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優勝作品專輯

作品編號　**160006**

參展科別　物理與天文學

作品名稱　**Bubble film with vortex**

得獎獎項　大會獎：四等獎

就讀學校　臺北市立麗山高級中學

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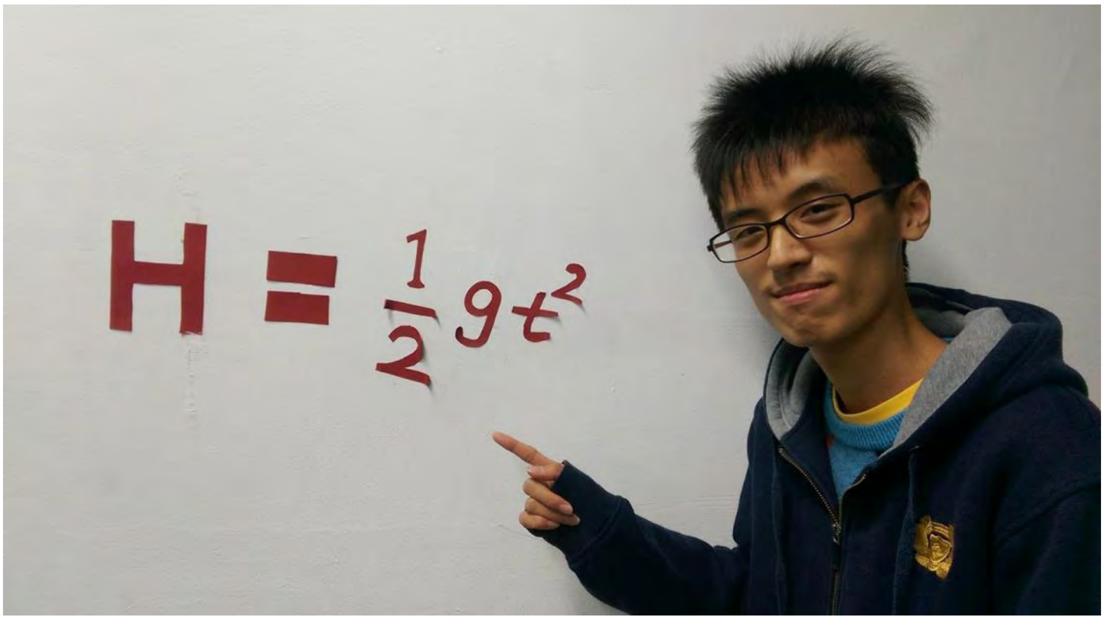
關鍵字　**bubble film、vortex、wings**

作者簡介

我是章本新，就讀麗山高中二年級，從小就對飛行物、資訊和體育有濃厚的興趣，雖然在數理資優班，卻同時參加麗山的田徑隊，放學常常跑完步再回實驗室做實驗，開始做專題後，就懷抱著參加 intel 科展的夢想，因為參加太多班級活動，又參加田徑隊，在做科展時常常壓力很大，趨近於崩潰，但每當我想起或許哪天能代表參賽 intel 科展賽，我就重新獲得繼續努力下去的能量。



我是黃諺恩，現在就讀麗山高中二年級數理資優班。個性活潑，是一個充滿好奇心的學生，興趣是打桌球。很高興有機會可以參加科展活動，一起和各學校來個切磋一翻。在研究期間，花了許多的心思、精力，花了大約一年多的時間來完成這項科展。雖然很辛苦，但從中學習到許多技術、報告的排版、分析數據等多種事物。希望未來能在科學領域有所發展，展現自己的才能。

Abstract

A simple and cheap bubble film experiment system was constructed by us. Although it is simple, it can observe the phenomenon similar to those observed in the wind tunnel system or PIV system. But because of gravity, bubble film become a little more complex. We programed some codes to analyze the data and showed bubble thickness is proportional to the Reynolds number. The low frequency sound can make bubble film rotate. And we also study the wing's attack angle, from 0 to 75 degree with interval of 15 degree, discovering the 15 degree is the best flying attack angle.

Introduction

1. Motivation

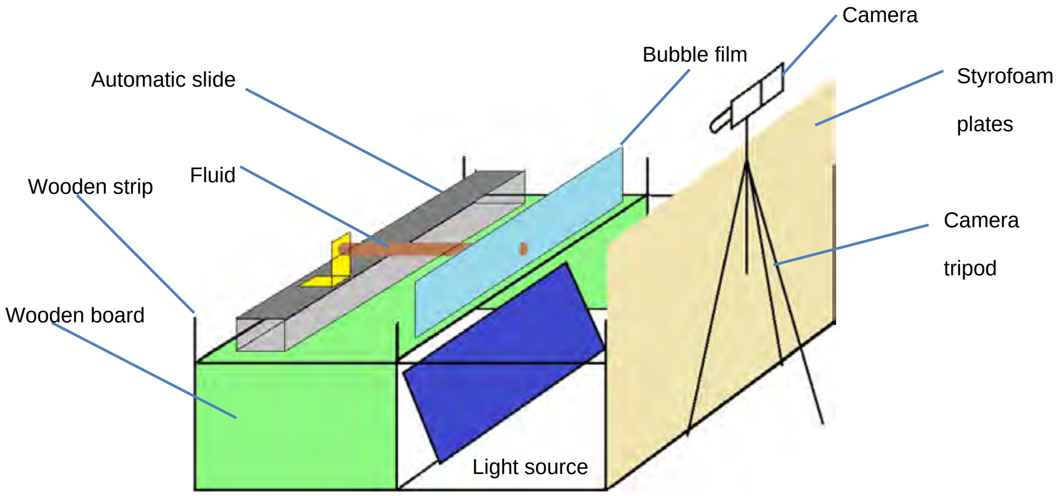
When we were young, there was a book called ''October Sky'' . That's a fantastic book and led us having a great interest about flying. Hence, we wanted to studied flying machine. Yet, constrained by the resource, we couldn't study the rocket flying. After asking for teacher's advises, we would use bubble film to simulated the water and studied "Scull''. However, making a device that could drive the scull todo three-dimensional movement wasn't an easy thing. The bubble wasn't a good tool to simulated three-dimensional hydrodynamics. Eventually, we determined to studied the wings of aircraft. During our experiment, we tried our best to decreased the effect that caused by environment. When testing sound and airflow, we found the sound in specific wave range could let the bubble "spin" coincidentally. Our experiment main study items including wings, sound, and bubble because the reasons above.

2. Research purpose

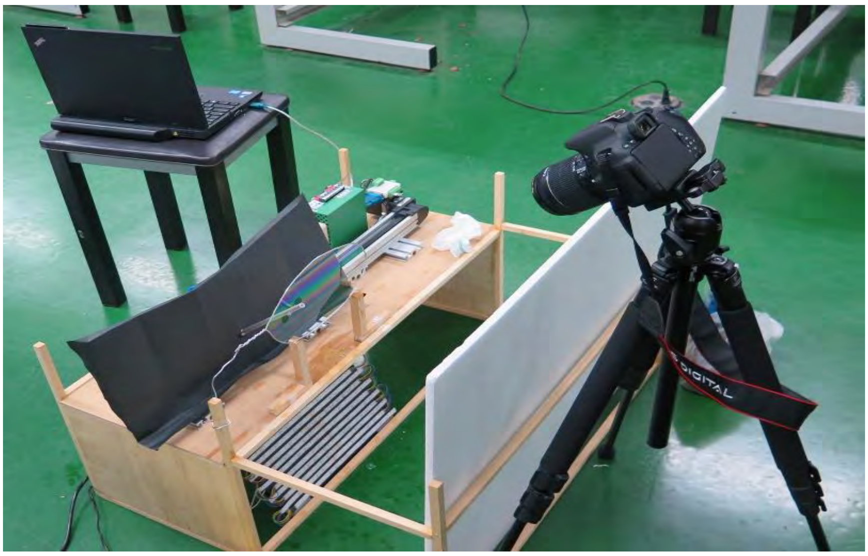
1. To establish a specialized experiment system that utilize the bubble to study two-dimensional fluid dynamics.
2. The relation between wings' attack angle, velocity, and lift.
3. The relation between sound frequency and bubble.

Method

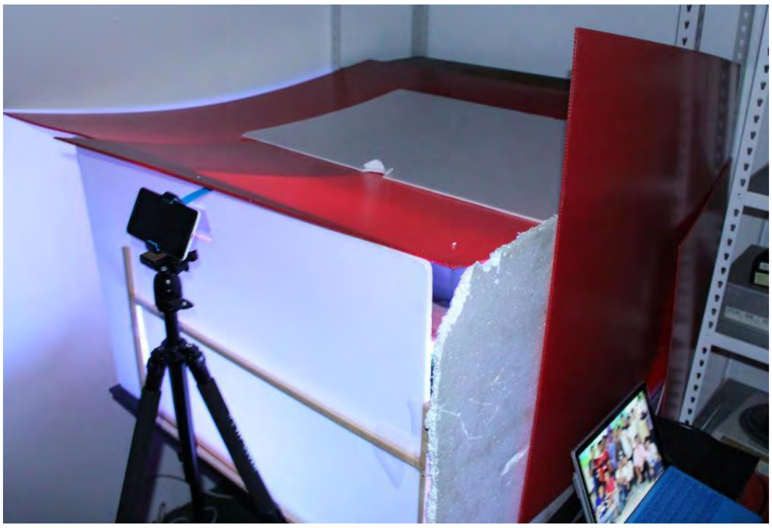
1. Experiment Instruments



2. Summer



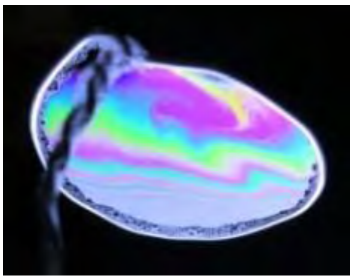
3. Winter

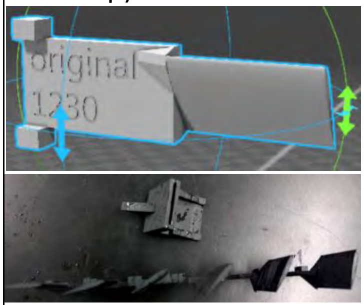
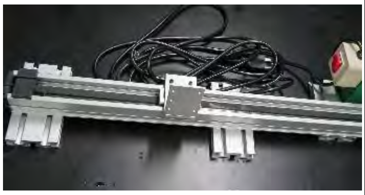


When the summer turn to the winter. We realize that the temperature is high relation to viscosity. So we put everything in the box and turn on the heater.

4. Materials/Instruments

<table>
<tr><td colspan="3">(1). Parallel light source
Home-made LED parallel light source.
Fifty RGB LED stripes  Circuit  boardRemote receiver 
Styrofoam  plates  product</td></tr>
<tr><td>(2). A smartphone with 240Hz video camera

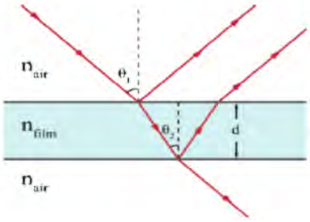
</td><td>(3). The aluminum frame
</td><td>(4).Heater </td></tr>
</table>

(5). Frequency Sound APP 	(6). Camera tripods 	(7).Wings(drawing by sketchup) 
(8).Speaker 	(9). Automatic slide 	(10). Thewooden shelf 

Principle

1. Interference and Bubble flow

Different thickness bring different interference on bubble, so we can utilize observing the color of bubble to calculate bubble's thickness.



$$\phi = \frac{2 \times d \times n}{\cos\ \theta \times \lambda} \times 2\pi$$

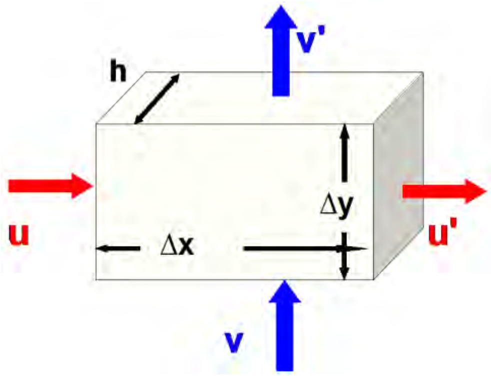
Bubble

d :thickness of bubble

n :Index of refraction

θ_2: second incidence

The flow and the velocity will affect the local thickness of bubble, so we can utilize observing the local thickness to calculate the flow.



u、v :flow
h : thickness
x、y : bubble’ s L W
t : time

Bubble flow

$$(u'-u)*\Delta y*h+(v'-v)*\Delta x*h=\frac{\Delta h*\Delta x*\Delta y}{\Delta t}$$

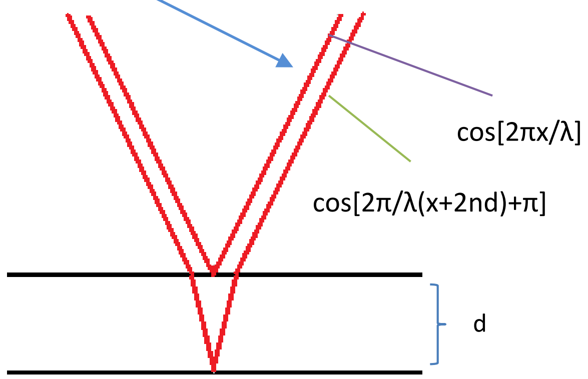
2. Calculation of bubble’s thickness

$f(x)=\cos[2\pi x/\lambda]+\cos[2(\pi/\lambda)(x+2nd)+\pi]$

$\rightarrow f(x)=2*\cos[2\pi/\lambda(x+nd)+\pi/2]*\cos[-(2\pi nd/\lambda+\pi/2)]$

$A^2\propto I$

$\therefore (f(x))^2=\{2*\cos[2\pi/\lambda(x+nd)+\pi/2]*\cos[-(2\pi nd/\lambda+\pi/2)]\}^2$



then deduced→

$I\propto 4*1/2*\sin^2(2\pi nd/\lambda)$

A(Amplitude)
I(Light intensity)
n(soap water’ s
Index of refraction)
d (thickness of bubble)
λ (light wavelength)

According to this formula, a light intensity could represent indefinite thickness. But we realized that we can define the thickness of the first bright zone on the top of bubble to be 1/2 λ (nm). Then we use the rule of increment to calculate the thickness at any place on the entire bubble film.

In our setup, the incident of our light is not vertical to the bubble but the incident angle is 45 degree. Because it would be very difficult to observe if it were vertical. As such, we modified the formula to accommodate the 45 angle of incidence.

d= √{1-[sin（π/6)/n]^2}*d0

d0is the thickness of original formula

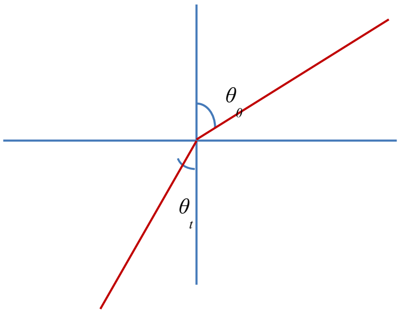
so

I∝4*1/2*sin^2{2π[n^2*d/√ (n^2-sin45)]/λ}

3. Refractive index (green) and wave

n (soap water refractive index)

We use pin to observe our soap water's "n" .



Snell's Law→ $\frac{\sin\theta_0}{\sin\theta_t}$ = n

θ_t =45 ° θ_0 =78 °

→ sin 78 °/ sin 45 ° ≒ 1.73

So n=1.73

4. Lambda(λ) of homemade light source

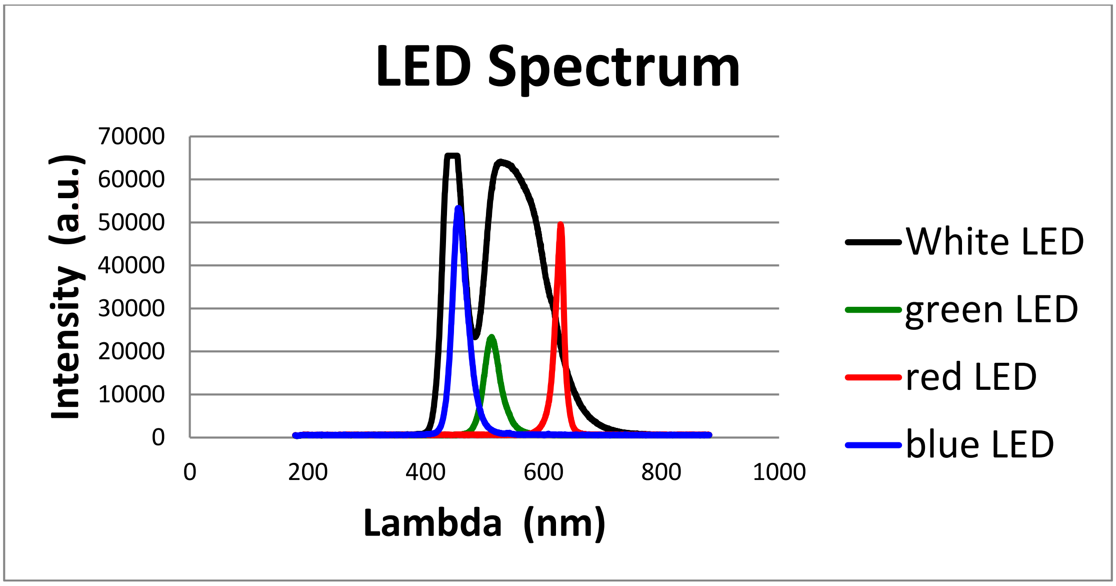
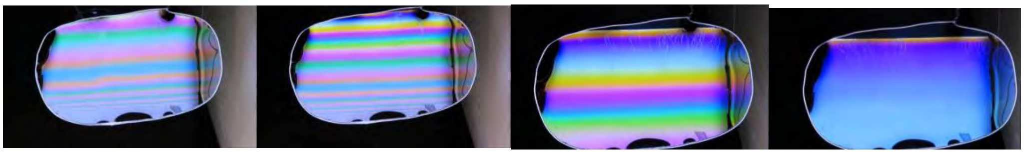


Figure 1. Intensity against Lambda

The wavelength λ of blue light is the shortest. According to formula, in the same range of the bubble thickness, blue light can report the largest number of cycles of the intensity change. When more cycles are observed, the more accurately the thickness can be measured. So we chose blue light to observe bubble film initially.

5. Soap water formula

We control the glycerin and dish soap and water to test the formula of soap water.
We observed that a very good ratio of (Glycerin: Dish soap: water) for our experiment is (2:1:0) that it can last 71minutes.
Video internet site:(Appendix 1)
Capture photos



Video internet site: (Appendix 1)

6. Viscosity ofbubble

So far, there has been no direct way to measure the viscosity of the bubble. To this end, we can use Reynolds number and Strouhal number to calculate the viscosity. According to the empirical formula of the relation between Reynolds number and Strouhal number, we can compute the Reynolds number, where f, L and U stands for sound frequency, diameter of the cylinder, speed of the flow respectively.

$$St=\frac{f\,L}{U}=0.212-\frac{4.5}{Re} \qquad 25<Re<200$$

The Reynolds number is defined as the ratio of momentum forces to viscous forces and it can be expressed by multiplication of U, flow speed, and d, diameter of the cylinder, and then divided by v, viscosity.

$$Re=\frac{U\,d}{v}$$

Based on this formula, we can get the viscosity of the bubble. Knowing the viscosity, we will make a figure of the relation between Reynolds number and Strouhal number.

7. Expected result

Theoretical relationship between light intensity and bubble thickness.

$I \propto 4*1/2*\sin^2(2\pi nd/\lambda)$

Then using the formula to calculate the bubble's thickness.

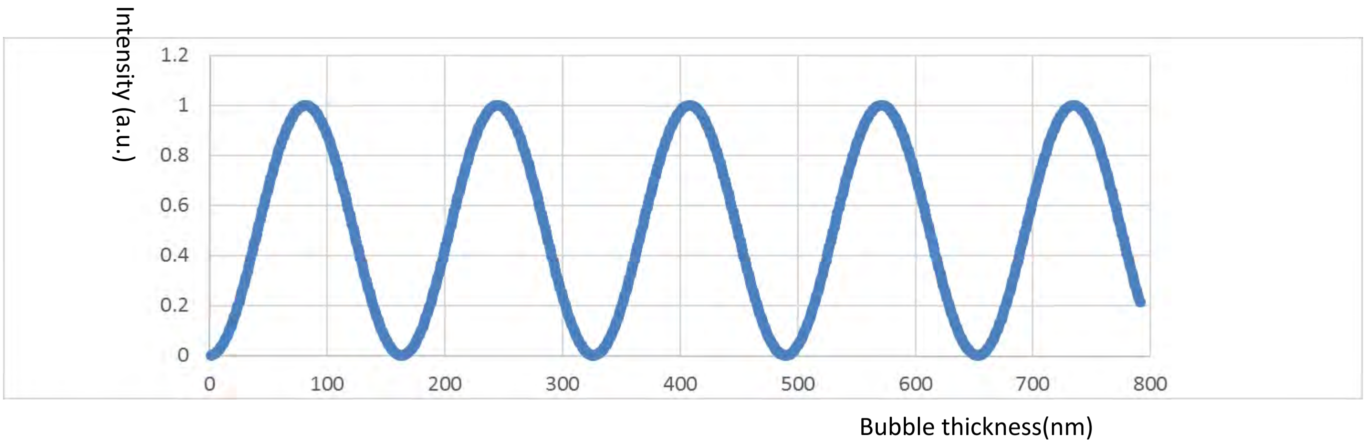


Figure 2. speculate the bubble thickness and light intensity.

Result

1. Reynolds number and Strouhal number

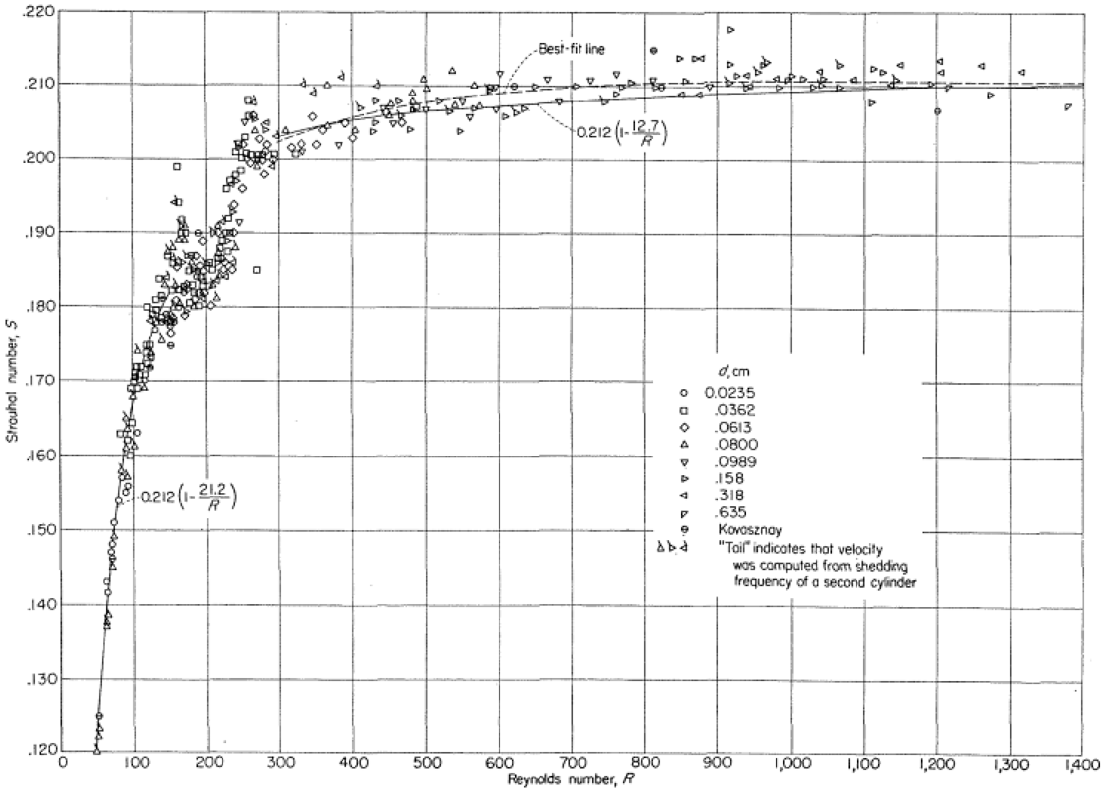


Figure 3. Strouhal number against Reynolds number for cylinder

(Anatol Roshko, 1954, p. 8)

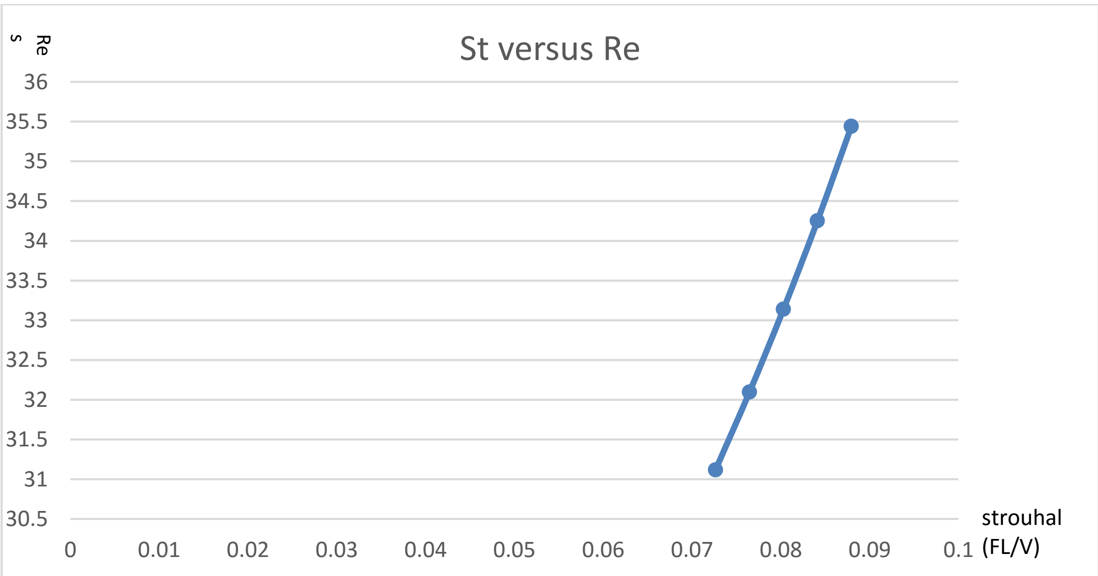


Figure 4. The research's Strouhal number against Reynolds number for cylinder

According to Roshko's figure, our figure of Strouhal number against Reynolds number follows the same trend.

2. Bubble's thickness

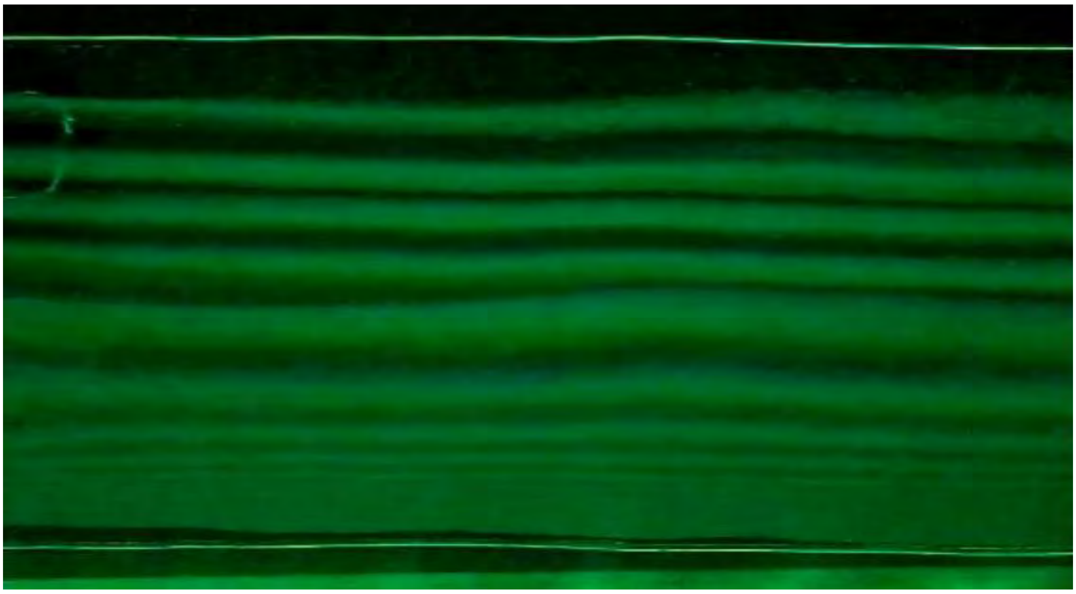


Figure 5. Bubble on green light

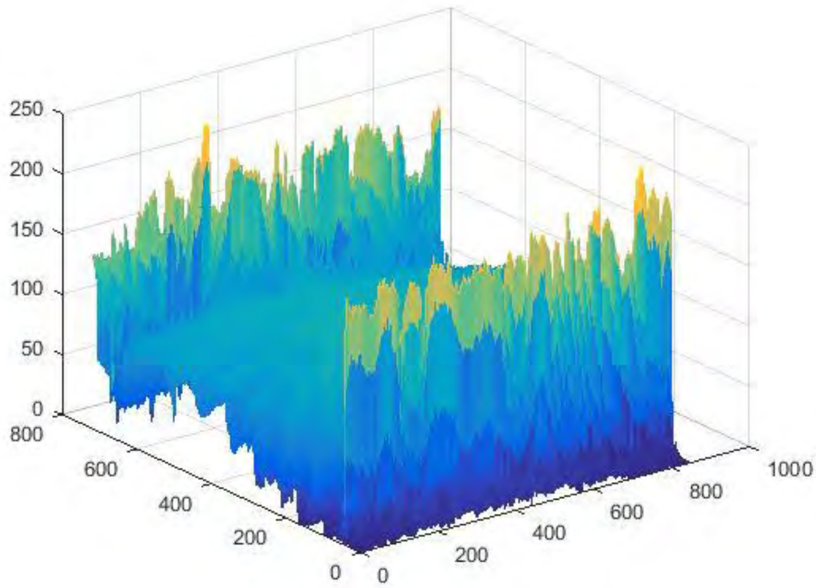


Figure 6. Light intensity in 3D view

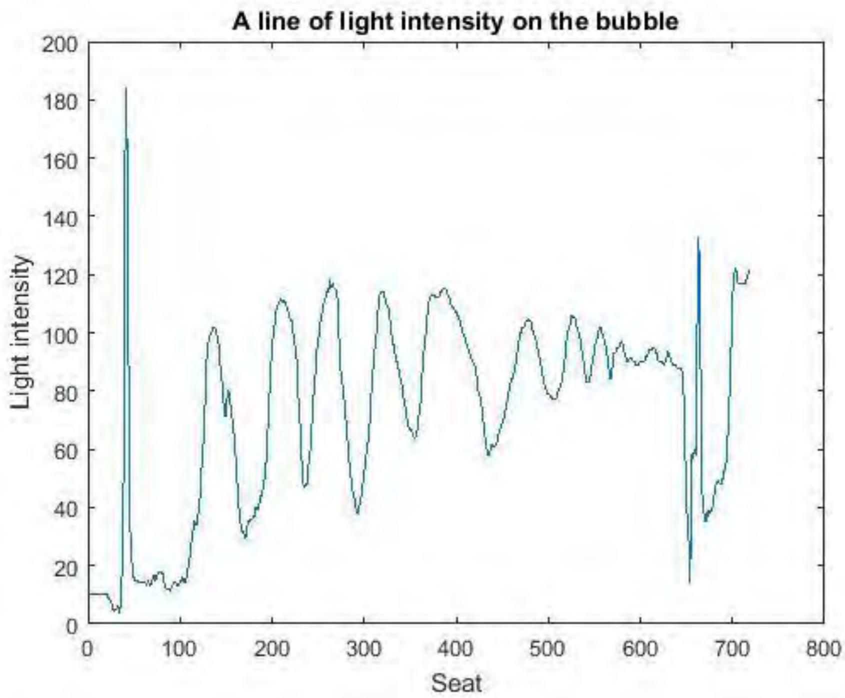


Figure 7. Line of light intensity on bubble

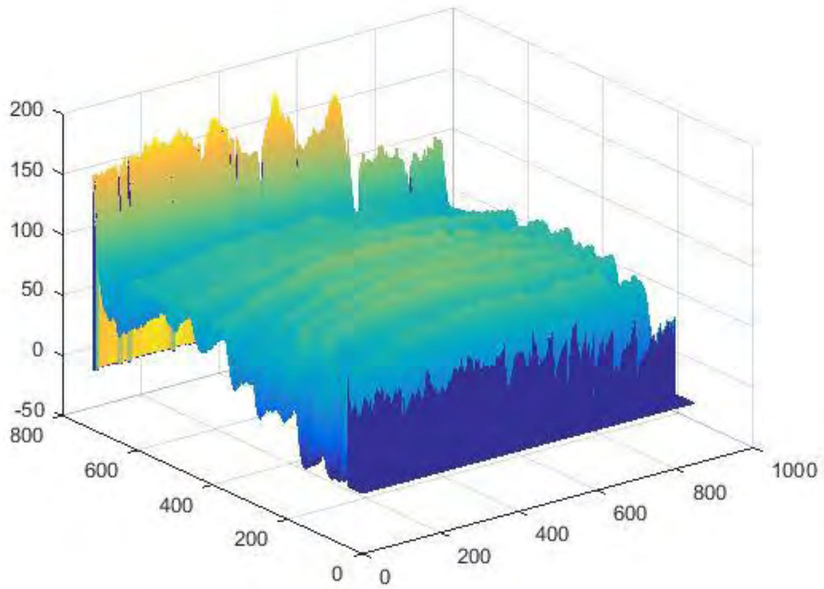


Figure 8. Light intensity in 3D view after smooth

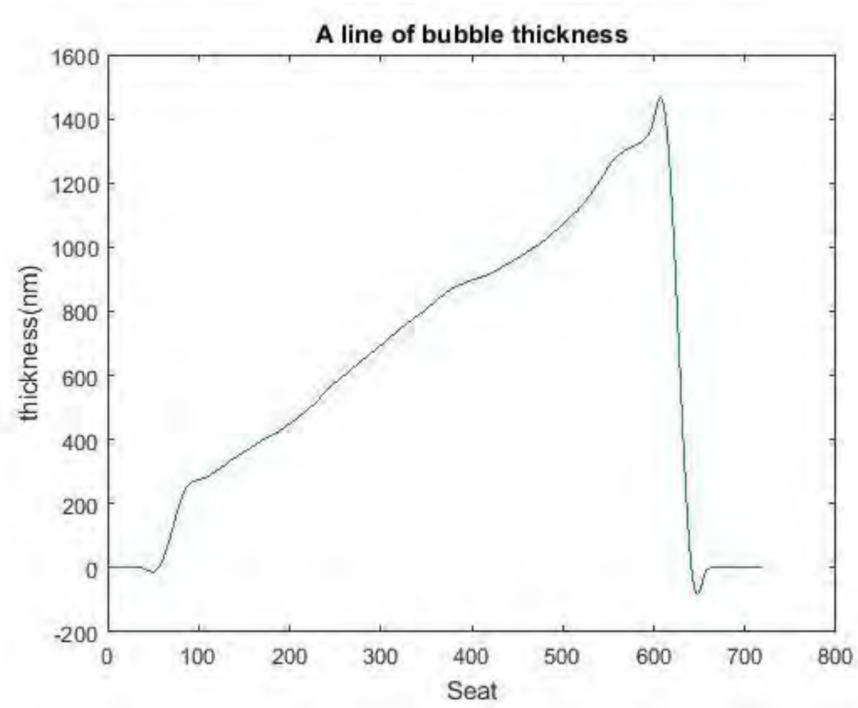


Figure 9. Line of bubble thickness

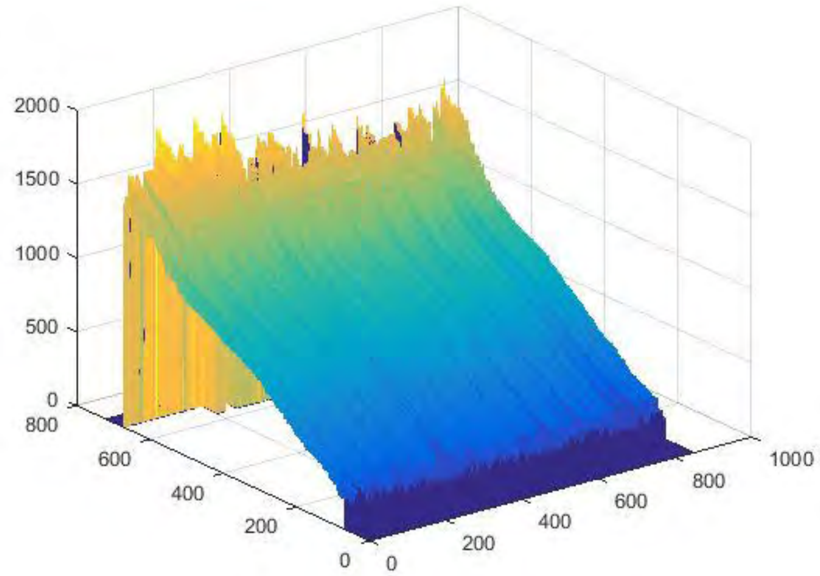


Figure 10. Bubble thickness in 3D view

For more Matlab programing details, please see it at appendix 2.

Gravity will influence the thickness of bubble. That's an obstacle for us to know the real thickness. Therefore, we used the interference formula above to calculate the thickness in several situations. By using Matlab, we input the formula and wait for few seconds before a figure was generated. The figure above clearly shows the thickness of the bubble is thinner on the top and becomes thicker on the bottom. The whole process of calculating an image of 1920*1080 pixel by pixel only took five seconds.

3. Thickness and Reynolds number

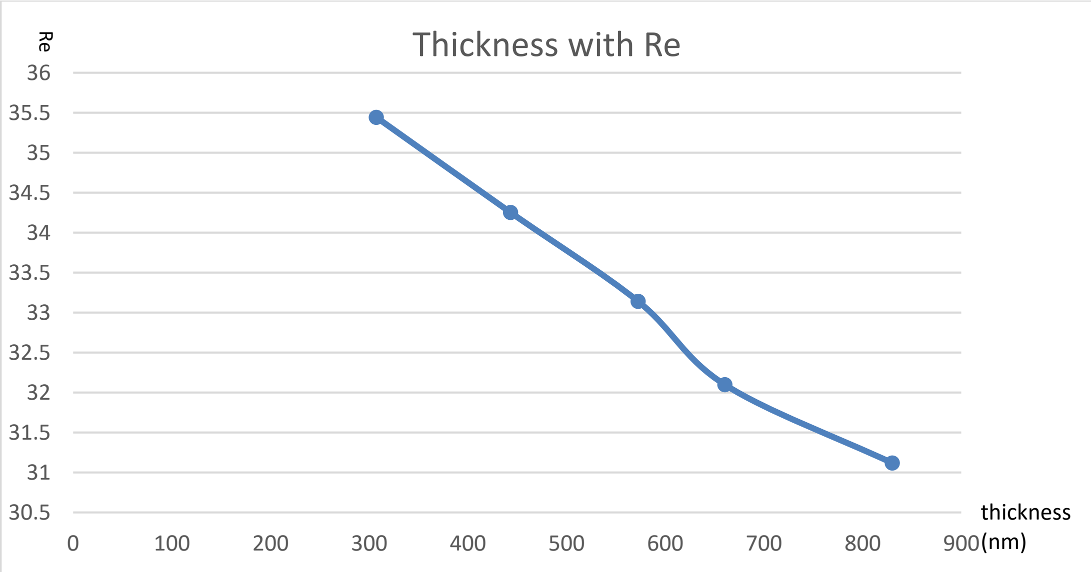


Figure 11. Thickness against Reynolds number

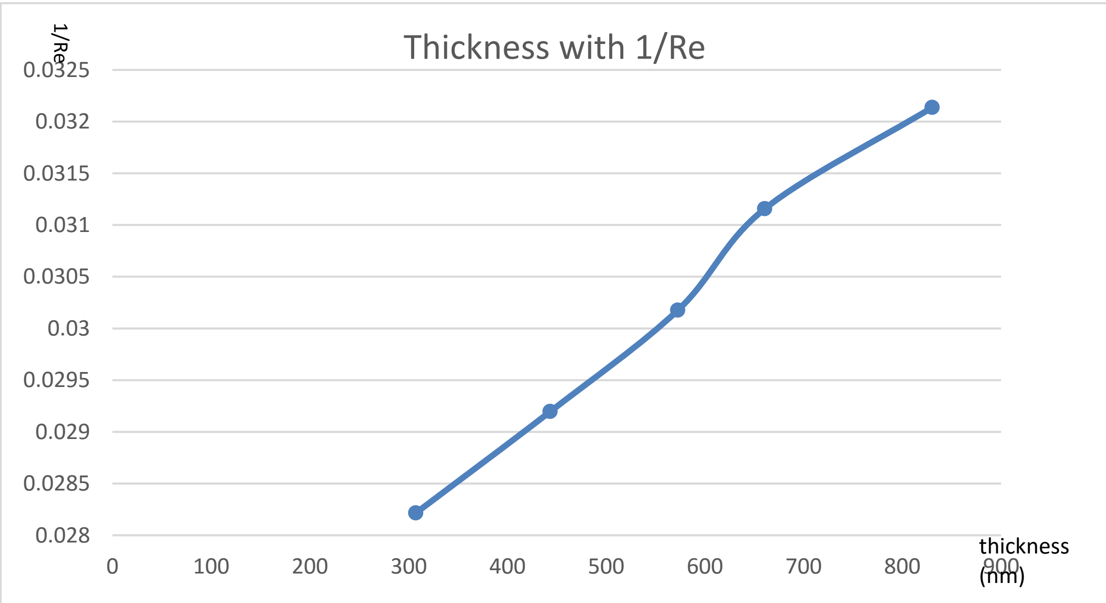


Figure 12. Thickness against reciprocal of Reynolds number

Base on the figure 11 and figure 12, the Reynolds number and the thickness have a positive correlation.

4. Bubble and sound

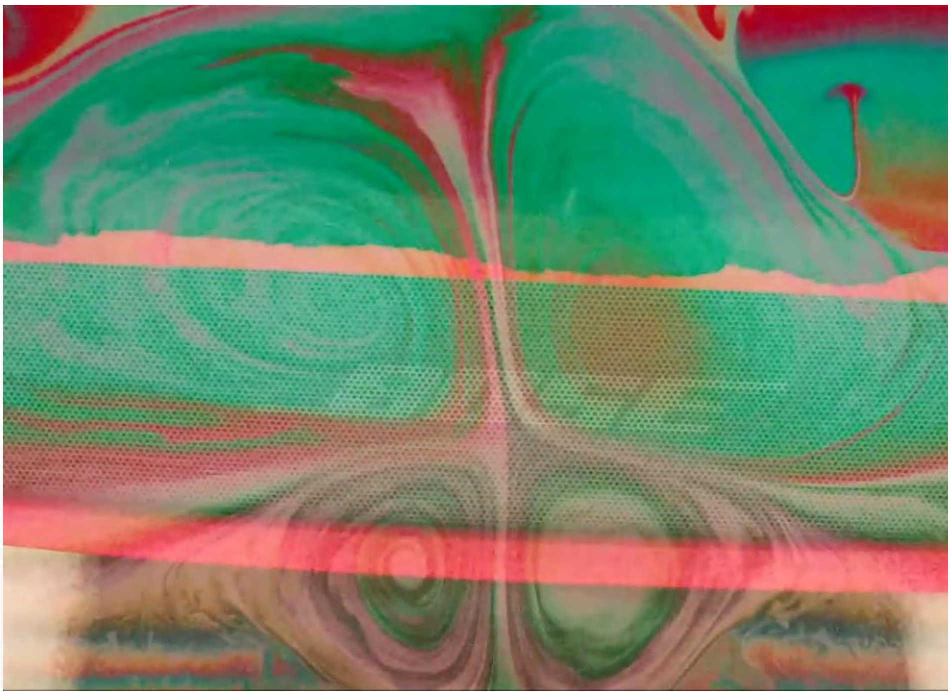


Figure 13. Bubble cause by frequency

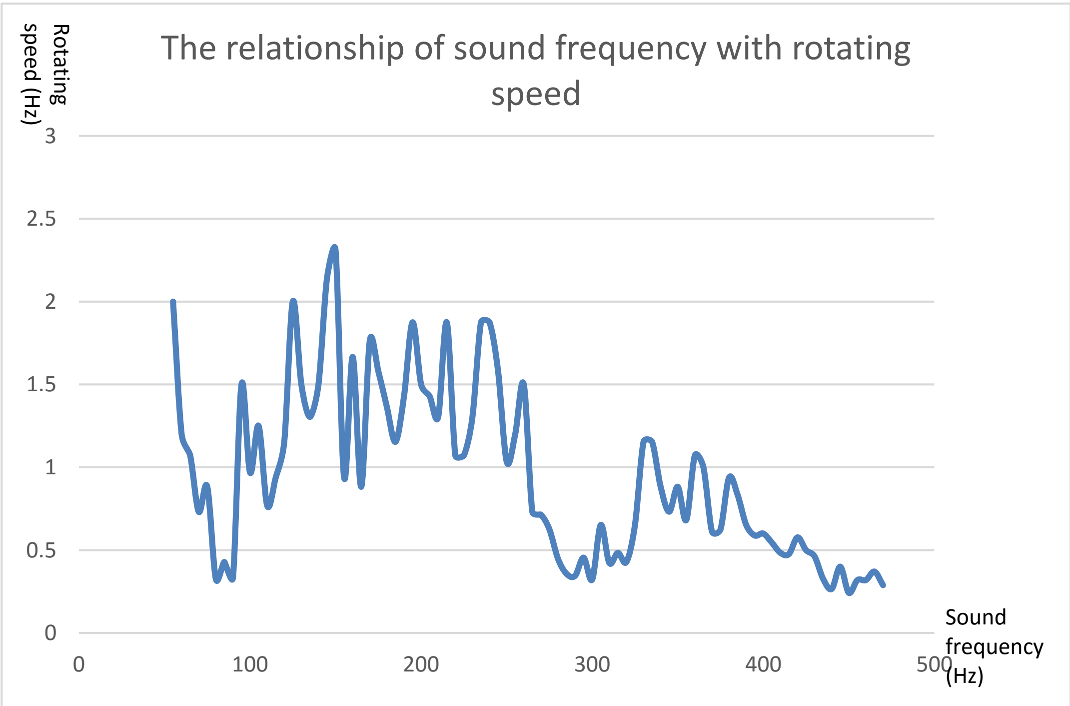


Figure 14. Rotating speed against frequency

The phenomenon of bubble rotating driven by sound wave in a particular frequency range had not been mentioned before. When the frequency goes higher, the rotating speed becomes bigger or smaller. But overall speaking, the rotating speed is modulated by a decreasing envelop.

5. Mixing

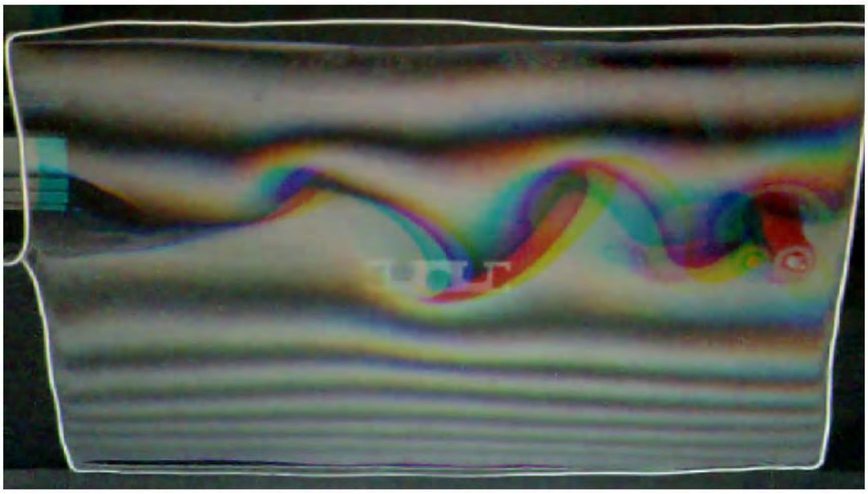


Figure 15. Mix different time in one in positive

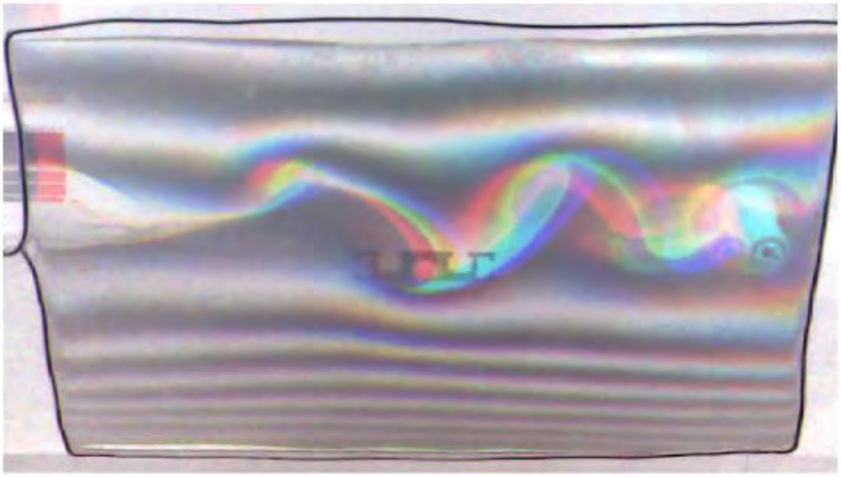


Figure 16. Mix different time in one in negative

By mixing the picture in different time, we can clearly see the trend of Karman vortex street from time to time.

6. Attack angle and lift force

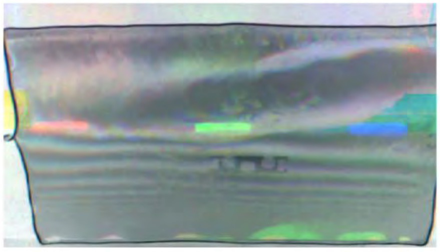


Figure 17. Wing in 0°

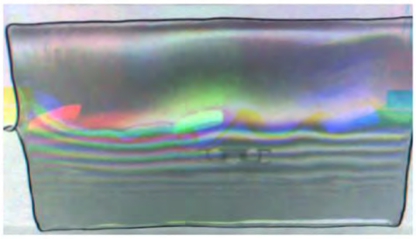


Figure 18. Wing in 15°

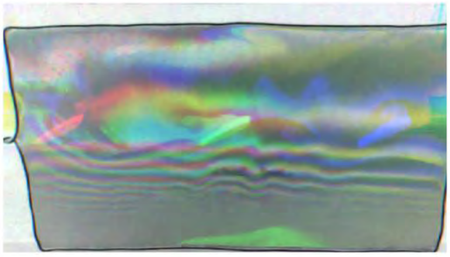


Figure 19. Wing in 30°

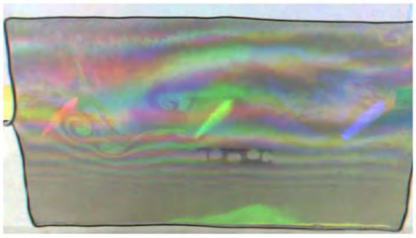


Figure 20. Wing in 45°

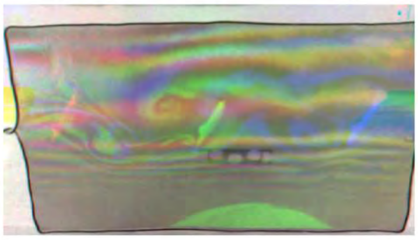


Figure 21. Wing in 60°

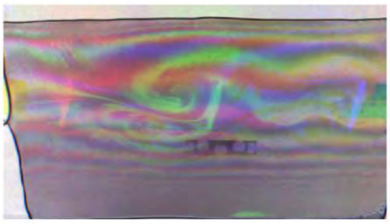


Figure 22. Wing in 75°

For more Matlab programing details, please see it at appendix 3.

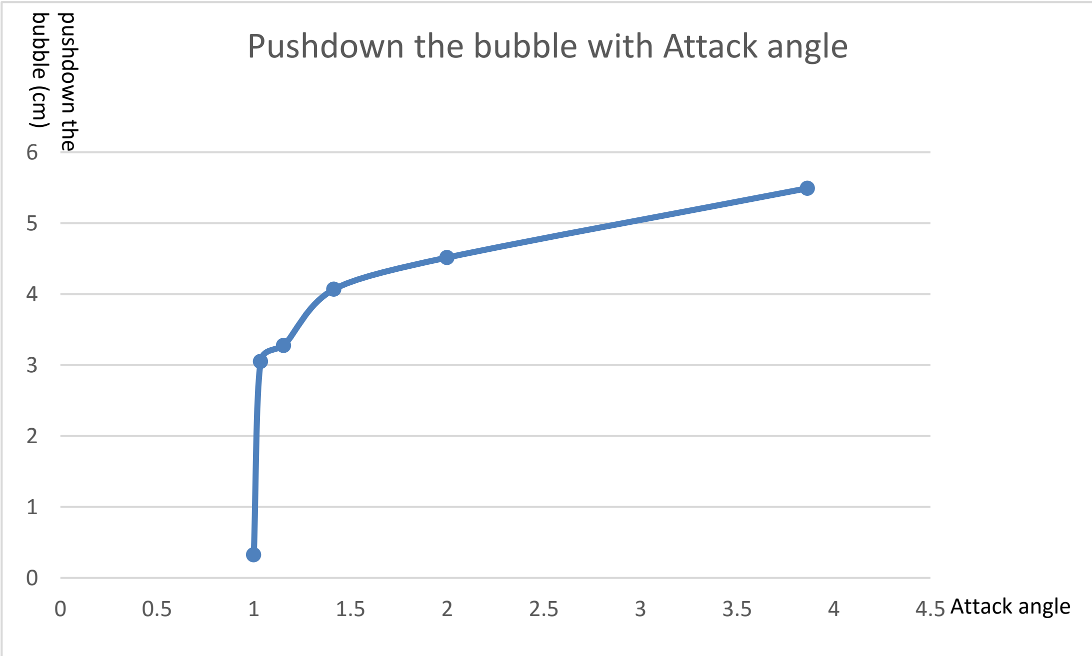


Figure 23. Pushdown the bubble against attack angle

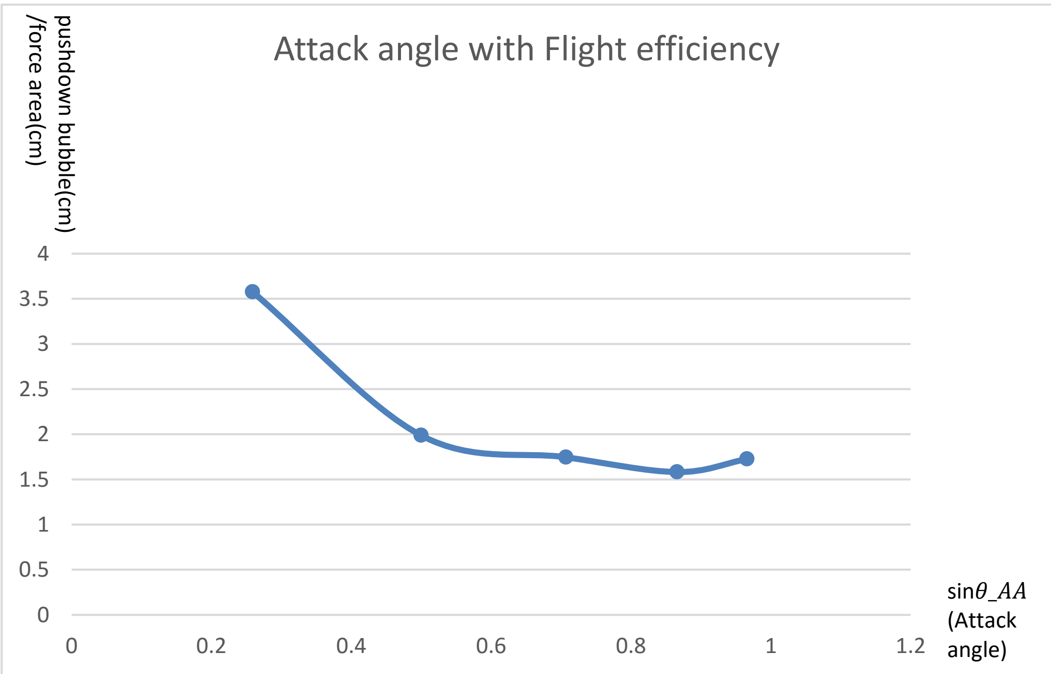


Figure 24. Flight efficiency andattack angle

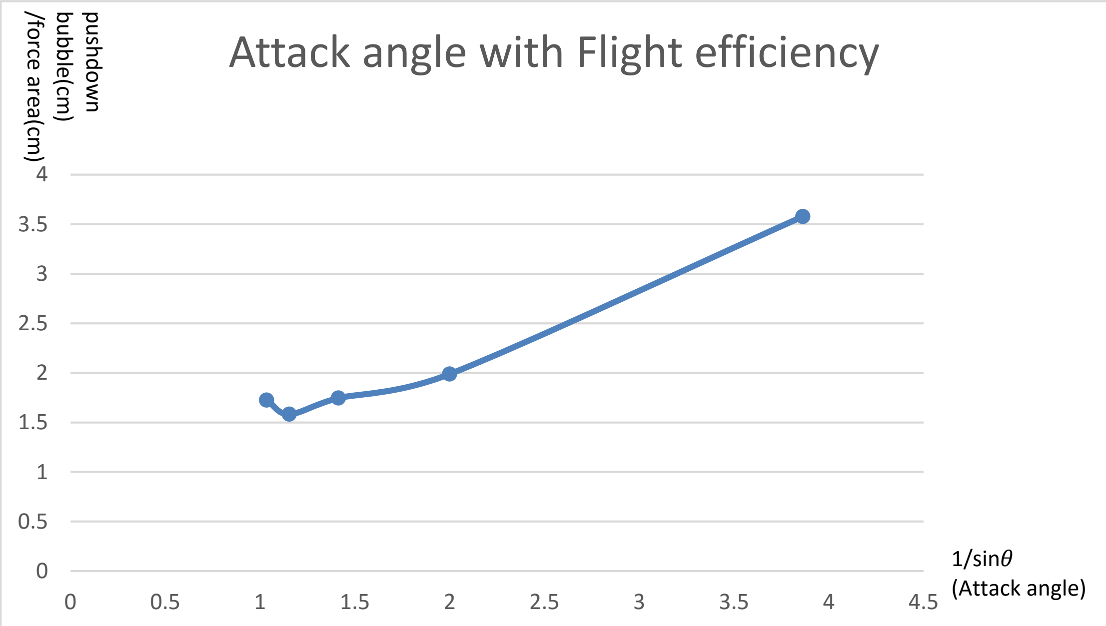


Figure 25. Flight efficiency andreciprocal of attack angle

According to the data above, the wing in 15 degrees has the best lifting force in three speed.

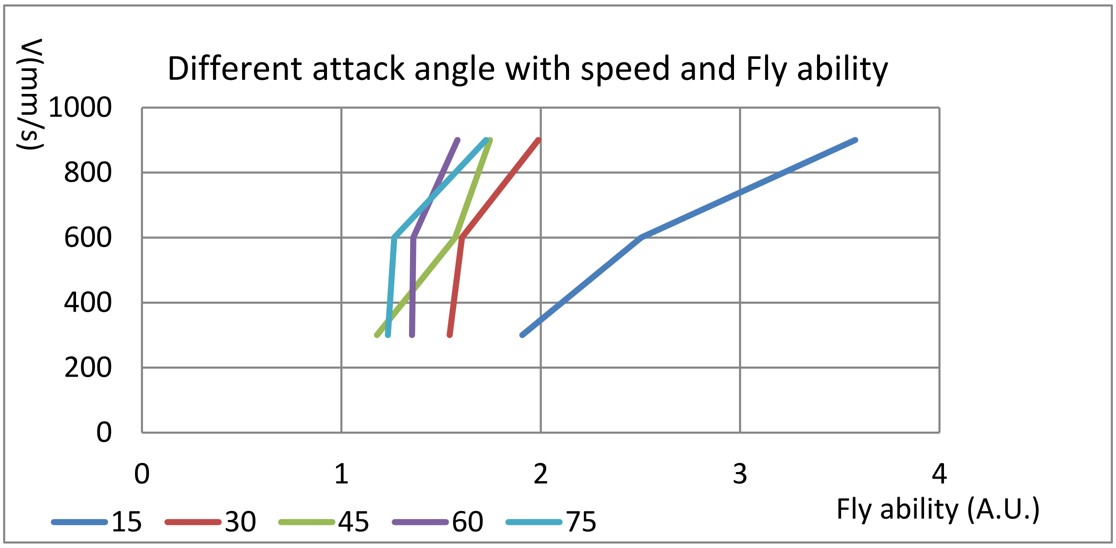


Figure 26. Attack angle (speed) and flying ability

As you can see, 15 degrees has the best flying ability. Flying ability is the pushdown force divide force area.

Discussion

1. A simple system to observe

Our bubble device system can be used to observe the phenomenon similar to those observed in wind tunnel system or PIV system. However, the dimension of flow in our system is more similar to the PIV system than the wind tunnel system.

2. The influence of temperature

The system failed often in early November of 2015. We identified significant increase in the viscosity was the problem, which was due to the temperature drop. We built a shelter to house our device with a heater. In the future, we will add a temperature control unit to study the temperature effect.

Conclusion

1. A device was constructed by us which could suitably observe bubble film, and it could control temperature and stability of airflow.
2. We designed Matlab programs that could calculate the bubble thickness routinely and efficiently by ourselves. The Picture-RGB-Superimposing algorithm could visualize the bubble flow.
3. The Strouhal number of the bubble data in this study fell in the valid range. Therefore, we could use an empirical formula to obtain the Reynolds number.
4. We found the inverse of Reynolds number was positively correlated with the thickness of bubble.
5. We could not observe a simple relationship between the bubble rotating speed and the sound frequency.
6. The fifteen-degree attack angle gave the best flying ability.

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11.**賴德彰**(2013) .以數值模擬探討低雷諾數圓柱流場尾流振盪之抑制
From: http://handle.ncl.edu.tw/11296/ndltd/25950598087518484006
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Appendix

1. Bubble film video

https://www.youtube.com/watch?v=FKWhpN9JGPU

2. Matlab program (thickness calculating)

Program (multi picture)

This program is to drive the single picture program calculate multi picture.

```
%一次計算多張照片 須配合function(OneBubbleThicknessFrame)使用
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%更改區
VideoName=x600;
FirstPictureTime=5;
TimeDelta=15;
NumberOfFrame=1;
XrangeStart=151;
XrangeEnd=1000;
YrangeStart=1;
YrangeEnd=720;
LightColor=2;
angle=pi/4;
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Allthickness=zeros(YrangeEnd-YrangeStart+1,XrangeEnd-XrangeStart+1,NumberOfFrame);
AllLightIntensity=zeros(YrangeEnd-YrangeStart+1,XrangeEnd-XrangeStart+1,NumberOfFrame);
Allframe=zeros(YrangeEnd-YrangeStart+1,XrangeEnd-XrangeStart+1,NumberOfFrame);
if(LightColor==1)
    lambda=454.11;
    n=1.711;
end
if(LightColor==2)
    lambda=511.01;
    n=1.733;
end
if(LightColor==3)
    lambda=627.96;
    n=1.755;
end
for Iframe=1:NumberOfFrame
    filename=VideoName(:,:,:,FirstPictureTime+TimeDelta*(Iframe-1));
    Iframe
    OneBubbleThicknessFrame;
    Allthickness(:,:,Iframe)=thickness;
    AllLightIntensity(:,:,Iframe)=smooth1;
    Allframe(:,:,Iframe)=red001d;
end
figure(1)
imshow(VideoName(YrangeStart:YrangeEnd,XrangeStart:XrangeEnd,:,FirstPictureTime))
figure(2)
mesh(Allframe(:,:,1))
figure(3)
mesh(AllLightIntensity(:,:,1))
figure(4)
mesh(Allthickness(:,:,1))
```

Program (single picture)

```
red001d=double(filename(YrangeStart:YrangeEnd,XrangeStart:XrangeEnd,LightColor));
thickness=zeros(YrangeEnd-YrangeStart+1,XrangeEnd-XrangeStart+1);
AL=zeros(YrangeEnd-YrangeStart+1,XrangeEnd-XrangeStart+1);
ALtop=zeros(XrangeEnd-XrangeStart+1,1);
ALbottom=ALtop;
line=1;
red576d=red001d(:,line);
 [Pa,Ca]=findpeaks(red576d);
i=1;
while i <length(Pa)
 if (Pa(i)>100)
     lup=Pa(i);
     luc=Ca(i);
     II=i;
     i=length(Pa);
  end
  i=i+1;
 end
  ALtop(line)=luc;
  AL(luc,line)=255;
  i=length(Pa);
  while i>II
  if (Pa(i)>30)
      lup=Pa(i);
      luc=Ca(i);
      i=1;
  end
  i=i-1;
  end
 ALbottom(line)=luc;
 AL(luc,line)=255;
 while line<=XrangeEnd-XrangeStart
     ytop=ALtop(line)-30;
     if ytop<YrangeStart
         ytop=YrangeStart;
     end
     %bug [illegible]
     ytopend=ALtop(line)+30;
     if ytopend>YrangeEnd
         ytopend=YrangeEnd;
     end
     [x,y]=sort(red001d(ytop:ytopend,line+1));
     ALtop(line+1)=y(ytopend-ytop+1)+ytop;
     AL(ALtop(line+1),line+1)=255;
     ybottom=ALbottom(line)+30;
     if ybottom>YrangeEnd
         ybottom=YrangeEnd;
     end
     [x,y]=sort(red001d((ALbottom(line)-30):ybottom,line+1));
     ALbottom(line+1)=y(31+ybottom-ALbottom(line))+ALbottom(line)-30;
     AL(ALbottom(line+1),line+1)=255;
     line=line+1;
 end
 smooth1=zeros(YrangeEnd-YrangeStart+1,XrangeEnd-XrangeStart+1);
 line=1;
 while line<=XrangeEnd-XrangeStart+1
```

```
    if (ALbottom(line)-ALtop(line))<=0
        ALbottom(line)=ALbottom+30;
    end
    if ALbottom(line)>=YrangeEnd
        ALbottom(line)=YrangeEnd-1;
    end
 smCurve = smooth(red001d(ALtop(line):ALbottom(line),line),0.1,'loess');
 smooth1(ALtop(line):ALbottom(line),line)=smCurve;
aa=1;
[lupX,lucX]=findpeaks(smCurve);
[lupN,lucN]=findpeaks(-smCurve);
lupN=-lupN;
cb1=1;
cb2=1;
```

```
if lucX(cb1)<lucN(cb2)
seat=lucX(cb1);  a1=1;
else
seat=lucN(cb2); a1=-1;
end
thickness0=zeros(YrangeEnd-YrangeStart+1,1);
end1=numel(lucX);
end2=numel(lucN);
end1=lucX(end1);
end2=lucN(end2);
while (seat<end1)&&(seat<end2)
   if(lucX(1)<lucN(1))
    if(cb1==cb2)
    seat=lucX(cb1);
```

```
    else
    seat=lucN(cb2);
    end
   else
    if(cb1==cb2)
    seat=lucN(cb2);
    else
    seat=lucX(cb1);
    end
end
delta=lupX(cb1)-lupN(cb2);
while (seat<lucN(cb2))||(seat<lucX(cb1))
    cc=red001d(seat+ALtop(line),line)-lupN(cb2);
    I0=cc/delta;
```

```
        if I0>1
            I0=1;
        end
        if I0<0
            I0=0;
        end
    I0=(I0)^0.5;
    phase=asin(I0);
    phase=aa*pi-a1*phase;
    d=((phase*lambda)/(2*n*pi));
    thickness0(seat+ALtop(line),1)=d;
    seat=seat+1;
end
if(a1==1)
```

```
            I0=0;
        end
    I0=(I0)^0.5;
    phase=asin(I0);
    phase=aa*pi-a1*phase;
    d=((phase*lambda)/(2*n*pi));
    thickness0(seat+ALtop(line),1)=d;
    seat=seat+1;
end
if(a1==1)
cb1=cb1+1;
else
cb2=cb2+1;
end
```

```
aa=aa+((1-a1)/2);
a1=-a1;
end
%thickness0=smooth(thickness0,0.05,'loess');
thickness(:,line)=thickness0;
line=line+1;
end
k1=sin(sin(pi/4)/n)^2;
k1=1-k1;
k1=(k1)^(1/2);
thickness= k1*thickness;
thickness=real(thickness);
%thickness=smooth(thickness,0.1,'loess');
```

3. Matlab program (mixing picture)

```
 xspeed=o1200900;    %檔名
startframe=138;      %起始照片
time=36;            %間隔畫面
color=2;            %顏色
Hz=240;             %每秒畫面數
frametime=1;        %儲存畫面編號
frameend=1;

x=xspeed(:,:,:,frametime:frameend);    %定義x
y=xspeed(:,:,:,frametime:frameend);    %定義y

for frametime=1:frameend

x(:,:,1,frametime)=xspeed(:,:,color,startframe);
x(:,:,2,frametime)=xspeed(:,:,color,startframe+time);
x(:,:,3,frametime)=xspeed(:,:,color,startframe+time+time);

y(:,:,1,frametime)=255-xspeed(:,:,color,startframe);
y(:,:,2,frametime)=255-xspeed(:,:,color,startframe+time);
y(:,:,3,frametime)=255-xspeed(:,:,color,startframe+time+time);

startframe=startframe+time;
%frametime=frametime+1;

end

%%output
z=y(250:280,450:600,:,:);
```

```
figure(1)
imshow(x(:,:,:,1))
figure(2)
imshow(y(:,:,:,1))
figure(3)
imshow(z(:,:,:,1))
```

4.

If you know to know more about the experiment, here is a film.

https://youtu.be/UHRfMOM5o6E

【評語】160006

本作品探究有趣的皂膜渦流現象，雖然相較於以往作品或文獻的科學性、豐富性與完整性仍有增進空間。作者們致力建構了皂膜製造裝置與光干涉實驗裝置，並且對於皂膜渦流進行了初步的研究，作者們的探究與實作精神可佳。