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论文题目：Investigation on the Blender Lift Effect

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2017 年 09 月 15 日

0 Abstract

This article aims to propose a plausible model for “the blender lift” phenomenon with experimental data. “The blender lift” effect describes the phenomenon that occurs when an immersion hand blender is functioning under water, enabling the blender holder to lift the entire device by exerting forces merely on the upper handle. In the research, a pressure difference induced theory was raised to explain the phenomenon. To further explore and investigate potential influential parameters involved in the process, we proposed an equivalent “magnetic stirrer” model to simulate the original one. This model effectively helps us to overcome the limits of the structure and physical properties of the original process, making it possible to measure and evaluate quantitatively. Our investigation shows that the pulling force the blending is able to generate is proportional to the ratio of the bottom area of the blender guard and the container; it is also proportional to the square of the angular velocity of the blades. The performance is also strongly related to the relative height of the water level and the blender guard due to the distinct properties of a partial or complete submergence.

Key word: Blender, fluid dynamics, pressure difference, equivalent model

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1 Introduction

In this essay we investigated on a phenomenon known as “the blender lift”, shown in the figure below.

Figure 1 The left presents the demonstrative figure of “blender lift” [1] [2]. The right shows the reconstructed “blender lift” effect conducted in our laboratory

This phenomenon happens, under certain circumstances, when an immersion hand blender’s blade is swirling under water in a beaker or a container in similar shape. The blender holder can lift the entire device by simply lifting the upper handle of the blender.

We reconstructed the described “blender lift” phenomenon by first immerse a handheld blender (both its blade and its protection guard) under water, and then turn it on. When the container is not too full, it is always possible to lift the entire system with forces exerted only on the handle.

In the following sections, further details about the blender and the container will be presented.

1.1 Blender

The blender we used in experiments resembles the one in the demo picture in both design and structure. It consists of a motor (shielded inside the handle), a long axis, a protection guard with openings located evenly, and blades arranged in a symmetrical manner.

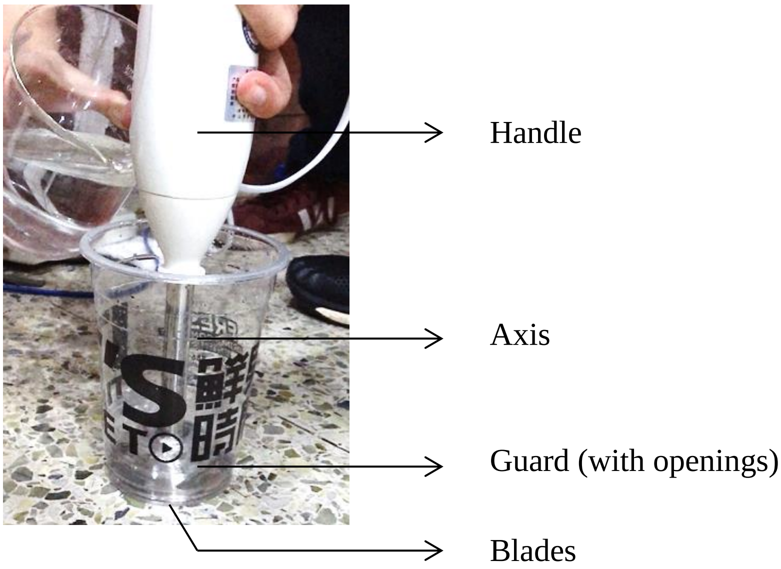


Figure 2 The diagram and corresponding description of the blender used in our experiments

When turned on, the blades, acquiring an angular velocity (provided by the motor), spin around the axis. This causes the surrounding liquid to move along the same direction due to liquid viscosity.

1.2 Container

As preliminary experiments suggested, the material or the mass of the container do not matter as much as the blender itself. The basic requirements of the containers are

1. An opening large enough to fit the blender; and

2. A height greater than that of the blender guard so the entire blade-guard structure can be immersed into the liquid.

While the first requirement is relatively easy to understand, the second one is summarized from empirical experience.

During the reconstruction trials, we discovered that when the amount of water inside the container is not enough to submerge the openings on the guard of the blender, lifting will not be possible. We confirmed our conjecture by conducting an experiment in which the initial water level in the container is very low. After turning on the blender, we slowly added water, a little at a time, into the beaker, we found that the lifting process become more stable and easier, once the water level had exceeded the height of the openings on the blender guard.

(a) (b) (c) (d)

Figure 3 A series of picture intercepted from a video clip documenting the water adding experiment described in the paragraph above. When the water level is low (shown in (a)), the blender lift phenomenon cannot be reconstructed (Fig. 3(b)). However, as water are added (Fig. 3(c)), the blender is able to lift the container in the end (Fig. 3(d)).

We suspect that this counter-intuitive phenomenon indicates that the "blender lift" is an effect mainly driven by pressure difference caused by the blender. After all, the more water means the more weight the blender would have to pull. And it is hard to imagine why a higher water level may in fact improve the stability and performance of the overall system.

1.3 Liquid

The type of liquid held in the container also influences the blender lifting process. As mentioned in section 1.1, the water (or liquid, as the two words are somewhat interchangeable in this paper) surrounding the blades is also driven to rotate, forming a swirl, due to the presence of viscosity. This indicates that different properties of liquid do have effects our investigated phenomenon.

Moreover, different types of liquid differ in density, which is also a factor that directly influences the blender lifting process.

2 Theoretical Model

After experiments and gaining preliminary understandings on the "blender lift" problem, we proceed to more concrete and detailed investigation on the entire model, either as a whole or as separate components. Analysis is made with our hypothesis that “blender lift” is a pressure-driven effect. The following sections will go into details on our proposed explanation.

2.1 Pressure-difference model and mechanical analysis

It can be observed from Figure 1 that the entire system consists of three elements: the blender, the container, and the water. In this section, detailed analyses are presented by evaluating the system as both a whole and a combination of several independent objects.

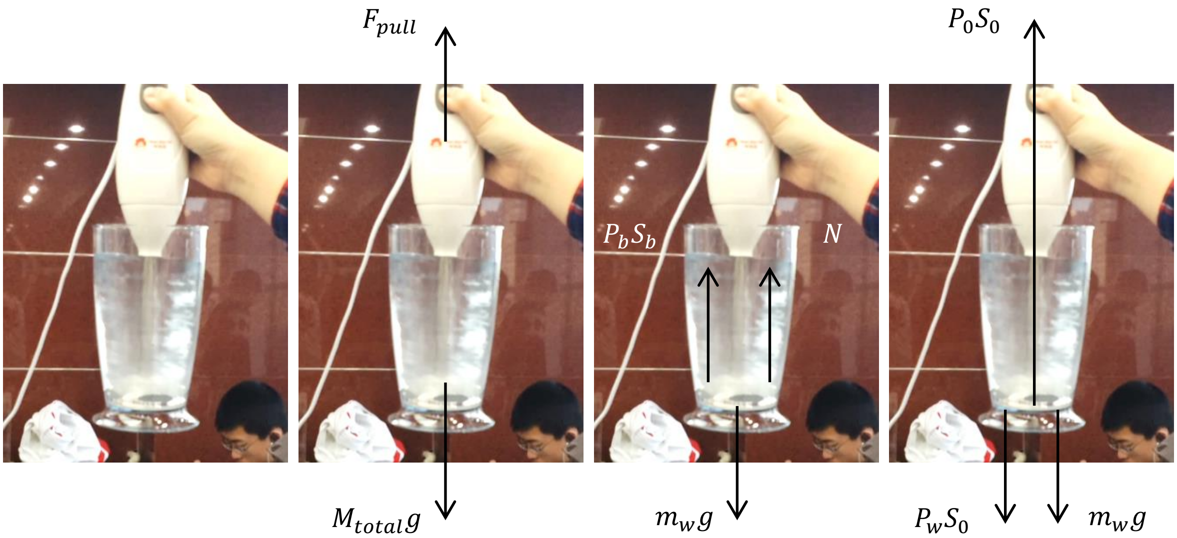


Figure 4 From the left to right are: (1) the original diagram, (2) the mechanical analysis if the system is viewed as a whole, (3) mechanical analysis on water, and (4) mechanical analysis on the container.

When the three components are considered as whole, we have

$$F_{pull} = M_{total}g \ , \qquad (1)$$

where F_{pull} stands for the pulling force exerted on the blender handle, M_{total} for the total mass of the blender, the container, and the water, and g for the local gravitational acceleration. Equation (1) suggests that the total gravitational force of the system equals to the upward pulling force exerted by the blender holder.

If considered separately, on the other hand, different equation set can be derived. Preliminary understandings on the described phenomenon suggest that a difference in air pressure is created, thus resulting in a “sucking force” that somehow presses the bottom of the container against the opening of the blender guard. Select the container as the investigated object, it can be found that

For water: $$P_bS_b + N = m_wg \ , \qquad (2)$$

For blender: $$P_0S_0 = P_wS_0 + m_wg \ . \qquad (3)$$

In equation (2) and (3), P_b stands for the pressure created by the blender, S_b for the area of the blender guard (at the bottom), m_w for the total mass of liquid held in the container, P_0 for the local atmospheric pressure, S_0 for the cross-sectional area of the container, P_w for the pressure passed by the water acting upon the container, and N the normal force exerted by the container upon water. Notably, the following relationship among S_0, P_w, and N hold true:

$$N = P_wS_0 \ . \qquad (4)$$

Diagrams on mechanical analysis can be found in Figure 4.

Through the force analyses, it can be seen that the determining factor in the "blender lift" is the pressure difference created during the spinning of the blender blades. However, we also find that other factor such as the openings on the protection guard of the blender also plays an indispensable role in the process. Thorough reflections on these problems lead us to deeper investigations into the blender, specifically the fluid dynamics inside the blender guard.

2.2 What's going on in the blender guard?

As directly measuring the exact pressure or force inside the blender's protection guard is of high difficulty or near impossible due to the restriction of the physical structure, we decided to adapt the means of computer simulation.

We constructed 3D model for the blender guard with openings and the blades, all submerged in water, with Solidwork. Diagrams for the 3D models for the beaker, the guard, and the blades are presented in Figure 5 respectively.

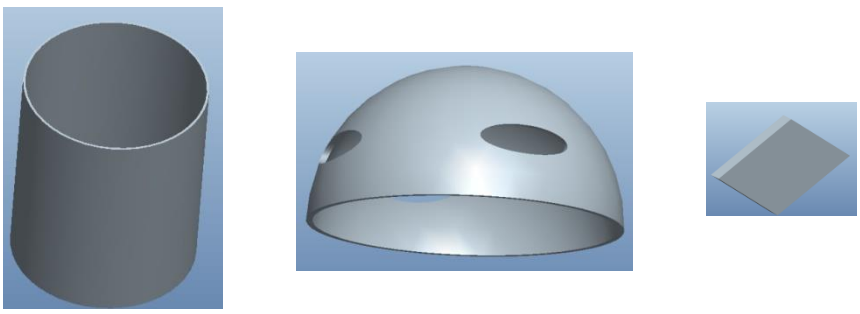


Figure 5 3D models constructed for the blender system. From left to right are: the beaker, the blender guard with 4 openings arranged evenly on it, and a razor.

With the three components demonstrated above, we are able to create a model for the fluid area by combining them with a water model.

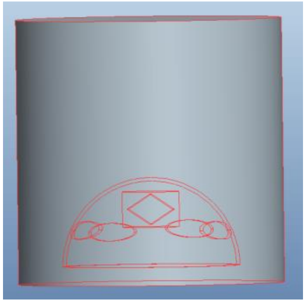


Figure 6 Model of the fluid area in the blender lift. Lines indicated in red are contours and outlines of the blender, with its axis omitted because of the assumption that the beaker and the blender are perfectly aligned so that the geometry center overlaps from a vertical view. The grey part inside the cylinder represents the space taken up by the liquids.

Simulation with Ansys Fluent was later conducted based on the 3D model we constructed. Results from the simulation are demonstrated as below.

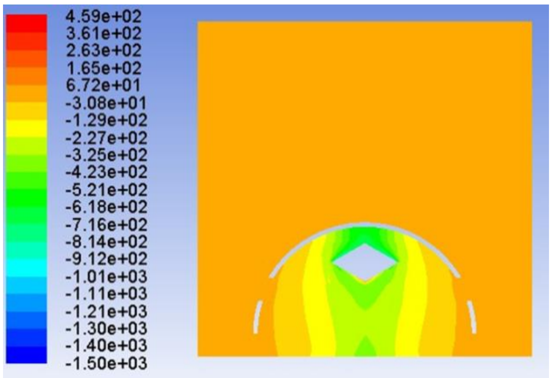


Figure 7 Nephogram on static pressure inside the fluid area, simulated with Ansys 15.0. The scale bar on the left side has a unit of *Pa*. The right is the version of the same nephogram with the addition of mechanical analysis.

A simulation of the entire system as a holistic whole suggests that P_w, which is the pressure of the water inside the blender guard, is a negative value. In other words, P_w is smaller than the atmospheric pressure P_0. Therefore, the resulting combination of P_0S_0 and P_wS_0 is a upward force, pressing the bottom of the beaker against the blender.

To better understand the property of fluids inside the blender guard, we went on to construct more detailed and delicate simulation on only the liquid behavior of the water inside the guard. The following modeling and investigations are made with respect to the water, blender, and beaker as three individuals.

According to the simulation results in Figure 8, it can be observed that water near the openings on the guard is inclined to escape from the semi-spherical space restricted by the blender guard. On the contrary, water flows into the blender guard through the very limited gap in between the main opening of the blender and the bottom of the container.

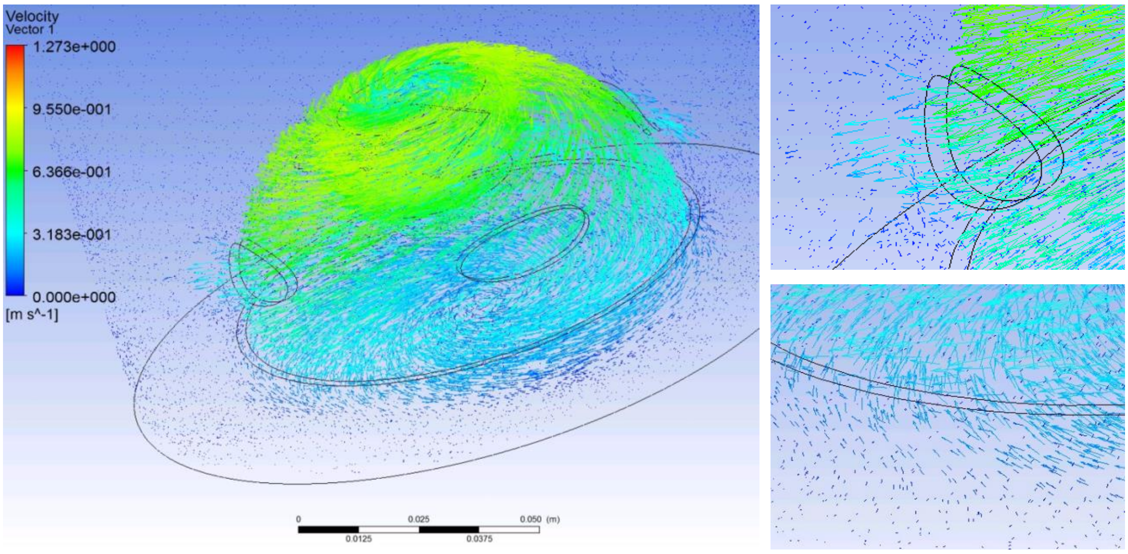


Figure 8 Velocity vector contours inside the fluid area. On the right side are close-ups on fluid behavior respectively around (1) openings on the blender guard, (2) the gap in between the bottom of the blender and the container.

Through this cycle, the fluid inside the beaker is able to maintain its consistency, with liquid in the neighborhood of the blender guard going in and out, and water outside in the beaker going in a generally spiral upward direction.

It also confirms our previous hypothesis on the influence of the openings on the blender. Although a immersion blender without openings on its guard can also result in supporting force that could possibly create the “blender lift” phenomenon (as later discussed in the equivalent model), the lifting of such device is much weaker compared to that generated with a blender experimented above.

2.3 Shear forces

Another factor that contributes a lot to the “blender lift” phenomenon is the *shear forces*.

In fluid dynamics, the shear forces are defined as a pair of forces which are near to each other, have similar significance, point to opposite directions and are perpendicular to the plain in which the initial force is acting upon. As the water outside the blender guard is pushed upwards and outwards simultaneously, shear force is formed due to the pressing effect of water on the side of the container. The mechanical analysis is diagramed as below.

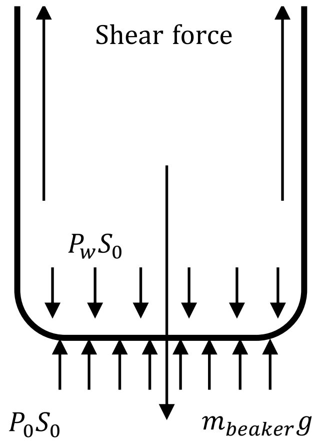


Figure 9 Mechanical analysis diagram on the generation of shear force inside the beaker.

Establish a spatial rectangular coordinate system and the significance of the shear force can be derived from the equation below:

$$f_s = [\frac{dp}{dz} y + (\mu \frac{u}{b} - \frac{b \cdot dp}{2dz})]S \quad , \qquad (5)$$

where p stands for the pressure normal to the contacting plane, μ the dynamic viscosity of the liquid, z the longitudinal force, b the gap distance between the blender guard and the container, and S the interior area of the beaker.

While the shear forces do add to the supporting effect of the blender, it is not the major account for the whole phenomenon. When the blender guard is dismantled, the inclination for water to go spirally upward still exists, hence resulting in non-ceasing shear forces. However, when we experimented with two identical blenders with and without the guard under the same circumstances, it is proved that a blender without the guard (leaving basically only a long thin axis and several blades spinning around it) performs poorly during the blender lifting.

As depicted in Figure 10, a regular blender with its guard on can easily reproduce the “blender lift” scene provided in the demo. On the other side, the “disabled” blender, now without its guard, shows great difficulty in achieving a supporting effect steady and powerful enough to lift the beaker and water up.

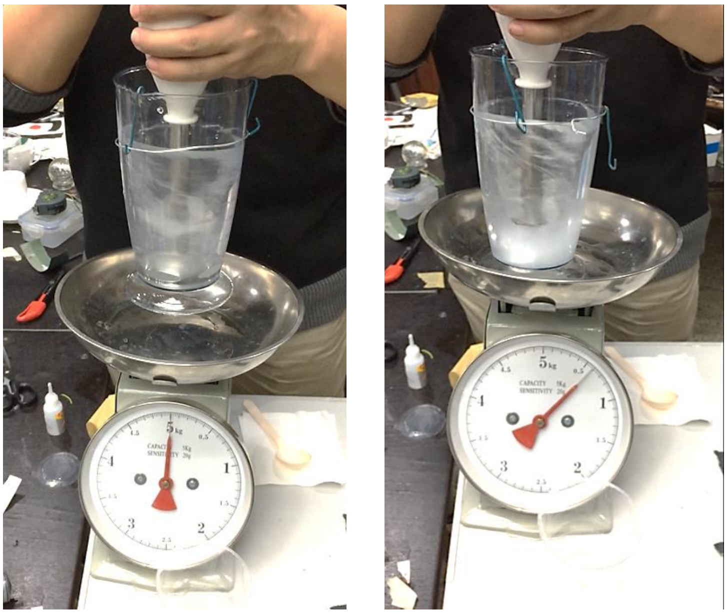


Figure 10 Experiments with blenders (1) with a guard and (2) without a guard. The platform scale placed under the beakers, pointing to 0 and nonzero in the two pictures respectively, indicates that (1) the beaker is lifted by the blender and (2) the “blender lift” effect is not strong enough to hold the entire system up.

This experiment provides firsthand proof that rather than shear-force-driven, the “blender lift” is actually a pressure difference resulting phenomenon, and that the low pressure zone created during the functioning of the blender is responsible for the major source of the “holding force”, as depicted in the contour below.

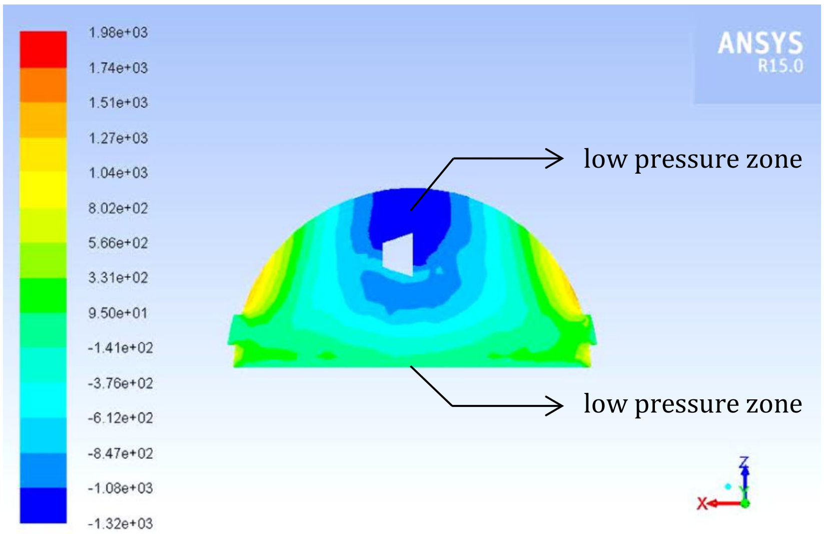


Figure 11 Contours of static pressure (pascal, or *Pa*) of water inside the blender guard.

In conclusion, the “blender lift” phenomenon appears to be a pressure-difference driven effect, with the major support of the system coming from the relative low pressure zone created inside the blender guard during functioning. Our model and verification on different hypothesis have also proved the importance of the blender guard and the opening on the guard. In fact, the low pressure zones (major cause of the “blender lift”) would not be stable and powerful, or even impossible.

3 Equivalent Model and Experiments

Now that we have identified the major reasons accountable for the “blender lift”, we proceeded to further identification of potential parameters and factors that influence the “blender lift”.

Physical structures and properties of the blender limit our ways to obtain accurate measurements within the original model. Therefore, we propose a equivalent model of the “blender lift”, and work on the substitute instead to continue our further investigations.

3.1 The magnetic stirrer model

A magnetic stirrer is an apparatus originally designed to automatically and more efficiently stir so that the solute can be dissolved quicker. It consists of two parts: the rotator, which is a small piece of magnet, and the motor, the main part of the machine that motivates the stirrer by alternating the magnetic field under the container rapidly.

In our investigation, the magnetic stirrer is used to simulate the functioning blender. Specifically, a larger beaker is placed on the stirrer as the liquid container, corresponding to the beaker in the original model. A smaller and shallower cup-shaped structure is placed up-side-down inside the larger beaker, simulating the blender guard. Under the guard lies the rotator, which plays the role of the blender blades: to drive the water around to swirl in the same direction. A brace attached to the “blender guard” is made to fix and also act as the handle of the blender so that it becomes possible for us to *lift* the entire structure.

One notable thing, however, is that unlike the original blender model, this magnetic stirrer model has a blender guard without small openings on it. This absence of an important feature does have effects on the performance of the system: it would almost be impossible to entirely hold up the system only through the “blender handle”, but it can still be observed (as discussed in the following sections) the presence of two low pressure zone and a significant upward force generated by the spinning.

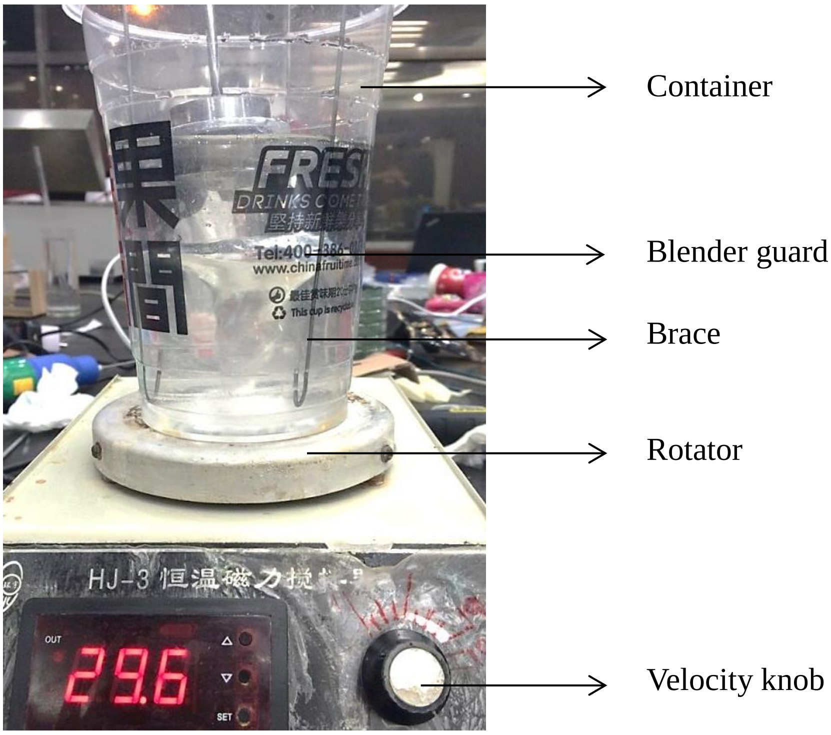


Figure 12 The magnetic stirrer model constructed and experimented with during our investigation.

First, we confirmed the validity of our proposed model by experimenting on its ability to produce two low pressure zones. These experiments are designed in a qualitative manner. Specific procedures are described as below.

We replaced the bottom of the larger container and that of the small cup-shaped blender guard with rubber films in the two sets of experiments, respectively. A notable mark is made on the film so that we can see clearly the displacement of the surrounding rubber film in a short period of time. By videoing the entire “blender lift” simulation, we are able to monitor and capture the fluctuating of the elastic film, thus indicating the change of pressure in the system. Results are presented in the following figures.

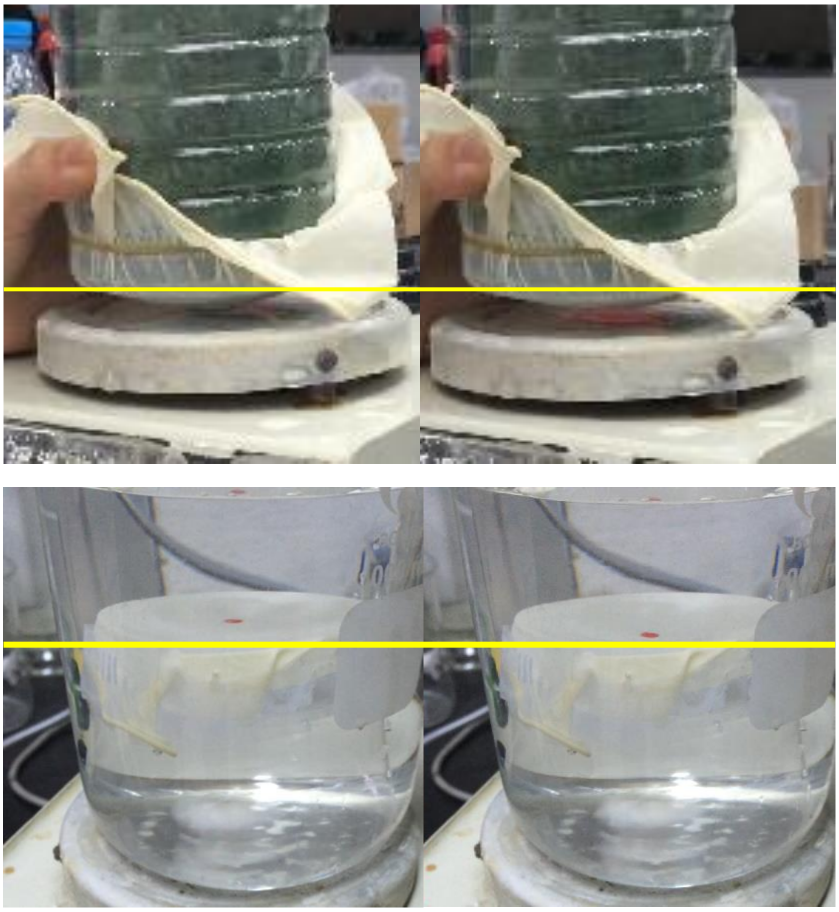


Figure 13 Validity proved for the magnetic stirrer model. Yellow lines are drawn for reference.

The upper collage in Figure 13 shows the change in pressure around the bottom of the container. It can be seen that after the stirrer is on, the rubber film at the bottom of the container, originally a little bit convex down, decrease in its extent, indicating that the film is somehow being "sucked up" to the inside of the container. Similarly, in the collage below, the red dot marked on the rubber film demonstrates a displacement downward when the stirred is turned on, indicating the existence of a lower pressure zone at the top of the "blender guard".

These results correspond to the theory we proposed in section 2.2, proving the reliability of the equivalent model. Moreover, as stirring is also capable of creating a similar upward spiral flow as the blender [2], we are confident with our proposed equivalent and deem it plausible to continue investigations on it.

3.2 Potential affective parameters

Based on our understanding of the problem, we proposed several possible parameters that are very crucial to explain the "blender lift" experiment. They can be summarized as follows:

(1) For the container: bottom area;

(2) For the blade guard: the bottom area, the height, and the material;

(3)Water level; and

(4)Speed of revolution.

There may exist a lot more parameters besides the ones mentioned above that could also affect the process. However, due to limitations on measuring equipment and apparatus, we are only able to test the up-listed variables.

4 Experimental Design and Results

In this following section, we will present our fundamental designs of apparatuses and the experiments. Slight modifications may be made in respect to a specific property that is targeted. Results for these investigations are also included.

4.1 Apparatus and overall layout

The basic idea of the apparatus set up is to try to amplify the force resulting from the pressure differences to a more measureable degree. We introduced a lever to achieve such a goal. The illustration of the set-up is depicted in the figure below.

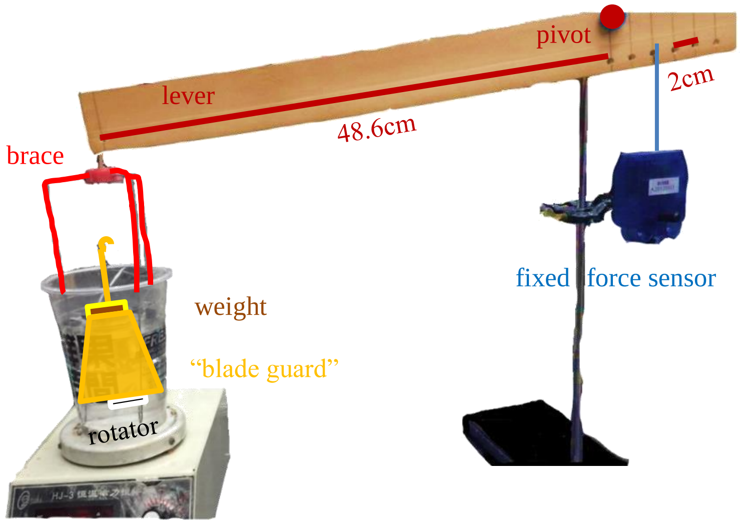


Figure 14 An illustration of the apparatus and measuring instruments

An in-situ force sensor is fixed on an iron stand, tied to the right side of the lever. When the magnetic stirrer is turned on, a small but still detectable force would be exerted. By adding weight onto the top of the "blender guard" in order to keep the system at the critical state, we managed to create an environment that best approximate the ideal situation, where the equations in section 2 hold true.

More specifically, the relationships among the measured variables are illustrated with the figure below.

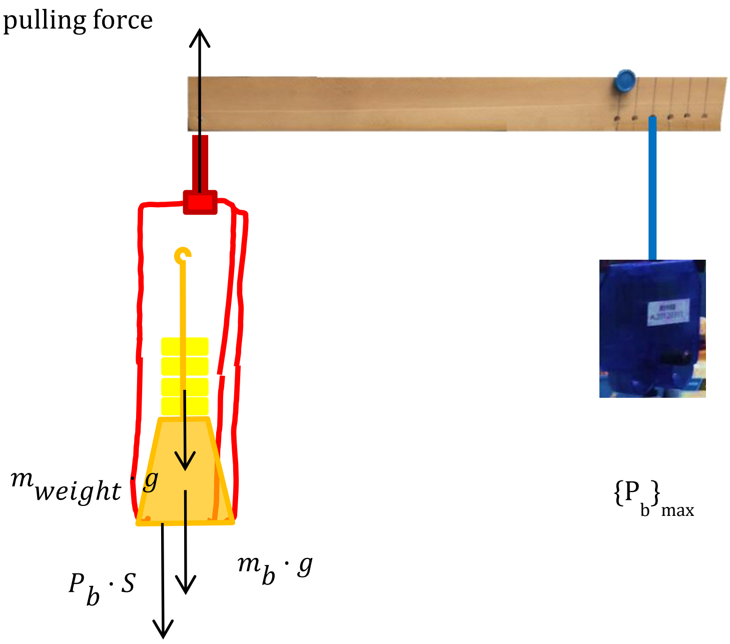


Figure 15 Mechanism of the proposed apparatus

By investigating the very moment when the "blender" is able to lift the entire system with the maximum extra weights m_{weight}, we are able to arrive the maximum of P_b, which stands for the maximum pressure that the blender is able to generate.

The following of section 4 will be organized according to different parameters that we experimented on.

4.2 Bottom area of the container/blade guard

The force sensor records the reading at an interval of a few seconds. Readings include the data points taken before the "blender" is on as well as those taken after turning on the "blender". Differences in the value of the forces are calculated.
The influence of the bottom area of the container or the blade guard on the magnitude of the sensed force is shown in graphs below.

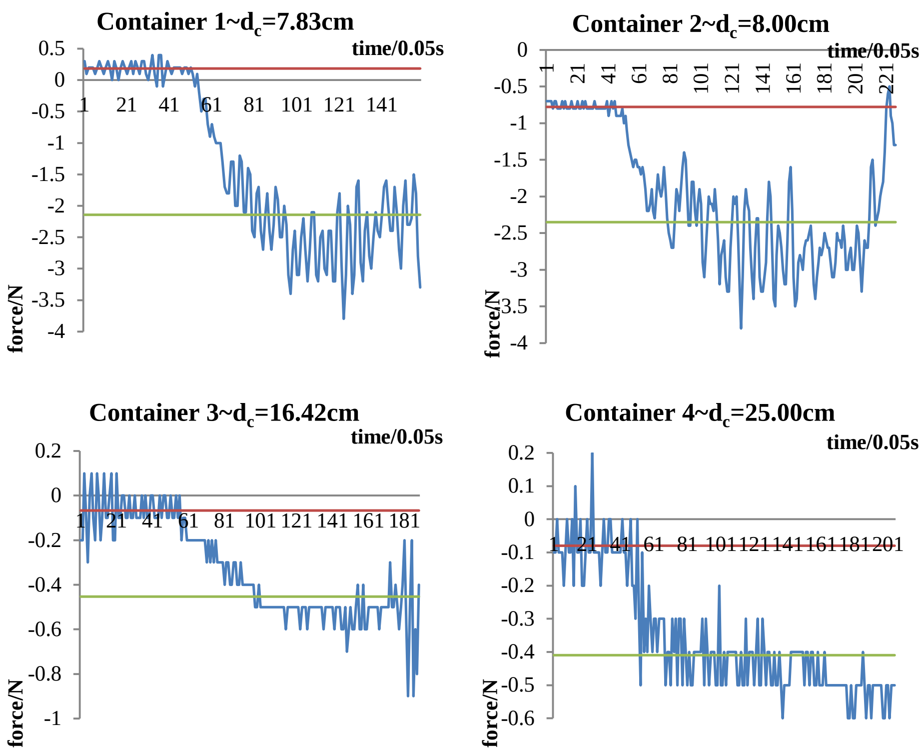


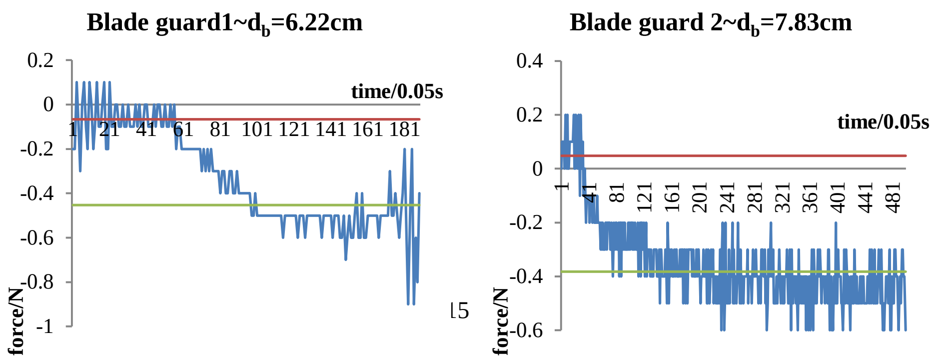
Figure 16 Graphs obtained experimenting with containers' difference bottom area. The blue line represents the actual readings, while the red and green line stands for the mean detected force before and after turning on the "blender".

The relationship between the diameter d_c of the container's bottom area and the force difference ΔF caused by the blender are presented in Table 1.

Table 1 d_c of the container and the corresponding ΔF caused by the blender

d_c/cm	$\Delta F/N$
7.83	2.32
8.00	1.57
16.42	0.38
25.00	0.32

Similarly, the relationship between the diameters of the opening of the "blender guard" and the force difference it is able to produce are also shown. Graphs of ΔF with time at specific diameters of blade guard d_b are plotted.



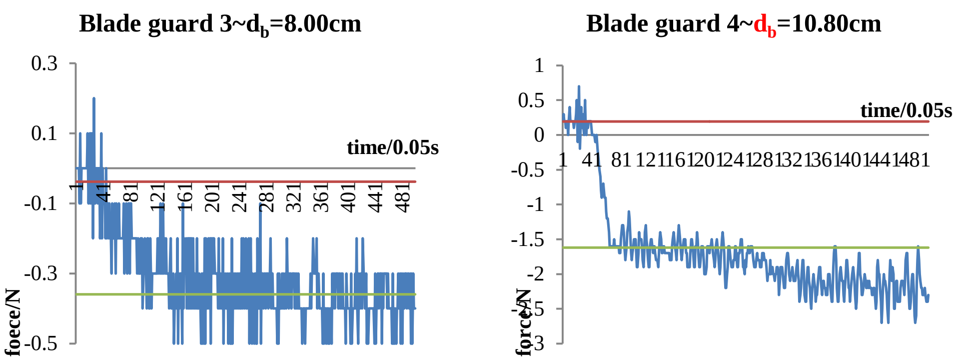


Figure 17 Graphs obtained experimenting with blade guards' different bottom areas.

Underlying relationship of ΔF and d_b is also investigated, as show in the following chart.

Table 2 d_b of the blender guard and the corresponding ΔF caused by the blender

d_b/cm	$\Delta F/N$
6.22	0.38
7.83	0.43
8.00	1.32
10.80	1.81

It can be seen in Table 1 and Table 2 that a larger d_c is likely to result in a smaller ΔF, while an increase in d_b contributes to larger ΔF.

4.3 Water level

According the theoretical analysis and observation made in earlier sections, it can be concluded that the water level directly influences the "blender lift". Therefore, an investigation on the relationship of water level h and ΔF is conducted.

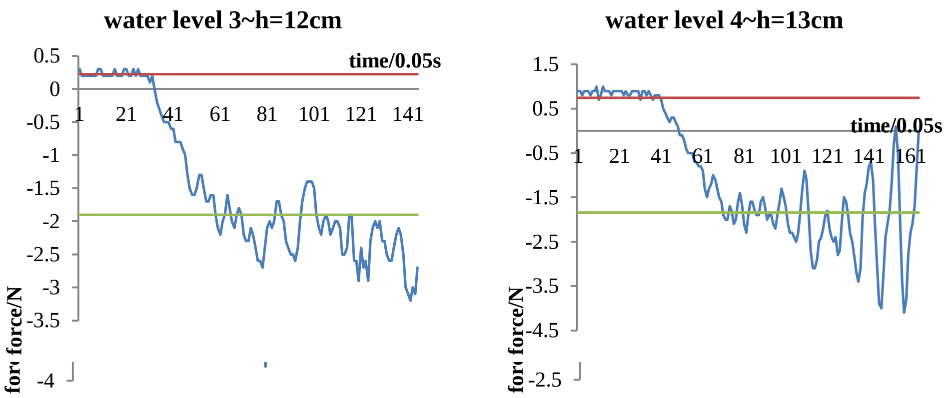


Figure 18 Graphs obtained experimenting with different water level. Water level is defined as the

height of water, in comparison to the bottom of the container.

Note that all experiments regarding water level are conducted with a magnetic stirrer model where the "blade guard" has a height of 10cm. This means that the blade guard may not be fully immersed during the experiments.

The specific relationship between the water level h and ΔF is listed as follows

Table 3 h of the water and the corresponding ΔF caused by the blender

h/cm	$\Delta F/N$
7.00	1.52
8.00	1.84
12.00	2.24
13.00	2.41

ΔF appears to be in positive correlation with the water level h in a certain range. However, this increase in ΔF may also be caused by the difference in immersed and non-immersed blade guard. As can be seen in Table 3, when h increase from 8.00 to 12.00 cm, transforming from a partially underwater mode to a fully submerged mode, the resulting ΔF jumps from 1.24 to 2.24 N.

4.4 Height of the blade guard

There is no way for us, or any other researchers, to first focus on the possible influence of the water level, and then ignore the coupling parameter: the height of the blade guard h_b.

As explained in former sections, both theoretically and experimentally, there exists a huge difference in the submergences of the blade guard, in the sense of the "lifting force" provided by the rotator. Therefore, the investigation on the height of the blender guard is also conducted.

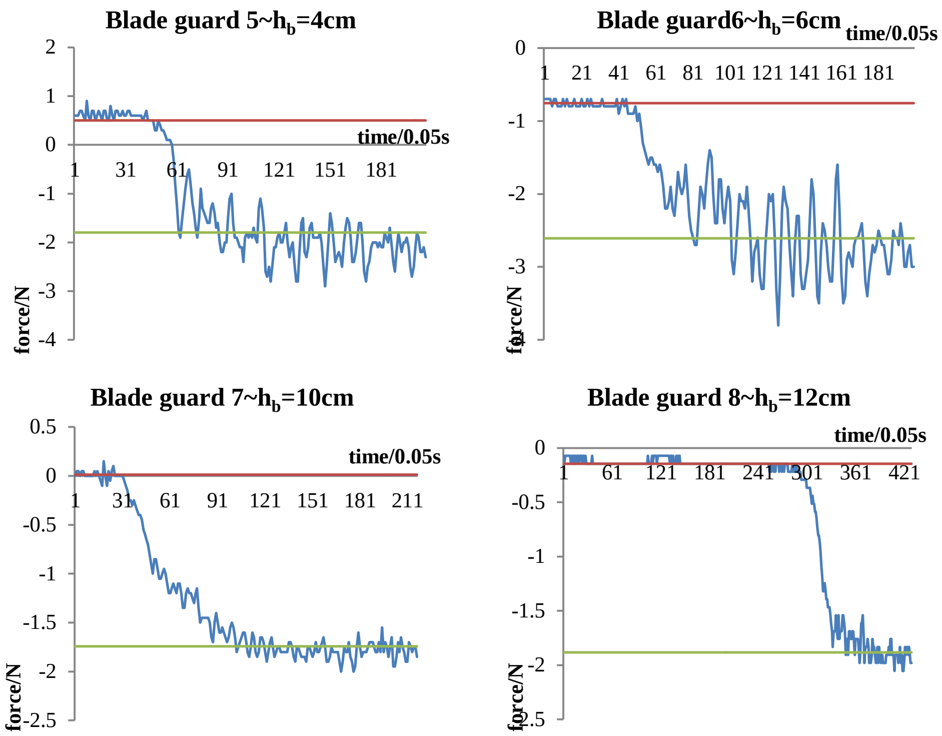


Figure 19 Graphs obtained experimenting with "blender guard" with different heights.

Note that all experiments are conducted with a water level of 9 cm. More specific information can be seen in the chart below.

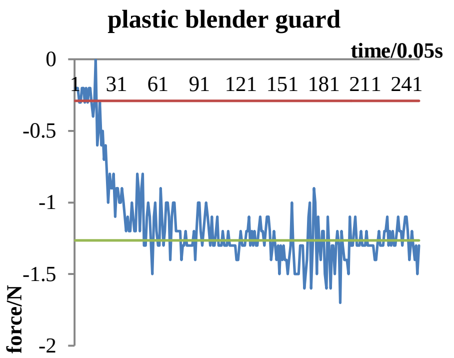
Table 4 h_b of the blender guard and the corresponding ΔF caused by the blender

h_b/cm	$\Delta F/N$
4.00	2.03
6.00	1.95
10.00	1.85
12.00	1.78

From the chart we can observe that as long as the water level is higher than the height of the blade guard, which means the total submergence of the blender guard, the up-lifting force generated by the system is relatively large. However, though data suggests that a blade guard without total submergence is unable to provide great and steady lifting force, the major reason responsible for this giant gap is that the structural integrity is sabotaged when trying to fix the extra weight onto the top of the "blender guard".

4.5 Materials of the blade guard.

A series of experiments on the different material of the blade guard is also conducted. Specifically, we focused on two types of different blade guard: the paper and the plastic ones. Data collected during this experiment is presented in the following graphs and chart.



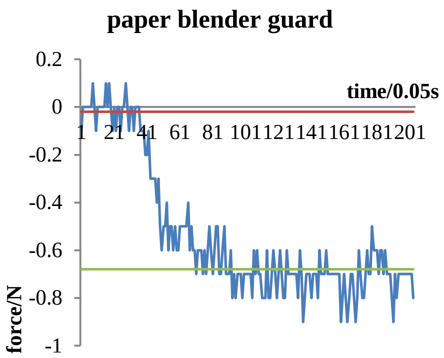


Table 5 Different types of materials of the blender guard and the corresponding ΔF

Material	$\Delta F/N$
paper	0.68
plastic	0.97

The data conforms to our intuition that coarser the surface of the blade guard is, the smaller its resulting supportive force would be, as most of the energy is consumed during the frictional movement between water and the blade guard, slowing down the water and leading to a smaller pressure difference (according to Pascal Law).

4.6 Speed of revolution

Last but not the least; we discussed the role of the revolution speed in the equivalent model. As stated in the *Pascal Law*, the pressure is lower where the liquids tend to decelerate faster, and vice versa. It can be logically deducted that the revolution velocity does have a unneglectable impact on the "blender lift" phenomenon.

During the experiment, we gradually accelerated the angular velocity of the rotator, and arrived at a long-period experiment results as presented in Figure 20 below.

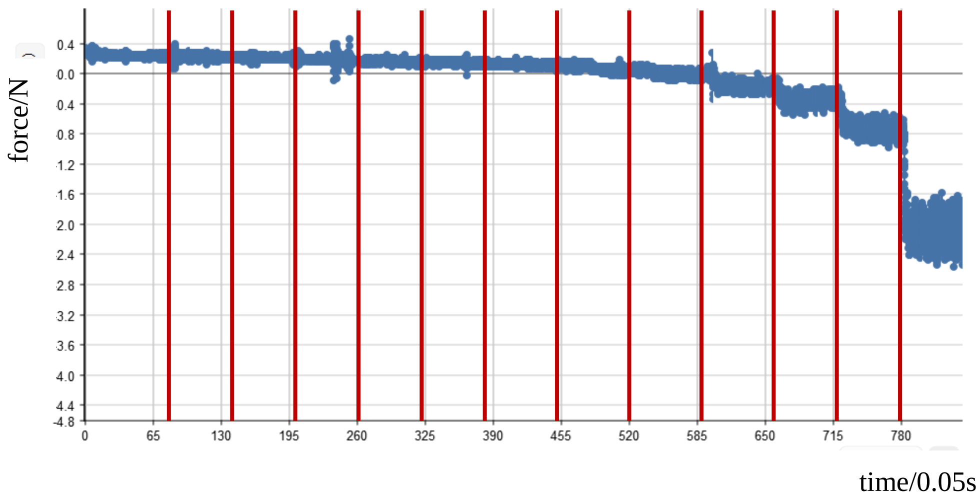


Figure 20 Force data extracted directly from the SparkVue apparatus and software.

Phases of the experiments, where the angular velocity of the magnetic rotator is different, are divided by the red lines. We extracted the mean reading of force in the phases, combined with preliminary speed measurement of the rotational velocity of the magnetic stirrer, the following graph on the relationship of the pulling force F_{pull} and angular velocity ω could be created.

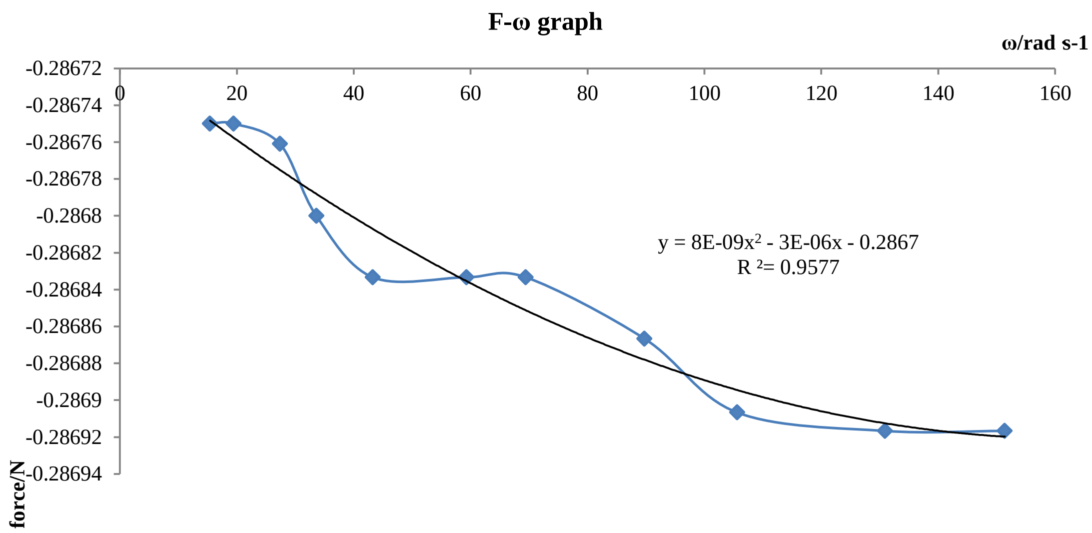


Figure 21 The $F - \omega$ graph plotted with data obtained in the velocity experiment.

It can be seen that the $F - \omega$ curve fluctuate within an acceptable range near a parabola, with a R^2 of 0.9577, indicating the high quality of the quadratic fit.

5 Conclusion and Discussion

Based on figures and numbers presented in section 4, it can be inferred that the supporting force generated during the "blender lift" phenomenon

(1) is positively correlated to $\frac{S_b}{S_C}$, where S_b stand for the area of the opening of the blender guard, and S_c the bottom area of the container;

(2) is positively correlated to the water level, negatively correlated to the height of the blender guard;

(3) is affected by partial/impartial submergence of the blender guard;

and (4) is proportional to ω^2, where ω stands for the angular velocity of the "blade".

Further fitting and statistical analysis shows that F_{pull} is actually proportional to $\frac{S_b}{S_C}$, as demonstrated in the graph below.

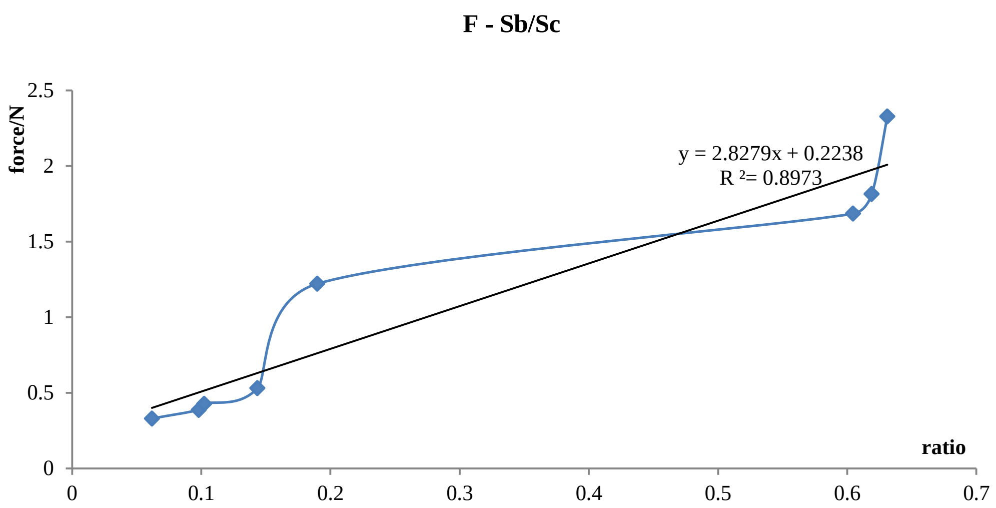


Figure 22 Correlation between F_{pull} and $\frac{S_b}{S_C}$

A R^2 of 0.8973 indicates that a linear regression is, somehow, not so bad, considering all the uncontrollable variables and possible source of deviations during the experiments.

To further understand the "blender lift" phenomenon, we attempt to use our proposed theory to explain the observed patterns.

As for pattern (1), we need to keep in mind firstly that it is the water insider the blade guard that provides the momentum for the water outside the blade guard. Such a process is completed with the constant frictional movements and the presence of viscosity of the liquid. With this idea kept in mind, we can proceed to extend on the phenomenon.

While the area of the blade guard holds the same, the smaller the bottom area of the container is, the more water outside the shell, resulting in a smaller velocity of the flow. This causes the pressure differences between the inside and the outside the blade guard to increase, yielding a larger pulling force to support the whole system. The same theory works for the second case where the bottom area of the container is a constant and the area of the blade guard increases.

In general, we believe that our adaption of an equivalent model successfully resolved the difficulty in obtaining actual and accurate measurements in the original structure. This magnetic stirrer model, which has been tested of its validity and resemblance to the original model, contributes tremendously to the quantitative approach of the “blender lift” problem. This novel idea of an equivalent model not only acts as the highlight of the whole research, but also points to a promising direction and a potential solution to other complicated physics problems and phenomena.

We admit that future works can be added to this current piece of work by filling the blank such as the coefficients of certain terms or investigating more potential effecting parameters, and more analysis and researches are conducted to further consolidate our theory. Specifically, we are considering eliminating a few source of variation, such as the airtightness of the equivalent model and the fluctuating temperature which causes turbulence inside the fluid area, and adding more potential influential factors into the scope, such as the viscosity of different liquids and frictional coefficients.

6 Acknowledgement

Our thank goes to The High School Affiliated to RENMIN University of China for providing us with the precious opportunity to conduct independent researches.

Our thank goes to Mr. Xi Chen and Mr. Yongping Zhang for their continuous supports and aids during our researching process.

Our thank goes to the parents who have always been extremely supportive during our researching process.

Our special thanks also go to all student delegates on the RDFZ team, who has always been open to discussion, willing to share, and ready to help.

We could never forget the generous help from Mr. Fuwang Zhao and Mr. Xiang Wang at the fluid dynamic laboratory at Beijing University of Technology, for coaching us with the computer simulation part and giving both criticism and inspiration.

Last but not the least, our thank goes to the committee of the US Invitational Young Physicist Tournament and every school and student participating in the 2016 competition, for giving us the opportunity to present, discuss, and reflect on our previous work and sparkle new inspiration.

During the research program, Wenyan Guan is responsible for background digging, the theoretical analysis and data procession, while Jiachen Pan is mainly in charge of the experiments.

Experiments and computer simulation are conducted in either the High School Affiliated to RENMIN University of China and Beijing University of Technology fluid dynamics laboratory during the period of Sept. 2015 - Jan, 2016. Related materials from this paper have been used in the USIYPT 2016 contest. No future publication have been intended or planned yet.

7 References

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8 Appendix

8.1 Notes

The reconstruction of “blender lift” phenomenon involves a 0.2 kg beaker filled with approximately 0.6L of water and 1.2 kg of weight, lifted by a blender functioning at 11,000r/min. or with 1.6 kg of weight, lifted with blender working under 22,000r/min.

8.2 参赛团队简历

参赛队员：

关文妍，女，中国人民大学附属中学 2018 届高中生。初高中读于人大附中早培班。多年参与数学竞赛，成绩突出，理化基础扎实；在校学习优秀，积极参与校内外活动；其神经生物学方向研究性学习合作课题“咖啡因成瘾与戒断对小鼠及其子代成瘾与戒断的影响”荣获一等奖，并作为优秀课题进行大会展示。任班级宣传委员，校辩论队核心成员；发起或组织过若干学术、公益社团与活动。校外曾作为辩手、队长，两次代表学校参与美国青年物理学家邀请赛，并获得优异成绩；课题“基于 WGAN 神经网络的汉字风格迁移”在 RSI Tsinghua 暑期科研项目中获 Top5 优秀论文与 Top10 优秀讲演。课余时间，爱好绘画，音乐与阅读。

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