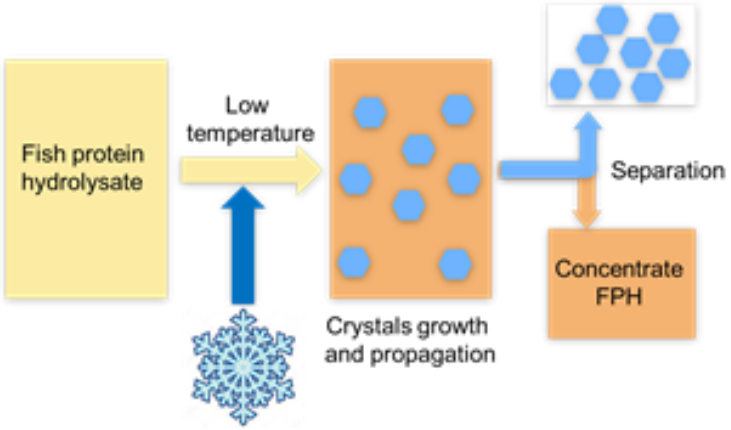

Figure 1: Principle scheme of freeze-concentration process

NTNU have developed several conceptual solutions for complete processing line for fish protein hydrolysates: from rest raw materials to fish protein concentrate and/or powder. The lines will utilize surplus heat from two stage CO_2 refrigeration system to provide low CO_2 impact of the production line.

Case 4: Design concepts for *integrated thermal energy units*, for cooling and heating

MMC has previously purchased components for a transcritical refrigeration system with CO_2, which will build and commissioned during the project period of CoolFish. NTNU, in collaboration with SINTEF, has assisted in planning and designing the system. The main function of the plant is to cool seawater (RSW). The plant has three compressors with flexible valve connections to different pressure levels, depending on the cooling needs for room cooling, RSW cooling and freezing. This solution is beneficial, due to that the need for maximum cooling capacity at RSW is only for relatively short periods.

One goal of the project is to develop simulation models for cooling systems with EES software. These models have been further analysed and optimized in terms of system performance, energy efficiency and applicability for future installations. The data must then be validated with the first performance data available from the commissioning phase. Due to delays in the commissioning phase, this has not been possible. It was therefore decided to focus further on the development of simulation models, now using Modelica/Dymola. There will also be a spotlight on the implementation of various ejector solutions, to demonstrate the benefits of active utilisation of expansion work.

5 simulation models were developed:

1) CASE 1: Simple throttling with one evaporation temperature level (RSW)

2) CASE 2: Double throttle with parallel compressor. Two evaporation temperature levels (AC, RSW)

3) CASE 3: Triple throttling with parallel compression. Three evaporation temperature levels (AC, RSW and LT).

4) CASE 4: Implementation of ejector. Two evaporation temperature levels (AC, RSW)

5) CASE 5: Implementation of ejector. Two evaporation temperature levels (RSW, LT)

The models and calculations clearly show that double throttling with a parallel compressor results in increasing COP and RSW cooling at high seawater temperatures. The simulations also show improvements in RSW cooling capacity and the system's COP when implementing the ejector. The results in CASE 4 show stable RSW cooling at increasing ambient temperatures, which is important for a transcritical CO_2 system. Maximum RSW cooling capacity and COP were obtained using the simulation model CASE 4 (440 kW and COP = 3.6). In addition, the results indicate that proper control of high side pressure and the design of the cooling system will ensure efficient cooling on board of fishing vessels in warmer climates.

Based on the findings and results from the project, an article will be written for the IIR Ohrid conference which will take place in September 2021.

Postdoc and master student

Besides Engin, we also have a new post doc student at NTNU, Mihir Mouchum Hazarika, who is now part of our CoolFish team. He will contribute to the work in CoolFish firstly by developing dynamic simulation models for the different CO_2-systems.

NTNU has put effort into recruiting new master students for the coming semesters. 3-4 students are interested in topics related to CoolFish. NTNU and SINTEF will have an introduction meeting with these students before summer. Some might also start the work during the summer.

We will also recruit other students to CoolFish through the project INDEE+, so that we can fulfil the goal indicated in the project description. This will give our partners in CoolFish a unique opportunity

to follow the next generation engineers during their final phase of their master education and maybe even find new colleagues.

Reports, publications and visibility

We are working with a report with the title "Equipment and systems onboard fishing vessels ", which should be ready for publishing before the summer holiday. It will give an overview of different types of fishing vessels in Norway including equipment and fishing and fish handling methods. It will also include information about energy efficiency, sustainability, and traceability.

Previous reports are available on the project's webpage. The plan is also to update the webpage, so that it will be easier to find information and documents there.

Eirik has sent a paper to the conference *Ammonia and CO_2 Refrigeration Technologies* in Ohrid, North Macedonia, with the title "Energy consumption of ammonia refrigeration system on board fishing vessel". Co-authors on this paper is Kristina Norne Widell, Tom Ståle Nordtvedt, Sepideh Jafarzadeh and Cecilia Gabrielii.

NTNU will send a paper to the conference *Ammonia and CO_2 Refrigeration Technologies* in Ohrid, North Macedonia with the title "Design and simulation of CO_2 trans-critical system for refrigerated sea water production". Authors will be Armin HAFNER, Ignat TOLSTOREBROV, Kristina N. WIDELL, Thomas LUND, Jostein ØY, Jan Petter URKE.

Cecilia has started on a memo which will give an overview on how the availability and characteristics of surplus heat (and cold) is affected by new types of fuel / propulsion systems.

Information from other relevant projects

Here is some information from other ongoing projects:

CruiZE: In the KPN project CruiZE, which is led by SINTEF Energy Research (Cecilia), we work within similar topics as in CoolFish, but with a focus on hotel operations (cooling and heating) on board cruise ships. The goal is to develop energy-efficient solutions that play well together with new propulsion systems and thereby contribute to zero-emission operations in, for example, ports and fjords. The focus so far is on CO_2-based cooling (AC and provision) with heat recovery, LNG cold recovery, thermal storage with PCM, and electricity production from surplus heat. SINTEF#Blog from CruiZE webinar.

INDEE+: This is a project led by NTNU where SINTEF Ocean and SINTEF Energy are also participants, together with several institutes and universities in India (more information on project webpage). The goal of the project is to develop refrigeration systems with natural refrigerants, as alternatives to those with high global warming impact. The project will have three pilot plants with CO_2 in India, for testing and education. These will be the primary demonstrator topics:

- Supermarket
- Chiller/hot water heat pump for hotel
- **Seafood refrigeration onboard fishing vessel**

PCM-Store: This is another KPN project, led by SINTEF Energy, where SINTEF Ocean and NTNU are participants. Good solutions for integration of cold thermal storages for different purposes will be discovered in this project. Phase change materials will be used, different types for various temperatures. Objectives of installing a cold thermal storage can be to reduce power peaks, reduce necessary installed refrigeration effect, and to increase the energy efficiency.

Project participants

Management group

- SINTEF Ocean
- NTNU
- SINTEF Energy

Industrial reference group

- MMC First Process
- Selvåg Senior/Sørheim Holding
- Danfoss
- Øyangen
- Perfect temperature group (PTG)
- Gasnor
- Bluewild
- Isotherm Inc. (USA)

Scientific reference group

- International Institute of Refrigeration
- London South Bank University
- Johnson Controls Denmark

Project funding

- Norwegian research council ENERGIX
- Industrial partners are contributing with 20 % of total budget

We hope you are staying safe and healthy. Please do not hesitate to contact any of us if you have questions or ideas.

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