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Industrialisation of Easy Boom

R. Justin [a], M. Sokovic [b,*]

[a] Savatech d.o.o., EKO programme, Skofjeloska 6, 4000 Kranj, Slovenia

[b] Faculty of Mechanical Engineering, University of Ljubljana, Askerceva 6, 1000 Ljubljana, Slovenia

* Corresponding author: E-mail address: mirko.sokovic@fs.uni-lj.si

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ABSTRACT

Purpose: Reason for writing the paper is to present the project of design and industrialization of floating containment boom made of PVC material, which was successfully finished in 2010. This project was supported by Savatech d.o.o. Kranj.

Design/methodology/approach: Research methodology of floating containment boom made of PVC has focused on a comprehensive analysis of this type of booms, which are used around the world. Based on this knowledge and over 25 years of experiences with rubber booms, a new type of PVC boom was developed.

Findings: The result of the project was the design and implementation of a new type of floating containment boom. The new boom is light weight, highly stable with no inflation system required. Boom has small volume when packed for transport and is simple and quick to deploy. It is made of UV and oil resistant material.

Practical implications: The new type of oil boom was tested in clean water and is available for application in oil spill accidents. Also calculations for salt water were made. Boom is suitable for closed waters, rivers and streams, harbours, canals, etc.

Originality/value: Product of research and development is an original Slovenian PVC floating containment boom marked as Easy Boom.

Keywords: Welding; Floating containment boom; Oil boom

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MATERIALS MANUFACTURING AND PROCESSING

1. Introduction

It is estimated that between 1.5 and 10 million tons of oil end up in oceans and seas. The major problem is caused by sudden spills of greater amounts of oil in smaller restricted areas such as the Adriatic Sea, the part of which is the Gulf of Trieste with the Slovenian coastal region. In this part, the Adriatic Sea strongly indents in the European continent, which is why a navigational route in the direction towards the heart of the Europe is facilitated. It is owing to this fact that ports in the northern Adriatic developed very rapidly, which resulted in a highly frequent shipping of various loads. Besides a continual pollution from the mainland, the sea and the coastal area are further endangered by the potential hazard sources such as crude oil and its products, as well as various chemicals in the maritime traffic [1]:

- crude oil and its products,
- periodic discharges of waste oils from ships navigating this area,
- periodic pollutions due to cleaning of facilities in the inshore area (industry, port, shipyard, marines, moorings, and other maritime traffic),
- polluted watercourses that flow into the coastal sea,
- throwing solid and other waste from ships and the mainland.

In addition to the enumerated sources, there still is a variety of waste and sewage which originate from the mainland and pollute the maritime environment. Recently, oil spills due to an explosion on the offshore platform in the Gulf of Mexico have met with a wide response in the media. The oil spills were extensive and the dimensions of this disaster were huge. Many a spill is due to tankers sailing the sea. Such and similar accidents will happen in the future too. The first consequence observable in such an accident is the polluted coast, which is more or less of an aesthetic feature. However, such vast oil spills as the one in the Gulf of Mexico, undoubtedly, have far-reaching consequences over a longer period of time, and are not merely a physical pollution.

Oil spills have a catastrophic impact on the maritime eco-systems and numerous living beings as their survival is threatened either directly or indirectly. Oil spills which reach the coast affect the well-being of the local residents, and can negatively influence the fishing trade, tourism industry, sailing, diving, etc. [2]. A long-lasting negative psychological influence is observable with people, which goes far beyond the elimination of the pollution. The affected residents have fear from illness, do not have trust in the food originating from the sea, and they fear accidents will happen again. The economic damage suffered by the local industry can have a fatal effect on various industrial branches.

Oil spills from tankers, oil platforms and pipelines are likely to happen in the future too, therefore, it is a must to be ready for a proper reaction in the case of such occurrences and be familiar with the consequences [3, 4].

For this reason, a well-organised and equipped sea protection service has to be established that not just takes care of cleaning sudden pollutions but also takes preventive steps and regularly monitors the sea condition.

2. Oil on the water

The physics of oil spills. There are many physical and chemical processes, collectively known as weathering, that changes the oil's properties and behaviour after it is spilled into the ocean. (Fig 1).

Many of these weathering processes happen at the same time, but as time goes on, some processes become less important. Those processes are:

- **Spreading:** When oil is spilled, it floats to the water's surface and starts to spread. The rate at which the oil spreads is affected by many factors, including weather conditions, the amount of oil spilled, and the oil's thickness. Generally, lighter oil (i.e. motor oil and diesel fuel), will spread more quickly than thicker oils like crude oil. Warmer temperatures and strong currents can also make spreading faster.
- **Evaporation:** The lighter components in oil begin to evaporate as soon as they reach the water's surface. But like spreading, the rate at which this happens depends largely on factors like the oil's original chemical composition and weather conditions. Approximately 20-60% of crude oil will evaporate, while lighter oils may evaporate entirely. After evaporation, any residual oil will be thicker and less likely to dissolve naturally.
- **Dispersion:** As oil is weathered, it can be broken down into small droplets. Dispersion occurs when these droplets sink below the water's surface and mix into the upper water column. This process can be promoted by chemical dispersants. If some of the larger droplets rise and collect on the water's surface again, they will form a thin film called sheen. Sheens are classified according to how they reflect light. The most recognized type of sheen is rainbow sheen, but there are also grey and metallic sheens.
- **Dissolution:** When oil spills into an aquatic environment, the water soluble compounds in oil may dissolve into the surrounding water. Since these same compounds are most likely to evaporate, dissolution is considered to be less important than other weathering processes.
- **Emulsification:** As waves mix ocean water into the spilled oil, a mixture of water and oil known as an emulsion begins to form. This process can increase the oil's volume by up to four times the original amount. These mixtures are more resistant to other weathering processes, making emulsification the main reason crude oils remain on water's surface. Water-in-oil emulsions are commonly known as 'chocolate mousse' because of their reddish-brown colour and foamy texture.
- **Oxidation:** As the hydrocarbons in oil react with oxygen, oxidation can either break down the oil or create long-lasting tars, as seen in tarballs. Tarballs are dense, gelatinous spheres with a solid outer crust of oxidized oil and an inner core of softer, less weathered oil. Most tarballs are the size of a coin, and they tend to last long after a spill.
- **Sedimentation:** After oil is dispersed or mixed with organic particles, it will sink to the sea floor or wash up on shorelines. If large amounts of sediment are incorporated into the spilled oil, dense tar mats may form. Oil and sediment mixtures may continuously build up and then erode in seasonal cycles.
- **Biodegradation:** During biodegradation, marine micro-organisms like bacteria, mould, yeasts, fungi and algae feed on hydrocarbons in the oil for energy. These micro-organisms are not capable of breaking down large amounts of oil, but they can remove small amounts of dispersed oil and final traces of spilled oil on shorelines.

When it comes to an oil spill, the competent authorities have to be immediately notified. In compliance with the set procedures they alarm the services and teams who take suitable steps using their know-how and equipment. Immediately after the oil spill is stopped, the priority task is to prevent the oil from spreading further. When the polluted surface grows larger, the cleaning becomes more difficult and expensive as well as lengthy. Therefore it is urgent to use the so-called *"floating containment booms"*, which form a part of the basic equipment in every such intervention. Containment booms are the first device to be applied in the event of an oil spill and the last one to be eliminated. The market offers many types of floating containment boom, each of them has its specific advantages and disadvantages. The efficiency of every individual boom depends on the weather, the amount and characteristics of the oil spill and the speed of the water current.

The floating containment booms can be divided in two groups:

a) **Air boom**

Such a boom is composed of the anchored perforated polyethylene pipe at the sea bottom, Fig. 2.

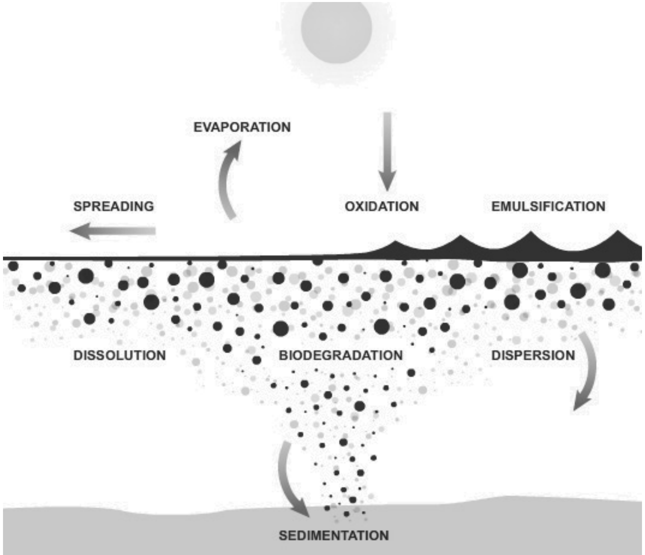

Fig. 1. The physics of oil spills [5]

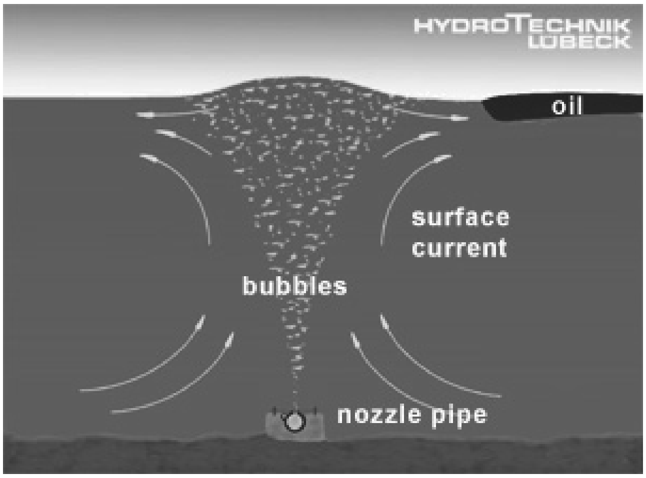

Fig. 2. Air boom [6]

Compressed air flows through the perforations, which at lifting to the sea level makes water circulate and that shoves the floating oil spill away. Besides preventing pollution from spreading, these booms can facilitate water ventilation, and in the Northern Sea they can protect navigational routes against freezing.

b) **Classic floating containments booms of various types**

This type is most widely used on the sea, in water courses and lakes. It consists of four elements, Fig. 3.

- floating body (above the water level), which prevents oil spill to spread across the water surface and provides for buoyancy of the boom,
- underwater boom, which prevents oil spill to pass under the sea level,
- longitudinal reinforcement (chain, steel rope, polyester band), which increases the mechanical resistance of the boom,
- connecting elements for connection and upright position of the floating boom.

Fig. 3. Classic foam filled containment boom [7]

3. Classical rubber floating boom

At Savatech, we have been manufacturing floating booms made of rubber for more than 25 years. During this period we have developed different types of floating containment booms with regard to the purpose of application. All booms consist of four elements, which differ with regard to the type of a boom. The floatable body prevents oil spill to spread across the water surface and assures buoyancy of the boom. The floatable bodies in the booms are intended for intervention actions, the longitudinal bodies should be filled with air before use. In the case of fixed booms, the floatable body is actually formed of longitudinal elements filled with polyurethane foam; therefore the air-inflation system is not required. The underwater part of the boom or the wing of varied lengths with regard to the size of the boom prevents oil from sinking under the sea level. The longitudinal reinforcement of the boom, e.g. chain, polyester band, steel rope, provides for a greater mechanical resistance of the boom and the stability of the boom, and makes sure that a proper buoyancy relation is achieved. The connecting elements are used for connecting several segments with regard to the requirements in the field.

Our booms are made by vulcanising a double-rubber coated polyester fabric, using special rollers. The rubberising process is repeated for the inner (NBR) and the outer (CR/CSM) layer separately. In a special procedure, the two double-rubberised fabrics are put one on the top of another and vulcanised applying the specified pressure, temperature and machine speed. After the vulcanised fabric is cut, the chain, valves and connecting elements are fitted. A containment boom is thus made; in the case of inflatable booms a check-up and test follows. The main advantage of rubber booms is:

- long service life and
- good resistance to various environmental influences.

Besides the classical containment booms, air-inflated or filled with polyurethane foam, Savatech also manufactures three-stage booms (SGB=Shore Guardian Boom), Fig. 4, and permanent booms (PB=Permanent Boom), Fig. 5, made of rubber.

Fig. 4. SGB - Shore guardian boom [8]

The three-stage booms (SGB=Shore Guardian Boom) are intended for transiting from the sea to the mainland, for pebble and sandy shores. The boom is made of three elements; the lower two are filled with water and the upper one is filled with air. Such a construction provides for an excellent buoyancy of the entire boom and its perfect adapting and sealing properties at passing from the sea to the shore.

Permanent booms (PB=Permanent Boom) are intended for use in conditions that require strong and robust booms, which need not be filled. Such booms are suitable for all water surfaces but they prove best effective in the sea water. Their above-water level part comprises 1/3 of the entire boom height. The buoyancy is secured with the in-built buoys, which on their bottom part are weighted.

Fig. 5. PB900 boom, Koper, 2009 [8]

All boom types can be fitted with connecting elements, which are made in compliance with the ASTM F 962-04 standard, and we can offer special connection with pins, depending on customer requirements.

4. Development of PVC booms

Owing to a rising demand in containment booms made from lighter materials (Fig. 6), and, as a result, lower price and faster supply, we have decided to develop a completely new type of oil booms using a new technology. These new booms are made from the PVC material using the high-frequency welding technology.

The material, from which these booms are made, is a polyester fabric with the PVC/TPU coating. Such coating is better resistant to oil and possesses better UV resistance than the usual PVC-material [9].

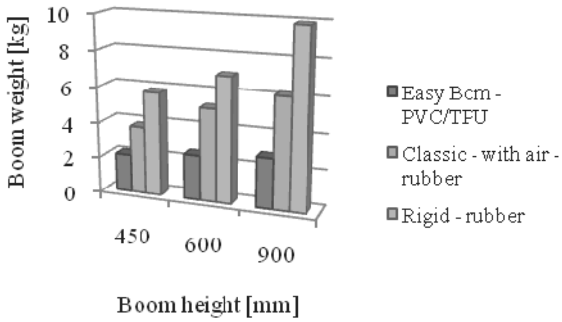

Fig. 6. Weight by different type of boom

The high-frequency welding technology is much faster than the vulcanisation procedure. Two shapes to be welded together are placed on the machine and a suitable electrode is selected. The electrode can be of any shape, however, it has to conduct electricity, and its size should correspond to the working surface of the machine and the required splice type. The electrode is made from aluminium which is very easy to process. The suitable welding time as well as cooling time and pressure, at which the machine presses on the electrode, are set. All settings depend on the materials to be welded. During the welding cycle, the circuit is closed, leading from the machine through the electrode and both shapes to the working table and back to the machine. When electric current passes through both materials, the PVC/TPU coating warms up strongly and it melts where the electrode presses. During a short cooling cycling the material hardens back and the shapes are welded.

The strength of a welded splice depends on the materials used and machine settings, therefore it is recommended to make a test splice and test it on a tearing machine. The strength of splices can be increased by using a ribbed electrode.

The working procedure and boom dimensions are adapted to shorten the procedure time and enhance the yield of material.

4.1. In-house PVC type of a boom

We have decided to manufacture only non-inflatable oil booms from the PVC/TPU-material, which are suitable for interventions, as the competition in the area of inflatable booms made of this material is too tough. The condition was that tensile strength of the material is one half lower than the tensile strength of the vulcanised rubber material, Fig. 7.

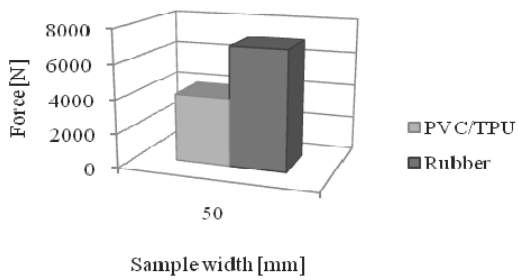

Fig. 7. Tensile strength of PVC/TPU and rubber for oil boom on 50 mm width sample

Preliminary sketches and calculations were made and three additional goals set:
- all components are built-in in the boom,
- a folded boom occupies minimum space,
- simple manufacture of the boom.

The majority of manufacturers offer materials which are suitable precisely for floating containment booms. We decided to use materials with a PVC/TPU coating of orange colour. In comparison with the usual PVC coating, this coating is slightly more expensive but provides better resistance to oil and UV-rays. Since it took some time for the first samples to be delivered (manufacturer's capacities were occupied), some preliminary specimens from different materials were made.

Specimens were tested in clean water and it was found out that the buoyancy calculations were correct. The first prototype did badly. The problem was that each separate buoyant body had to be welded on the basic material at a definite distance, which caused many problems in the procedure and was rather time consuming. The floating body had a shape of a square, therefore material wrinkled and, as a consequence, sealing was problematic and it had leaks. As those samples were rejected, new sketches and calculations were prepared. A great deal of attention was devoted to the shape and dimensions of a floating body. Foamed polyethylene in the form of thinner sheets was applied and it proved good. Every meter of a boom contains two such buoys and due to a low thickness, the welding procedure is simplified. The boom is not only pleasant to look at but it folds excellently. In the case of an intervention, it can't become stuck; it is simply pulled into the water and deployed. On its bottom part, the boom is weighted with a properly selected hot-zinc-coated chain to provide for a good stability and higher tensile strength.

The boom is connected with a high-capacity zippers (found on the internet), which can be exposed to up to 3000 N/5cm. The main advantage of these zippers is their low weight and a simple use. Specimens of boom were made and tested in fresh water. They proved excellently in every respect. Booms are noted for their low total weight, good buoyancy, simple use, fast manufacture procedure and favourable price. The specimen was released.

All tests and specimens were made in compliance with the ISO 9001standard.

4.2. Manufacturing of PVC boom

Before introducing the boom into the series production, the specifications were elaborated. The entire set of booms of various heights was specified and manufactured: 250, 450, 600 and 900 mm. Standard lengths of segments are 3, 5 and 10 m. These sizes can cover the majority of customer requirements; however, it is possible to manufacture custom-made booms as well. Drawings for all types were produced and a working procedure was specified. Furthermore, the control procedure was specified, according to which the quality of the manufactured boom is verified.

Each boom has a waybill in conformity with the ISO 9001 standard, which is to be completed throughout the manufacturing process until its finish. In the waybill, any difficulties at the manufacture and the results of visual test should be noted. The completed and signed waybill is the prerequisite for shipping the boom. Besides the waybill, the test report is to be completed, which actually reports about the work performed. The test report is attached to every manufactured boom and serves as a certificate of quality.

The production process for floating containment boom starts with the preparation of tools and materials. The material is bought and every delivery is supplied with a quality certificate but it is nevertheless checked for quality by the in-house quality control [10]. The basic shapes are then cut and all required lines for folding and welds are marked, Fig. 8.

A corresponding number of floating bodies from polyethylene foam are cut, as well as handles for transporting the boom. A corresponding number of zippers are prepared. A welding procedure on a high-frequency machine follows. Only a small number of simple welds are required. First, pockets for the chain and steel rope are welded on the upper part, which is then followed by transversal welding of pockets for inserting the foamed polyethylene material and their closing. Finally, a connecting zipper and a label with the data and serial boom number are welded on the material. The chain is inserted in the boom bottom and the steel rope in the upper part. The boom is finished and checked whether it is in compliance with the control specifications, the test report is filled out, the product can now be packed and shipped.

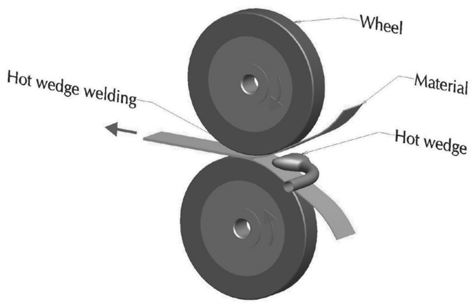

Fig. 8. Hot wedge or hot air welding [9]

Using this production process and technology, we managed to achieve a yield of material that surpasses 90%. The manufacture of such type is at least three times quicker than the production of booms made of rubber, Fig. 9.

4.3. Test in the field

Tests were carried out in clean water (Fig. 10) and booms proved excellently. We have named it Easy Boom and have already offered it in the market

The project results have met all set goals. Thus Easy Boom:
- doesn't require an inflation system,
- is used in stagnant (wave less) water and lakes,
- is intended for interventions,
- is made from the material that is good resistant to oil and UV-rays,
- is simple for use thanks to its well-considered and resource-full manufacture,
- light-weight but highly stable,

- occupies little space when folded,
- is noted for its favourable price (Fig. 11).

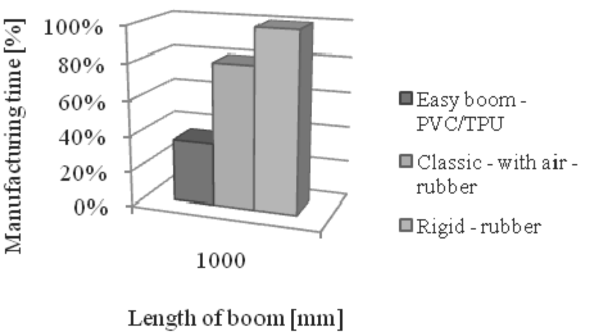

Fig. 9. Manufacturing time of boom [8]

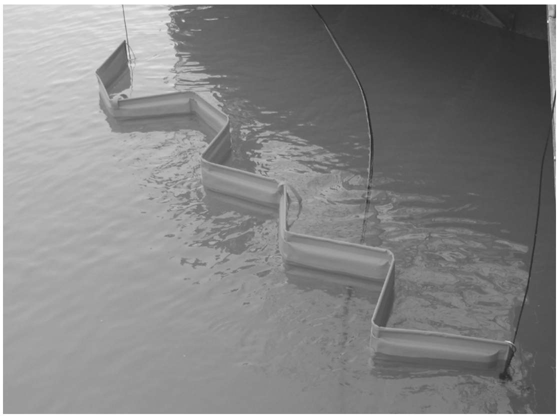

Fig. 10. Testing of new type of boom, Zbilje 2010 [8,9]

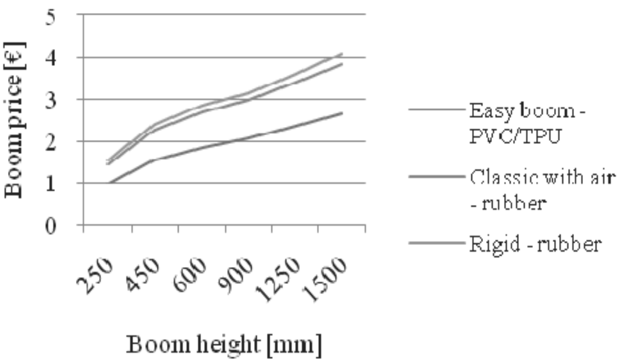

Fig. 11. Price of different type of boom

The offer will be continually rounded with accessories, such as boom fixation onto the shore, boxes for storing, wind-up reels, and we are considering the idea of making a special car trailer for transporting all required equipment needed in this type of interventions.

5. Conclusions

The result of the project was the design and implementation of a new type of floating containment boom so-called Easy Boom. The new boom is light weight, highly stable with no inflation system required. Boom has small volume when packed for transport and is simple and quick to deploy, (Fig. 12). It is made of UV and oil resistant material.

Easy Boom has already attracted attention of a Slovene customer who in December 2010 bought 230 m of new developed boom and plans to make further purchases in this year. We are discussing with that customer a purchase of accessories and universal on shore fixation system. The offers have been prepared and we are waiting for a response.

Fig. 12. Folded Easy Boom 250 [8,9]

The customer is highly satisfied with our product, and pointed out its light-weight and simple use. Furthermore, he found connecting with zippers highly resourceful, despite being slightly sceptical at first. The boom contains handles used for transporting the boom, and will be used on lakes and slowly flowing rivers.

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