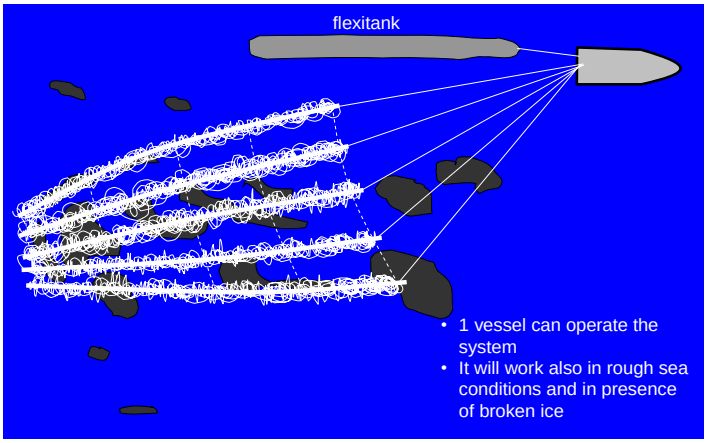
Advanced textile-based mop skimmers for oil spill recovery in harsh sea conditions

The FORCE7 textile mop skimmer system, developed within the FP7 European research project bearing the same name, represents a technical breakthrough in the field of oil spill responding, providing a flexible, environmentally friendly and cost efficient mean for collecting oil spilt on the sea also in presence of harsh conditions such as high waves and presence of ice.

The hunt for oil has lead to its exploitation in environments characterized by low temperatures and harsh sea conditions typical of the polar and sub-polar regions. Although a wide range of technologies currently exist for the removal of oil spilled into water, each with pros and cons and with applicability depending on the specific operation conditions (e.g. oil type, water conditions, etc.), none is capable of efficiently recover spilled oil from cold, rough seas. In-situ burning and dispersants, the first choices of many companies, are of limited value and must be implemented within 72 hours, even in a warm climate, and they fail to remove all the oil from the environment even under the best conditions. Containment and collection is also a common solution, working quite well in calm temperate seas (rarely the real condition in case of a ship wreckage…) but largely inapplicable when wave conditions become severe and temperatures are colder, due to oil splash over and failure of pumping systems. Moreover, the presence of ice often makes it impossible to deploy large surface methodologies due to solid bodies and floating debris that can damage the equipment, also affecting operations' safety.



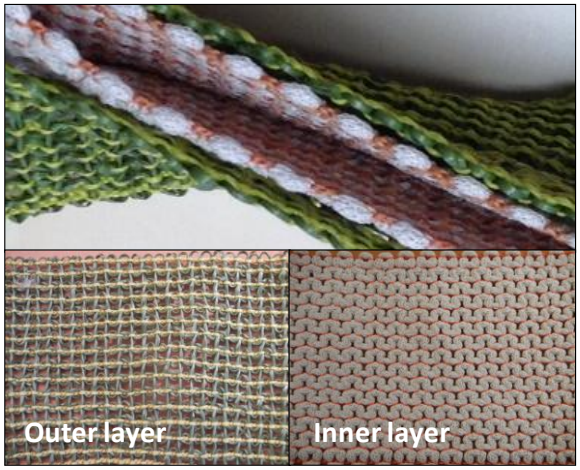
The innovative approach brought by FORCE7 is based on the use of advanced technical textiles with **controlled oleophilic and hydrophobic properties** and **special multilayer design**. Advanced textile structures are woven in order to create strong interconnected mops that can be deployed aside or astern of a single tugboat, and dragged through an oil slick. Once they are saturated, the mops are squeezed by rollers to collect the oil absorbed, and then redeployed for another cleaning cycle by a single small-medium sized tugboat, fostering response preparedness optimization while reducing overall capital costs. The oil collected can be stored in a flexible buoyant tank (flexitank) offboard. Also, the same mop structure and equipment can be modified and deployed vertically on a small confined spill, as for example in the case of a polluted spot surrounded by solid ice or in industrial closed basins, following a more traditional drum- or disk-skimmer approach.

The typical dimension of the mop skimmer developed corresponds to a total amount of 4/5 interconnected textile tail, about 30 metres long and 0,3/0,4 metres wide, capable of absorbing up to 2 times their own

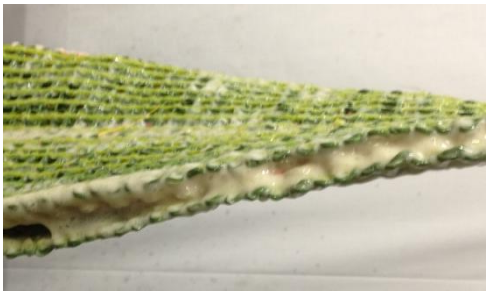
weight for each cycle, with **oil recovery efficiency over 92%**. Target speed for dragging cycles is about 5 knots. Various textile architectures were tested simulating different working conditions in terms of deployment mode and oil types, in order to optimize their functional characteristics and increase recovery efficiency. Full-scale operability has been assessed via open sea trials.

Textile mop structure:

The mop design has been developed in order to optimize use in cold seas where oils spilled behave as heavy oil grades: in particular, priority has been given to "mechanical" collection (high void net-like structure, which exploits high stickiness of heavy oil grades) instead of capillarity absorption (which becomes predominant with light oil grades).



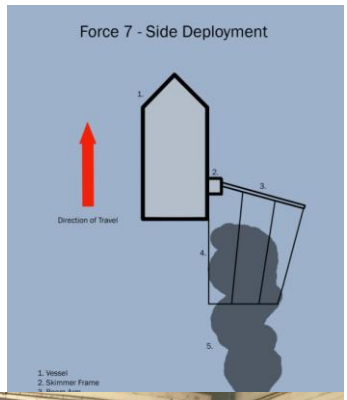
Each mop tail is composed of a **four-layer 3D textile structure** with specific design oriented to maximize the collection and release of heavy oils, thanks to a "multiple wing" configuration. Outer layers are made of a net-like crochet knitted structure, made of PE multifilament tape similar to synthetic grass grades tied with standard PP monofilament. This layer gives the required stiffness to the structure, avoiding folding while providing sufficient mobility and void grade. Inner layers are made of a net-like crochet knitted structure, where a special PP braid is tied with standard PP monofilament (red). The special PP grade filament section has been developed to provide high affinity with oil grades and high void grade, so that both heavy and light oils can be collected. The 4 layers stitched together with a high-strength tensioning belt providing sufficient mechanical resistance to be dragged on the water.



The textile structure has been tested at small scale to evaluate performances in oil collection: as a result, it is worth of collecting 2 times its own weight when deployed on an oil slick, with efficiency over 92%: this means more than 92 liters of oil out of 100 liters of total liquid collected. Also, advanced modeling tools has been applied to simulate buoyancy of the mop when dragged on the water: this activity made available a first model for deformable body simulation to be used with CFD software.

Onboard equipment:

The onboard equipment is composed of a rolling/squeezing unit, a telescopic arm to guide the mop tails off-board, and a collecting unit, from where the oil recovered can be pumped into a flexible tank off-board. The onboard equipment has been designed as compact as possible so that it can be installed at the side of the vessel and deploy a mop net behind it directly into the sea as per the conceptual image on the right. To keep the operation simple and versatile it was decided to build the prototype as an electrically powered unit. This means the machine can be controlled by a separate control station away from the machinery on the deck of the vessel.



Whilst designing the equipment it was possible to integrate two design elements so that the prototype could be used for dual purpose in the market place: the solution was to incorporate a *'Vertical Continuous Deployment'* (VCD) as well as the original concept *'Horizontal non-Continuous Deployment'* (HnCD). The VCD is built in to the frame of the HnCD which can be removed and used separately if required. The advantages of the VCD can be summarised as follows: allows multipurpose functionality providing competitive advantage over competition in the market as a selling tool, can be used with an on board crane arm with a vessel of opportunity, reduces set up and deployment time for emergency spill response, uses looped mops for continuous skimming (potentially in conjunction with floating booms), provides smaller contact on the water surface so can be used in broken ice spots or closed small basins for static conditions.

The final outcome of the Force7 project was the development and successful full-scale demonstration of a 15 metres long, 4 tails mop dragged on the sea in the Cardiff bay using a small fishing vessel, demonstrating as well the solution potential in terms of installation flexibility. Considering the trend in oil production, northern European seas will strongly benefit of this new technology: on the basis of the successful results of the original research project, the consortium is fully committed to a follow-up action one step further towards the market. It is estimated that proper prototype upscale and validation could bring Force7 system to be ready for service in 1 – 1,5 years.

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