SPS Chapter Research Award Proposal

Project Proposal Title	A Rope within a Rope: Fluid Polymerization in the Liquid Rope Coiling Effect
Name of School	Purdue University - West Lafayette Campus
SPS Chapter Number	SPS Chapter 5781
Total Amount Requested	$1930.00

Abstract

The liquid rope coiling effect describes the propensity of streams of viscous fluids to coil when falling onto a surface. This process has been modeled and observed for homogenous Newtonian liquids. In this study, the liquid rope coiling effect is observed and characterized for variable-length polymer solutions.

Proposal Statement

Overview of Proposed Project

The main purpose of this research is to analyze how the polymerization of fluids affects the fluids behavior in the liquid rope coiling effect. The liquid rope coiling effect is the folding of viscous fluids on themselves in a regular pattern as they fall from a certain height. It has been observed and mathematically modeled over the past 60 years [1-3, 5-7]. However, throughout all of these studies, the fluid was some viscous Newtonian fluid that was assumed to have laminar flow. However, polymerized fluids are non-Newtonian and have irregularities in flow at high fluid velocities due to the polymers in the fluid. In our research, we intend to find the impact that polymerization has on the liquid rope coiling effect.

In our research, we will create solutions of polymer fluids using polyethylene oxide, or PEO, that will be analyzed in the liquid rope coiling effect. The fluids will be dropped onto a platform using custom built funnels that are based on previous studies [3]. The coiling will be filmed with a high-speed camera, mapped using a position tracking software, and analyzed using a code we have constructed to take the fast-Fourier transform of a data set.

We hope to contribute to this small field and present a potential new area of study; this research project will give a better insight into the liquid rope coiling effect and hopefully show promise in the analysis of non-Newtonian fluids within the liquid rope regime. Through this project, we hope to allow younger members of the club to see what research is like in a more casual setting and to engage with an accessible research project. This project will bring our chapter together under one cause and foster a sense of community. In this, our chapter will be among the many who have contributed to an area of study in physics under the name of SPS.

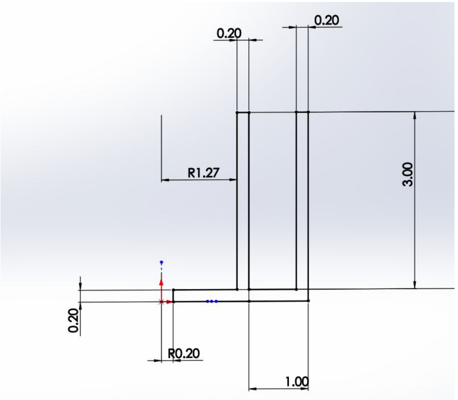
Background for Proposed Project

The liquid rope coiling effect was first discussed in a 1958 paper covering some of the most basic properties [1]. This prompted a second paper discussing the relationship between fall height and coiling frequency [2], though the field remained relatively dormant after this. In the early 2000's, the field was revitalized, as researchers defined four regimes for liquid rope coiling: viscous, gravitational, inertio-gravitational, and inertial [7]. The motion of the liquid ropes were also modeled using 21 differential equations with 21 boundary conditions [6]. Since then, there has been experimental work on liquid rope coiling [5], along with the tangentially related dragged liquid rope effect [8]. In all this work, the fluid was assumed to undergo Laminar flow. The use of polymer fluids would break this assumption at high velocities [4], providing a new field of study. We intend to study this new field with the funding provided from SPS National.

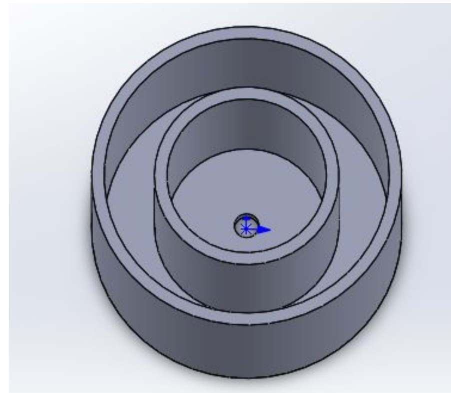
Expected Results

Through the data analysis and acquisition, we hope to obtain several different graphs of frequency versus height. These will be compared to the theoretical and observed curves from the current body of literature. This comparison will be a first look into how polymerization affects fluids in the liquid rope coiling regime and will hopefully show promise as a new direction for theoretical analysis.

Description of Proposed Research - Methods, Design, and Procedures

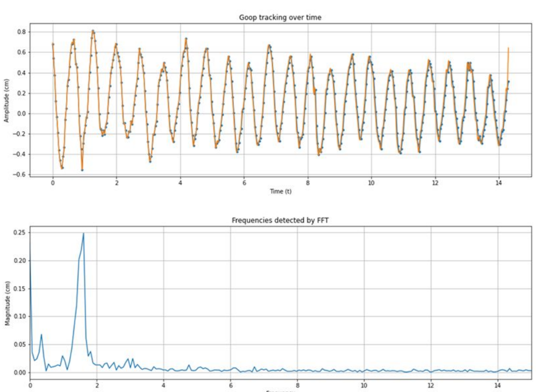


Our proposed setup for collecting data is similar to other studies involving the liquid rope coiling effect. It consists of a 2 chambered device, with a beaker above pouring liquid into the center chamber. In order to achieve a constant outflow rate, the liquid must maintain a constant fluid height. Fluid from the inner chamber is thus allowed to overflow into the outer chamber to achieve this constant height. This setup is a direct mirror of one of the experimental designs used in a previous study [3].



The fluids will be made of a 1%-2% PEO solution by mass with deionized water, which can be obtained for free.

The fluid will fall from this funnel onto an inverted petri dish from a fixed height. This will be captured by the camera in a sufficiently-lit environment. The excess fluid that falls from the dish will be collected in a 4 liter flask for reuse. Once the experiment is complete, the fluid will be returned to the container in which it will be kept and the whole apparatus will be cleaned after each session.



Once taken, the video of the coiling will be analyzed using the Tracker software from Open Source Physics. The interface of the coil with the plate will be analyzed and data of its position as a function of time will be generated. This data, specifically the horizontal coordinate, is then analyzed in frequency space using a fast-Fourier transform algorithm. This allows us to analyze the data in the frequency domain. The highest peak in the FFT that is displaced from zero (low peaks show up due to offset in the data and low-frequency noise) will be considered the frequency of oscillation for that specific height. The graph attached shows test data from a viscous-fluid hourglass in our SPS lounge that initially got us curious as to how viscous fluids coil.

This process will be completed for several different heights and will be combined into frequency vs. height graphs, which are some of the main deliverables from works on the subject [6].

Data sets and other important documents will be shared in the Google drive folder created for the project on the SPS Google account. Communication about the project will occur via our chapter's Discord server.

Plan for Carrying Out Proposed Project

This project will be carried out by SPS members. One group of members will be involved with operating the camera, dealing with the experimental apparatus, and taking all of the data we need for the experiment. Another group will be dedicated to using tracking software in order to find the position of the coil as a function of time. A final group will take this position data and do fast-Fourier transforms to obtain the frequency of coiling for a given data set. The research space that will be used in our SPS specific space ("The Well of Infinite Potential") in the basement of the physics building that we have full access to. A certain portion of the room will be dedicated to the experiment so that data can be efficiently taken.

Each part of the project has its own expert helping to make sure that everything goes smoothly: one member has done a substantial amount of research into the liquid rope coiling effect; one member has modeled our experimental apparatus in CAD; one member knows much about cameras and has found the best camera for our purposes; another member is very familiar with the software used to take data; and several members have the coding expertise and knowledge of frequency-domain analysis.

We expect limited assistance from the department and our faculty advisor. With the recent COVID epidemic, both funding and time have been very limited in certain regards. Thus, we have elected to keep the project as self-sufficient and self-contained as possible.

Project Timeline

- [Jan 19] - Semester begins, receive materials
- [Feb 1] - Completed test trial (to become familiar with camera and pouring polymers).
- [Feb 6 - 28] Take data each weekend (different polymer length for each weekend). Begin data analysis as soon as data is available.
- [Mar 28] Begin rough draft of interim report
- [April 12] Finish first round of data analysis
- [April 24] Finish rough draft of interim report
- [May 8] Finish final draft of interim report
- [May 15 - Aug 15] Summer break, think of what new data needs to be taken to form stronger conclusions
- [Sept 4] Train new students on using equipment
- [Sept 11-Oct 3] Take new data, begin analysis as soon as possible
- [Oct 16] Being rough draft of final report
- [Nov 6] Finish all data analysis
- [Nov 20] Finish rough draft of final report
- [Dec 4] Finish final report

Budget Justification

There are two main financial aspects: the experimental design and the data acquisition.

For the experimental design, we need to construct funnels and create the liquid we will be using in the experiment. For the funnels, we will 3D print them with different sized holes, requiring enough filament to print a sufficient amount of funnels to fill out the dataset we want to collect. Thus, we have built in money for filament ($150) to account for this. In addition, for the liquid, we will need to create the PEO fluids by buying the chemical in powder form and mixing it. The cost of the chemical from Sigma Aldrich to create 1-1.5L solutions of each polymerization of the same concentration by weight ($630) has been included.

For the data, we need a high-speed camera to capture the coiling of high frequencies. We have been in contact with the corporation Ximea and have gotten a quote for their MQ013CG-ON camera model. The cost of this camera plus shipping and handling ($800) have been included in the budget. In addition, the camera will require a lens ($200), tripod ($50), mount to interface the camera and tripod ($50), and a cable to interface the camera with a computer ($50). The cost of all these necessary accessories is included in the budget as well.

Bibliography

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