The Golden Fleece: Innovative Ways to Clean up Oil

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Marine oil spills pose serious threats to the birds and mammals inhabiting the contaminated environments. Externally, the oil can penetrate feathers and fur, compromising movement and body temperature control. The oil can also severely affect metabolism, water retention, and hormonal balance when ingested. To better protect the environment and the wellbeing of these animals, we must discover more efficient methods of cleaning oil spills. In this paper, Kais and Preston design a skimmer that absorbs oil and deposits it in a plastic container to be recycled. They compare the oil absorptivity of different materials and use the best one in their design. The authors finally build and test a model of their skimmer to demonstrate that it is experimentally successful.

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Companies and governments around the world have historically used bioremediation, dispersants or controlled burns to clean up oil spills. However, more innovation is evidently required to adequately combat oil spills. According to Christopher Haney – the chief scientist for Defenders of Wildlife – 75% of the oil from the BP Gulf Oil spill still remains in the Gulf environment. Recently, the Philippine government and companies like Tecnomeccanica Biellese have experimented with hair and wool in an effort to make this process more effective and efficient.
This project compared the ability of various materials to absorb oil and involved modeling a machine with real-world applications. Paper towel, cedar wood, hair, and wool were tested for oil absorptivity based on changes in weight after being placed in beakers with varying amounts of oil and water. The most absorptive material, wool, was applied to a number of conceptual designs to fight oil spills.
Our solution involved making an oil skimmer that would be able to absorb and collect the oil so that it could be reused. The skimmer features a conveyer belt on which wool has been attached. The conveyer belt passes over oil, allowing the wool to absorb the oil, and carries the soaked wool through two wringers. The oil is collected in a plastic container. The skimmer is innovative, experimentally successful, and holds the potential to better fighting oil spills in the future.

Dans le passé, les entreprises et les gouvernements à travers le monde ont fait appel à la bioremédiation, aux dispersants ou au brûlage contrôlé afin de nettoyer les déversements de pétrole. Cependant, des méthodes de gestion et d'intervention innovatrices sont évidemment requises afin de lutter les déversements d'hydrocarbures. Conformément à Chrisotpher Haney, le scientiste-chef de l'organisation américaine Defenders of Wildlife, 75% du pétrole dû au déversement d'huile dans le Golfe du Mexique repose toujours dans les environs du Golfe. Récemment, le gouvernement philippin et les entreprises tel Technomeccanica Biellese ont mené des expériences avec certains matériaux afin de rendre le processus d'opérations plus efficace.
Ce projet comparait la capacité d'absorption d'huile de divers matériaux ainsi que la modélisation d'une machine vis-à-vis des applications du monde réel. La capacité d'absorption d'huile du cèdre, des serviettes en papier, des cheveux et de la laine fut comparée par rapport à leur variation de masse après

avoir été placée dans des béchers avec différentes quantités d'huile et d'eau. Le matériel le plus absorbant, la laine, fut ensuite appliqué à certains modèles conceptuels pour lutter contre les déversements d'huiles.
Notre solution consistait à concevoir une écumoire d'huile qui serait capable d'absorber et récupérer le pétrole afin qu'il puisse être réutilisé. L'écumoire dispose d'une bande sur laquelle la laine y ait adhéré. La bande transporteuse passe au-dessus de l'huile permettant à la laine d'absorber l'huile, et amène la laine imbibée à travers deux essoreuses. L'huile est ensuite recueillie dans un récipient en plastique. Cette écumoire est une méthode innovatrice, a du succès expérimental et détient le potentiel de mieux combattre les déversements de pétrole dans le futur.

Background

An oil spill is a release of liquid petroleum hydrocarbon into the environment, largely resulting from human activity. Around 14,000 oil spills are reported each year in the United States alone. Current methods to resolve spills involve combustion, chemical dispersants, bioremediation – using bacterial to metabolize the oil – and running oil skimmers to recover it. Unfortunately, current cleanup methods are gravely inefficient. Two months after the Deepwater Horizon oil spill, for instance, 75% of the oil still remained in the Gulf of Mexico. Spill response technology has remained stagnant for the past 20 years and is an area desperately seeking new innovation. The 2011 Wendy Schmidt Oil Cleanup X Challenge offered a million dollar prize to any company that could significantly increase the rate at which oil was skimmed from water. One company managed to quadruple the rate, but even so, there is room for improvement. Furthermore, companies have begun to discover the absorptive qualities of wool that make it an ideal material for cleaning up oil spills. It has the ability to absorb up to 10 times its own weight in oil and can be re-immersed a dozen times before its absorptive capacity begins to diminish. No current technology incorporates the use of wool in cleaning up oil spills thus making it a hidden gem with a bright future.

Purpose

Given the ineffectiveness of current methods, the need for an efficient, cheap and sustainable technique for cleaning up oil is imperative. This project tested whether or not an oil skimmer incorporating the use of wool into its design could recover oil in a simulated oil spill. Once a conceptual design was completed, a small scale model was built to test the actual efficiency. The machine displayed a high level of functionality and demonstrated the principle of absorbing oil with wool and wringing it out.

Hypothesis

We believe that wool will absorb significantly more oil than any of the other materials tested. Secondly, we believe that by incorporating this material into a skimmer, we can clean up at least 70% of the oil from our simulated spill.

Procedure

Absorptive Capacity of Different Materials

This part of the experiment aimed to determine which material was best at absorbing oil: wool, cedar wood, paper towel, or human hair. Exact quantities of each material were measured, as were the masses of two empty beakers. Water and oil were added to one beaker. The material was placed into the beaker with the water and oil, and the timers were started for an allotted amount of time. A strainer was used to extract the material, which was transferred into the empty beaker. The beaker was then measured- absorptive capacity was measured by comparing the mass difference between the material with oil and the original amount of the material. In order to ensure that those numbers only included wool and oil separate tests were run with oil and wool, without water, using the procedure mentioned above.

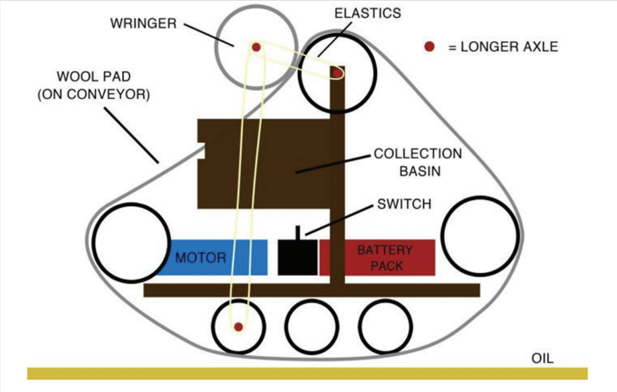

Figure 1. Oil skimmer, side profile

Building the Skimmer

The concept for this machine involves absorbing oil from a spill, wring it out from the wool, and then re-immersing it in the oil to repeat the process. Two sets of model tank tracks were used as the conveyor belt, and a double gearbox motor and battery pack with a switch were used to propel the belt on a hex shaft. Stilts were added on to transform the shape of the machine from linear tank tracks to a more triangular shape. This would allow for the wrung oil to fall downwards into the collection basin. The collection box was built from a plank of basswood, and it was extended beyond the width of the wringer to catch the falling oil. The next step was to build the wringer. A number of different options to create tension between two rollers were considered, but elastic bands proved to be the best choice. A lathe was used to accurately put holes in the center of 1.5" diameter wooden dowels so that they could rotate on axles. 1/8" high speed steel foot long drill bits were used as the axles. The two axles were then elastic banded together to create tension. A plank of wood with holes was used to affix the wringer in place. The following materials were used in the final machine: Tamiya tank tracks set, Tamiya double motor gear box, 1ft by 1/8" basswood stilt, 6" by 8" basswood plank, 3 x 1/8" high speed steel drill bits, braces elastics, 10 yards of elastic garter, and 400g of greasy wool.

Testing the Skimmer

To test the machine under different conditions, each of the different variables was isolated and compared to a control. The variable conditions included temperature of the water, waves simulated by a fan, salinity of the water, material used for the wringer, and further combinations of these factors. The control conditions were 13°C water, no salt, no wind, and one minute of running time. To conduct the test, a plastic bin 1ft by 1.5ft and 6" deep was filled with 750mL of water. 250mL of SAE 10W-30 viscosity oil was then added to the bin, the oil was mixed around in the water to allow an adequate dispersion over the surface area and time was given to allow all of it to rise to the top. The skimmer was suspended over the surface of the water by resting the long axles on two dowels. After running it for the specific duration, the machine was extracted and the fallen tufts of oil were weighed to account for error. The final liquid in the bin was then poured into a 1L graduated cylinder. In addition, the mass of the bin was then measured and subtracted from the mass of the empty bin to account for any remaining residue. All of the motor oil rose to the top in the graduated cylinder and the markings on the side were used to identify how much oil and how much water remained. By simple subtraction, the amount of oil cleaned was then deduced. All of the materials were then thoroughly rinsed and the procedure was repeated to simulate different conditions.

Results and Observations

Absorptive Capacity Results

	Mass of material	Oil absorbed	Absorptive capacity
Wool	1g	10.45g	10.45x
Paper towel	1g	4.75g	4.76x
Cedar wood	1g	4.19g	4.19x
Hair	1g	8.90g	8.90x

Table 1. Results of Test 1

	Mass of material	Oil absorbed	Absorptive capacity
Wool	10g	102g	10.2x
Paper towel	10g	45g	4.5x
Cedar wood	10g	43g	4.3x
Hair	10g	87g	8.7x

Table 2. Results of Test 2

Wool was the best absorbent, capable of holding 10.2-11x its own weight. Human hair was also a good absorbent, with an absorptive capacity that ranged from 8.7-8.9x. Paper towel had an absorptive capacity that ranged from 4.6-4.76x, and cedar wood held 4.19-4.3x its own weight. According to the Economist, wool is made effective by the fact that it can be immersed up to twelve times for up to twenty seconds in oil without losing that high absorptive capacity. Wool fibers are absorptive because of their structure- they have an oleophilic outer cuticle that is covered by lanolin, which repels water. Hair is also a good absorbent because of its structure. Hair fibers have an outer cuticle made up of keratin. Over time, keratin flakes off, allowing oil to seep in through empty spaces.

Building the Skimmer

Many factors were considered when constructing the skimmer. First, the material of the wringer was questioned. Wood was the only thing that could be drilled through with a lathe, but we predicted that it would absorb oil. Thus, the dowel was varnished to repel as much liquid as possible. An acetal plastic roller was used because of its hydrophobic properties and ability to be drilled into. Secondly, the perfect tension between the rollers had to be created so that they would wring out the oil effectively, but not stop the motor. In the end braces elastics were used to pinch the rollers- they allowed enough flexibility to adjust for thick patches of wool on the pad. However, they were not anchored to any fixed point so the motion of the conveyor belt would push the wringer. Thus, a wood plank was drilled into with three holes to affix the wringer to the roller and an axle. Another issue with elastics was that they got caught on the spokes of the conveyor belt. Thus, long axles were used so that the elastic bands could be distanced from the belt. Unfortunately, the longer axles were too flexible so high speed steel foot long drill bits were used. Finally, it was problematic to create a pad of wool – the goal was to create a disposable pad that would be easy to replace. We tried using Velcro, but the resulting wrapping was too thick to fit between the rollers. The final solution was to use linen elastic garters, onto which we glued greasy wool.

Testing the Skimmer

The ability of the skimmer to absorb oil stayed fairly constant in the different tests. We are unable to accurately compare it to existing skimmers because they are evaluated on their recovery rate of oil. The point of the model was to demonstrate the principle mechanism in collecting oil through wringing. In almost all scenarios, the amount of oil cleaned up was consistently within a 5% range. The acetal plastic was the only problem – because of its oleophobic properties, it probably did not absorb any of the oil. The viscous oil adhered to the plastic and diminished its ability to wring the wool pad. Though oil cleanup amounts were consistent in different conditions, the amount of water absorbed compared to the amount of oil absorbed differed. The harsher the conditions, the more water was soaked up with the oil. Even so, in severe ocean conditions, there was a very high concentration of oil recovered compared to water.

	Oil Cleaned out of 250 ml poured (%)	Water Present in Final Liquid (%)	Oil Concentration of Final Liquid (%)
Control	76.21	4.96	95.04
Salinity (35 ppt)	75.77	8.58	91.42
Cold water (3.5°C)	81.36	19.60	80.44
Wind (High power fan)	77.18	24.34	75.66
Acetal Roller (Mean)	64.51	40.52	59.48
Ocean (35ppt, 3.5°C and wind)	76.22	9.41	90.59

Table 3. Oil recovery in different conditions

Conclusion

Our tests clearly demonstrate that wool has a miraculous ability to clean up oil spills and that its properties must be put into application. We deem the results of the tests run on our oil skimmer successful with a consistent 75% cleanup rate in a variety of harsh conditions. All in all, we believe that with proper funding and investment, this concept could be magnified on a much grander scale. If this technology was to be executed in a real live spill, we are confident that it would prove an efficient and effective means of cleaning up the oil.

Acknowledgements

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Review of ***The Golden Fleece: Innovative Ways to Clean up Oil***

This paper presents the results of some experiments using wool to soak up oil floating on water (a simulated oil spill). Two types of experiments are presented. The results are interesting and, as far as I know, relatively original. I congratulate the authors on what clearly was a demanding project and the promise shown in their results. However, there are a number of improvements suggested before the paper should be published.

The paper needs to be improved in how it is written, so it better conforms to accepted scientific format. This includes adding references for all the facts provided. In addition, the paper needs to more clearly spell out what work has been done previously regarding wool's abilities to absorb oil to highlight what is new about this study. In addition, the language used needs to be adjusted to be more objective; for example, all exaggerated adjectives should be removed (e.g., 'hidden gem', 'miraculous'). Also, all figures need captions and all tables need headings, and these tables and figures need to be referred to in the text. The paper could also be improved by removing all discussion of what options were tried and focusing instead on the final product made.

A further suggestion is that the authors dig a little deeper into the science about hydrophobic and hydrophilic materials and explain better why the wool is so good at absorbing oil, and why it is better than the other materials tested. Also they should try to explain why the performance of their apparatus changed with different conditions tested.

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