Drag Reduction Using Graphene in Viscous Laminar Flow with Water and Isopropanol

Jessica Patalano[1,2], AKM Newaz[3], California State University, San Bernardino[1], STAR[2], San Francisco State University[3]

Purpose

There are over 2.6 million miles of pipelines in the United States that are used to transport resources. Currently, considerable amounts of energy and pressure are used in order to overcome the drag to get the materials where they are needed. Reducing the drag will therefore lower the amount of energy and pressure needed to transport these materials, making transport more efficient.

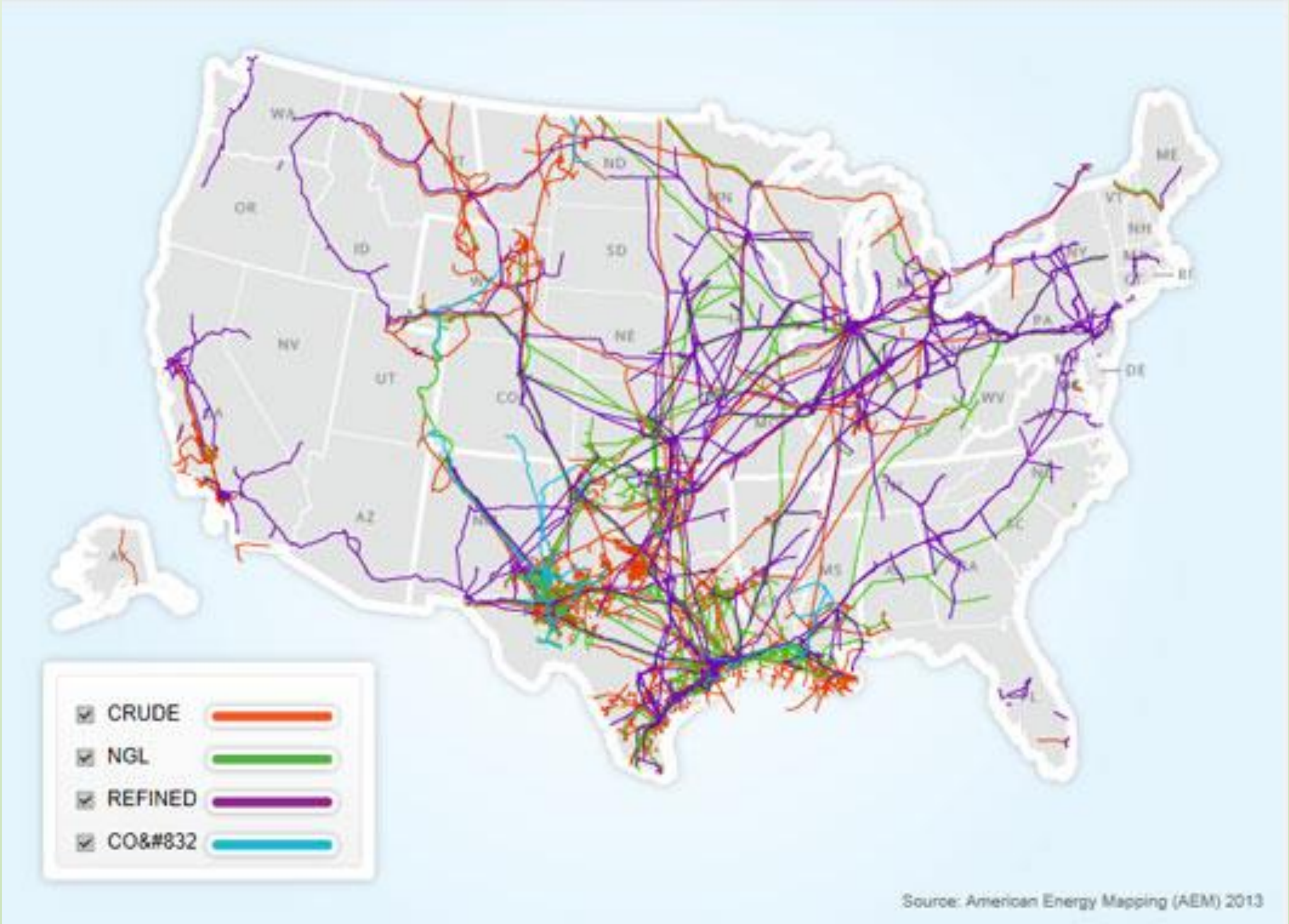

Figure 1. Map of US Pipelines and the Resources They Transport

To do this, we need to find a suitable coating material. Our approach was to coat copper pipes with graphene, a 2-D allotrope of carbon, in order to reduce the drag experienced at the liquid/solid interface of a cylindrical pipe.. We chose this material because it exhibits two critical properties:

1: Ultra-low kinetic friction coefficient due to its weak out-of-plane bonds.
2: Easily synthesizable on cylindrical surfaces.

We define drag as the force on a an object that resists its motion. It is generated by a difference in velocity between the object and its surface. In this case, we are observing the difference in velocity between a stationary copper pipe and the laminar flow of water or isopropanol.

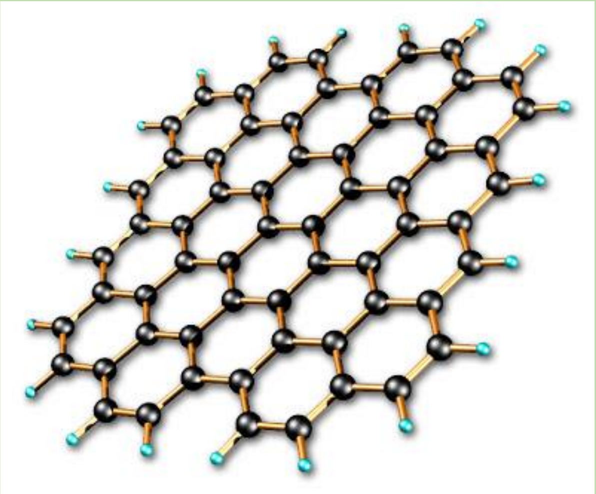

Figure 2. Graphene's 2-D structure. A single layer is only an atom thick.

Methods

Figure 3. Furnace used for CVD

Preparation of Samples

1. All pipes went through oxide removal under 35 sccm of hydrogen at 1035°C for 50 minutes.
2. Graphene samples were exposed to 40 sccm of methane and 15 sccm hydrogen for 30 minutes.
3. Samples cooled under 100 sccm of Argon.

Fluid Flow

1. Connect copper pipes with Parafilm.
2. Measure height of water column after 200mL has flowed.
3. Flow 20-30mL at each height measurement to eliminate any pressure differences.
4. Measure time elapsed through Origin program.
5. Calculate pressure and flow rate.
6. Calculate drag.

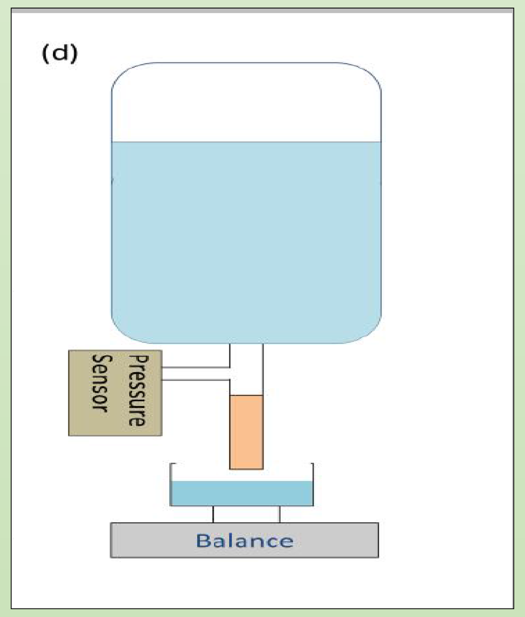

Figure 4. Setup of the fluid flow system.

Calculations

$$Flow\ Rate = \frac{Volume\ of\ Liquid\ (cm^3)}{Time\ (s)}$$

$$Pressure = \rho g h$$

Where ρ is the density of the liquid (g/cm^3), g is acceleration due to gravity (cm/s^2), and h is the measured height (cm).

$$Drag = \frac{Pressure\ Experienced\ by\ Fluid}{Flow\ Rate}$$

This was calculated indirectly by findingthe slope of the graph of Pressure vs. Flow Rate.

Results

The 6cm long pipes showed a significant reduction in drag between the uncoated and coated samples. We observed a 28% difference when using water and a 19% different with isopropanol.
The 4cm long pipes showed a significant increase in drag between the uncoated and coated samples. We observed a 28% increase when using water and 19% difference in isopropanol.

Discussion

Based on our findings, we have not observed any conclusive difference between the control and graphene-coated pipes, as the pipes gave opposite results. While both samples had changes at factors of 28.5% and 19.5%, they suggested completely opposite findings. More samples need to be used in order to see what the possible causes of such differing results could be. Possible causes include the inaccuracy of our measuring devices or a potential error in the labelling of the samples. We cannot confirm or reconcile any of these issues until more experiments are done. This would require more pipes of varying diameters and lengths to be tested, as well as improvements to the precision of the measuring devices.

Regardless of the disagreement between the samples, we did observe consistent, significant changes in the drag found at the solid/liquid interface between the coated and uncoated pipes. If we do find that these changes are accurate, then there are several possible implications for the petroleum industry. If future research confirms that there is a reduction in the drag when pipes are coated with graphene, then the experiment could be magnified onto the industrial scale. If future experiments find that coating the pipes with graphene raises the drag, then we would need to search for a more suitable coating material.

References

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