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# Usage of Oobleck as a Packaging Material

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***Abstract*-**Oobleck is a non-Newtonian fluid made of cornstarch and water, easily made and biodegradable. The aim of this research article is to evaluate the performance of Oobleck as a packaging material and compare it with Polyethylene, the most common packaging material in use today. To compile this article, a review of literature in the field of packaging material was done, leading to the design and realization of a simple experiment to make a comparison. The result indicates that Oobleck may possess better packaging shielding than the conventional methods of packaging.

***Index Terms***- Non Newtonian Fluids, Oobleck, Polyethylene, Packaging

## I. Introduction

Pressure in all areas of industry to try to reduce the environmental impact of products has pushed forward the development of new materials for manufacturing, but also for packaging and product protection purposes. A much used material in this field is Polyethylene (PE). The usage of fluids as packaging material is not very common in the industry. In an attempt to propose an alternative to this, the authors suggest the use of Oobleck as a protective packaging material, from the observation of the non-Newtonian fluid properties, and its successful use in the sport padding industry. Depending on the kind of fluid used, they might be easier to obtain, biodegradable, and reduce the use of plastic products derived from oil. Cost can be reduced as well. A Non-Newtonian fluid has the property that the viscosity is a function of other parameters beside the temperature. One of these parameters can be the shear rate applied to the fluid. In some special case of the non- Newtonian fluids called shear thickening, the viscosity increases up to the point that the fluid behaves as a solid when a high shear rate is applied. Then, the energy in the fluid gets dissipated trying to break into the inner part of the fluid. In a packaging application, this property might be interesting, as the fluid dissipates high impacts on the product being protected [1].

## II. THEORY

Packaging is the science of enclosing or protecting products while they are distributed, stored or used. Film packaging, plastic boxes, Thermocol packaging, textile packaging and foam packaging are common types of packaging. Almost all the products that are to be used in our everyday life involve packaging. Damage of goods can happen for various reasons. These include inappropriate packaging, incorrect or faulty materials or mishandling of packages.

The major necessity of egg packaging is the protection of the eggs by prevention of eggshell breakage. The main reason for egg breakage is too much pressure on the shell of the egg. It is a common fact that more eggs are broken during egg transportation than any other step during processing and distribution [2].

In the packaging industry, packages are subjected to a well-defined computer-simulated vibration test on an electrohydraulic test machine. A.C.Seydim and P.L.Dawson made a research study on the packaging effects on shell egg breakage rates during simulated transportation [3]. Shell eggs are usually packaged in so called egg cartons made from either expanded polystyrene (EPS) foam or molded paper pulp (MPP). During transport these are usually bulk packaged in either polypropylene crates or corrugated boxes. When cartons were packed in 15-dozen corrugated boxes, no significant difference was found in total eggshell damage rates between the MPP carton and the EPS carton. However, when eggs were packed in 15-dozen plastic crates, there were more eggshell damages in the EPS cartons than the MPP Cartons.

Nethercote et al. in 1974 [4] also compared the molded pulp and foam cartons in corrugated boxes arranged in different configurations. They also assessed their individual protective properties using different laboratory procedures. From their results, it was evident that crossed tiers of cartons protected eggs better than cartons all aligned in the same direction. Furthermore, they concluded that the carton design was more important than material in determining the relative protective ability. Roland in 1988 [5] estimated that the percentages of cracked eggs at final destination (retail store) ranged from 5% to 7%. This result is not only due to poor eggshell quality but also to the protective quality of egg packaging.

Egg was chosen as the test subject, since it would be easy to see the damages if any. In all the above cited background study, it was found that careful attention needs to be paid while packaging egg. Also, it was evident that packaging in different configurations also affects the credibility of the shell damages. A new kind of packaging material which focusses on lesser production time was investigated with the result being the usage of Oobleck as packaging material. Oobleck is produced by mixing water with cornstarch. Both components are cheap and easy to find. One important advantage of Oobleck is that is non-toxic so it can be used in the food industry. Oobleck is also environmentally friendly since it is biodegradable.

## III. Non Newtonian Fluids

Already in the 17th century Sir Isaac Newton described how liquids behave; they all have a constant viscosity which means that the behavior changes depending on temperature and pressure. Some fluids however have been found to not follow these basic rules, hence the name non-Newtonian fluids [6]. Newtonian fluids change the viscosity under stress. The sudden change of stress can change the fluid thickness or in some cases it gets thinner. Several different kinds of non-Newtonian fluids exist [7].

Rheopectic and Thixotropic both exhibit the same behavior, when exposed to stress or a force is applied for an extended period, the fluid changes its viscosity. A rheopectic fluid thickens under constant stress. An example of this is cream, when you whip it, it gets thicker. A thixotropic on the other hand shows the opposite behavior, when force is applied the fluid gets runnier. Dilatant and pseudo-plastic fluids both have in common that under stress (for a short period) the viscosity changes. When the force is removed the viscosity changes back to normal. The dilatant is shear thickening, which means that when a force is applied the fluids viscosity immediately increases. This property may make it attractive as a packaging protection material since the force exerted on the fluid is distributed over the whole surface, meaning that the pressure is lower. Example of this is Oobleck, which is subject to the test presented in this article.

Pseudoplastic is the opposite to dilatant, shear thinning. This fluid gets runnier as more force is applied to it. One example of this can be found in kitchen; Tomato ketchup is pseudoplastic, when shaking the bottle the fluid changes its viscosity and can flow through the bottle Oobleck is a common example of a dilatant fluid, and it is also easy and cheap to make. Our goal is to demonstrate the possibilities for shear thickening fluids, using this as an example. This fluid presents the following advantages in our experimental setup:

- Instructions on how to make it are available online easily.
- The materials required to create it are available in any convenience store.
- The cost of making a lot of this material is small.
- Oobleck behaves similarly to other shear thickening fluids.

The following research question thus emerged in need for further investigations?

How much can a biodegradable non-Newtonian fluid like the Oobleck outperform a standard used polyethylene cushion?

## IV. TEST METHODOLODY

The experiment is a drop test of an egg. The test is performed to compare three different materials, Oobleck, Polyethylene and a normal egg carton.

### *A. Oobleck*

The name Oobleck is inspired from Dr.Seuss children's book - Bartholomew and the Oobleck, where Bartholomew had to protect his kingdom from the sticky fluid Oobleck. The basic recipe for this fluid is cornstarch and water. The small particles in cornstarch repels each other slightly which makes the fluid float normally but when a sudden force is applied the small repulsing force is overcome and the particles now stick together, making the fluid hard. As the force dissipates the particles repels each other and the fluid becomes normally floating again.

### *B. Polyethylene*

Polyethylene foam is widely used as packaging material due to its shock absorbing properties. Other good properties which make polyethylene classify as packaging material is its ability to absorb vibrations and the fact that it is lightweight.

## V. EXPERIMENT

The research is based on experimental method under a quantitative approach which allows:

- General validation of the hypothesis
- Numeric measurement of variables
- Repeatability of the results
- Objective analysis

The experiment is only performed in order to see if a 5mm packaging of Oobleck can be able to prevent the damage of Egg or not. Egg was chosen as the test material, since it is a very delicate material and any damage shall be easily observable.A review of relevant literature in the area of packaging and testing was performed in order to understand whether other studies using similar procedures and materials to the ones we are proposing have been performed or not. The experiment was performed by dropping an egg, enclosed in the material to be tested, from a specified height. This made easier to assure that the energy applied to each execution was the same. The egg was then checked for breaks, if the egg is still intact, the test is repeated at more height. For each drop a mark of break/no break was logged. Successive tests for each material start at the last good height (where the egg did not break). The test was performed with three different materials namely Oobleck, Polyethylene and a normal egg carton. Egg cartons were chosen as they are the normal way to transport eggs. Polyethylene was chosen since it is a major material for packaging in the world [8].

Oobleck was enclosed by placing 30cl of liquid in a 1 liter bag. Then another bag containing a single egg was placed inside the first bag. The egg is positioned in the center of the first bag and the openings strapped together. Figures 1 show the setup for Oobleck. The bag was dropped by holding where the bag is closed.

***Figure 1*: Test setup for Oobleck.**

Since the polyethylene is not a liquid, the setup was a bit different. The polyethylene material was wrapped around the egg, so as to form a protective shell, and glued with duct tape. Figure 3 show the setup.

***Figure 2:*** **Test setup for Polyethylene.**

In order to be able to test one egg at a time, we had to make some adjustments when testing the egg carton. By placing plastic bags with the approximate weight of a large egg (65 grams) in place of the other eggs, we made sure the weight distribution was correct.

***Figure 3:*** **Test setup for egg carton.**

Three tests were performed per each material. The first test was performed from a low height. The subsequent tests were performed from the last good drop in the previous test. The motivation is that the dropping may affect the structural integrity of the egg and therefore the reliability of the results. Small cracks can be produced when hitting the ground making the egg breakage more likely in the next droppings. Starting the test from the last good drop eliminates the problem.

## VI. RESULTS

The results of the experiment are shown in Figure 5. The Y-axis represents the height at which the eggs wrapped in the packaging material are dropped. The X-axis represents the different tests performed with the packaging materials.

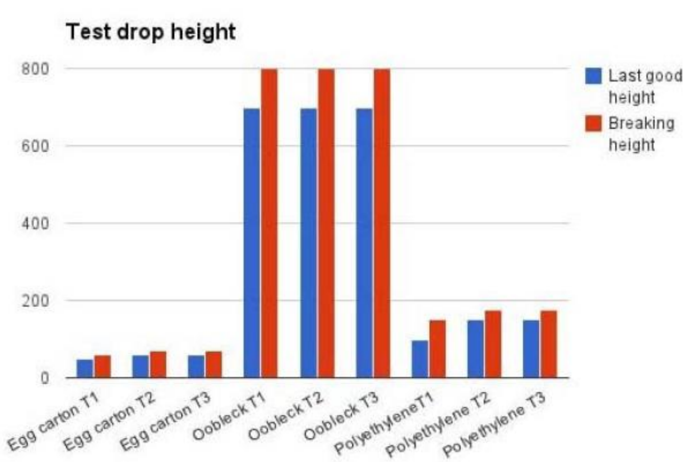


***Figure 4:*** **Test Results**

The result of the test is that the carton package withstands a 0.6m drop. The Polyethylene package has an improved performance resisting a drop from 1.5 meters. The best packaging material is the Oobleck with an outstanding height of 7 meters.

Table 1: Heights withstood by the materials

| Material | Height |
|---|---|
| Polyethylene | 1.5 m |
| Oobleck | 7.0 m |
| Egg Carton | 0.6 m |

The Oobleck package withstood a 7 meters drop whereas the egg carton package withstood 0.6 meters drop which represents an improvement in the performance of 6.4 meters or 1066%.

## VII. ANALYIS AND DISCUSSION

Initially, our hypothesis was that the Oobleck package would protect the egg better than the egg carton. However, we did not expect the comparison test to result in the large difference in performance as it did. Especially considering that the setup for this experiment consists of no special packaging design, just regular bags filled with the solution. In several of the tests with Oobleck, the bag broke before the egg. This might lead future tests to discover the influence of the container in the protection level of the egg, because it seems that it could be possible to get an even better performance when considering design parameters for the container [9].

There are several theories that can be used to explain the superior performance of Oobleck in this experimental setting. One of them, states that shear thickening fluids at a molecular level, are two-phase suspensions that dissipate energy when submitted to shear stresses through the flow of the liquid phase between the molecules of the solid state. When a high shear rate is applied, the solid phase molecules are rearranged closer between each other, thus making more resistance for the flow of the liquid phase of the suspension. This results on a fast rise of the viscosity, until a certain point where the fluid stops acting as such and behaves like a solid [10].

Another hypothesis that tries to explain this is presented in [11] by Boersma, Laven & Stein. The aforementioned authors define a critical shear rate that defined the behavior of the fluid in terms of the molecular interaction in it. If the shear rate is below this critical shear rate value, repulsive force between particles will maintain an ordered structure in the fluid. When the shear rate applied is above the critical shear rate, these repulsive forces are counteracted, forcing them into an irregular, disordered state, which in the end is what causes the increase in viscosity. For the purposes of this report, the first hypothesis is better to explain the resultant phenomena, because it not only describes the behavior of the fluid, but also the energy dissipation.

In this testing there are several limitations that might affect the results and it is suggested to improve these in order to carry on more investigation in this topic. The first limitation is the type of PE that was used for testing. Despite it is PE, it's a slightly different version of the material commonly used for packaging applications. The second limitation is the container of the egg in the tests, which is a standard 1 liter plastic bag. As it was previously mentioned, the quality of the container should be improved, so this doesn't affect the results. Also the number of test samples should be substantially increased, in order to be able to get more reliable data. The result in this study indicates that Oobleck may outperform standard packaging materials.

Literature shows that there are several steps that Oobleck need to go through to become widely implemented as a new packaging material. There are five main bullets in the general framework presented by Azzi, Battini and Sgarbosa [10] which need to be considered when developing this material as a packaging solution. These are: Safety, Marketing and Communication, Logistics, Sustainability and Ergonomics.


***Figure 5*: Roadmap for packaging design studies and research**

These will define the processes and tests defined for the material before its implementation. In the next figure a diagram developed by the aforementioned authors is shown. These bullets won't be addressed in depth, since it escapes the scope of our research, but it is shown as a reminder for future work in this topic to further develop.

## VIII. APPLICATION IN INDUSTRY

Once we concluded that Oobleck can be used as a packaging material, the main challenge was regarding the incorporation of Oobleck in packaging industry. The experiment was conducted just to see if Oobleck has a better packaging capability with regards to Egg. We noted that if the material is to be covered around with Oobleck in 5 mm thick layer of plastic, we could achieve the desired protection. For the same protection, we might need to implement more volume of paper or polyethylene, which is not currently practiced in the industry. Should the industry stick with the current allowances of packaging material thickness, then Oobleck might be a good solution.

The Design of the proposed packaged material shall look like the commercially available egg carton (with some modifications).The outer layer will be paper like the commercially available ones while the inner layer will be a polyethylene plastic cover. A 5mm layer of Oobleck will have to be sandwiched between these two layers. Although the new design will be comparatively heavier, it is assured that material won't be damaged. Since the cost of making Oobleck is very minimal, only a slight increase in packaging cost will be observed.

## IX. CONCLUSION

Despite the successful usage of Oobleck in similar applications [12] and the fact that our initial test results have proven that the properties of Oobleck are excellent for protective packaging usage, further investigations from other authors show that this is only the first step when conceiving and implementing the material as a packaging solution. Although in order to be implemented in packaging industry there needs to be further tests that has to be carried out for qualification, it is to be noted that by further modifying the package setup, we can design the optimal packaging layer for the corresponding content. Though we might be adding to the cost, we can rely on the fact damages in the material enclosed won't be occurring.

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