Using A Frisbee To Understand How Ice Creates Turbulence On An Airplane

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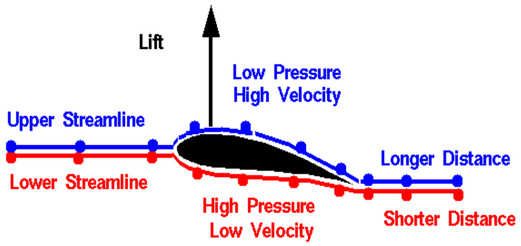
Introduction and Background

Is there a certain amount of ice that can go on a Boeing 737 and still not cause any turbulence? I know from the online sources *Slack Davis*, *Explain That Stuff*, *and* *Scientific American* that turbulence can be caused by disruptions in the airflow as an airplane flies. I also learned from www.scienceiq.com and www.nasa.gov that airplanes fly because of the force created by the jet engines, which is called thrust. Thrust is the force which moves the airplane through the air to overcome the drag and the weight of the airplane. Furthermore, the wings are designed to make the airplane fly. The wings enable "lift", which actually makes the airplane go up. The wings are shaped such that the air goes faster on the top, and slower on the bottom. That makes higher pressure on the bottom and lower pressure on the top, which results in lift. Interestingly, this is the same concept in a ***frisbee***. That is why I am using a frisbee as a model system for understanding how ice and freezing rain cause turbulence on an airplane. Based on this information, the purpose of this project is to predict how much ice can be on the wings of a Boeing 737 and still not cause turbulence.

The Bernoulli Effect On An Airplane Wing



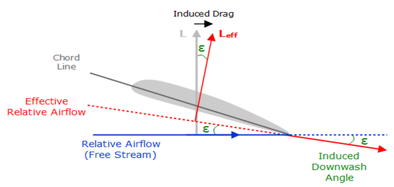
"Longer Path" or "Equal Transit" Theory

Hypothesis

We know that ice on an airplane wing is bad. Grounds people de-ice the plane so there is no ice on the airplane wing. In the past, there have been crashes because of ice on an airplane. In 1980 there was a crash because there was still ice on the airplane which caused turbulence which led to a crash. Now they completely de-ice the airplane so there is no ice on the plane at all. But can there still be some amount of ice that can go on the airplane and there won't be any turbulence?

My hypothesis is that given these conditions (4%, 11%, 20% of the mass of the frisbee) I believe that 4% of ice on the frisbee won't lead to any turbulence because the amount of ice is not large enough.

This Shows A Diagram Of A Frisbee's Airflow And Flight Path



Materials

Frisbee	Paper
Ice	Pencil
Speedometer	Python Book
Camera	Protractor
Computer	Water
Glass	Open Field
Balance	Safety Goggles
Pan	3D printed ring
Freezer	Eyedropper

Procedure

- Gather all the materials and go down to the basement
- Take a glass and fill it with an appropriate amount for that specific trial
- For trial 1, put 2.81 g of water.
- After measuring the amount of water for a specific trial, put a 3D printed ring in the center of the frisbee
- Use an eyedropper and put the water in the 3D printed ring
- Spread the water around throughout the inside of the ring
- Put the frisbee with the 3D printed ring and the water in the freezer
- Slowly take the 3D printed ring off the frisbee before you freeze it
- The water stays where it is because of surface tension which is a force that holds liquids in the center
- While you are waiting for the water to freeze, set up three cameras and a place where you would stand to throw the frisbee
- After the water has frozen on the frisbee, go downstairs to the designated spot where you marked it and throw the frisbee
- You control the throw by having 1 camera measure the angle of release (0 degrees) and another camera measuring the speed of the release (16 to 24 kph)
- There is 1 other camera that sees the angle of turbulence
- The throwing process takes about 30 seconds
- Do this 9 times with different amounts of water on the frisbee

Independent Variable: The amount of water that is being placed on the frisbee by the % of the frisbee's mass (4%, 11% and 20%)

Dependent Variable: The degree of turbulence that the frisbee makes

Constant Variables: Frisbee, Water, Throw Speed, Angle of the Throw, Location, The Wind Speed, Location of the ice on the frisbee

Control Variable: No ice on the frisbee

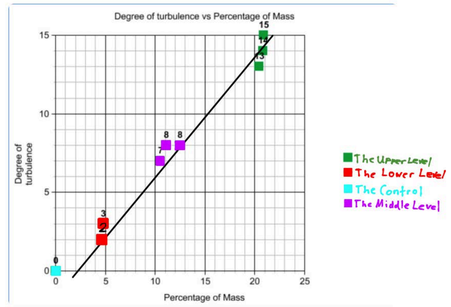
Data, Figures and Graphs

The table below shows three data points (amount of ice: 4%, 11%, and 20% of the weight of the frisbee) measured with three trials for each given point. The graph below shows all the trials plotted and then a best fit curve drawn through the average of the three trials.

Lower	Trial 1	Trial 2	Trial 3
	4.68%	4.8%	4.5%
Degree of Turbulence	2 degrees	3 degrees	2 degrees

Middle	Trial 1	Trial 2	Trial 3
	12.08%	11.34%	10.51%
Degree of Turbulence	8 degrees	8 degrees	7 degrees

Upper	Trial 1	Trial 2	Trial 3
	20.58%	20.05%	19.89%
Degree of Turbulence	15 degrees	14 degrees	13 degrees



All of this was on a frisbee but the purpose of this is to see how much ice can go on an ***airplane*** and there still won't be any turbulence.

Code: This code is a calculator so if someone inputs what is the mass of an airplane wing then it will output how much ice can go on that airplane's wings and still there will not be any turbulence caused by ice

```
print("Ice causes turbulence on an airplane:")
print("A Boeing 737 wings 10,128 kilograms:")
Print("The amount of ice that can go on a Boeing 737 is 236 kilograms of ice and there won't be any turbulence caused by ice:")
Print("There is a certain amount of ice that can be on any airplane and the airplane won't have any turbulence caused by ice:")
x = int((input("What is the mass of your airplane wings:")))
print(2.34 / 100 * x)
Print("This is the mass of ice that can go on your airplane wings and there still won't be any turbulence caused by ice:")
```

Results for the code: The code outputs the amount of ice when given the mass of Boeing 737 wings.

Ice causes turbulence on an airplane:
A Boeing 737 wings 10,128 kilograms:
The amount of ice that can go on a Boeing 737 is 236 kilograms of ice and there won't be any turbulence caused by ice:
There is a certain amount of ice that can be on any airplane and the airplane won't have any turbulence caused by ice:
What is the mass of your airplane wings:***10128*** **(**mass of the airplane wing)
236.99 **(**amount of ice)
This is the mass of ice that can go on your airplane wings and there still won't be any turbulence caused by ice
Ice causes turbulence on an airplane:
A Boeing 737 wings 10,128 kilograms:
The amount of ice that can go on a Boeing 737 is 236 kilograms of ice and there won't be any turbulence caused by ice:
There is a certain amount of ice that can be on any airplane and the airplane won't have any turbulence caused by ice:
How much does the wings of of your airplane:***43090***(mass of the airplane wing)
1008.3059(amount of ice)
This is the mass of ice that can go on your airplane wings and there still won't be any turbulence caused by ice

Results

In my hypothesis I said that 4% of ice can go on the frisbee and there still won't be any turbulence. The main outcome of this experiment was that there can be 2.34% of ice on a frisbee or a Boeing 737 wing. A point to notice is that my data is correct because when I put a line through the graph it crosses the x axis. If it intersected the y-axis then mathematically it wouldn't make sense. The amount of ice that will be on The Boeing 737's wing is 236 kilograms. After the Boeing 737 has the ice, there still won't be any turbulence caused by ice. The amount of ice that can be on the frisbee and the frisbee won't have any turbulence is 1.04g.

Conclusions

The purpose of this project was to predict how much ice can be on the wings of a Boeing 737 and still not cause turbulence.

My hypothesis was that given these conditions (4%, 11%, 20% of the weight of the frisbee or the weight of the airplane wings) I believe that 4% of ice on the frisbee won't have any turbulence caused by ice.

My hypothesis was partially supported. My data and graph showed that when there was 2.34% of ice on the frisbee, there was no turbulence caused by ice. I think this happened because as the frisbee was in mid flight, it was able to regain stability because the amount of ice was not large enough to cause severe turbulence. A source of error was that the thrust at the start of the flight caused turbulence just like when a plane takes off there is some turbulence and then it flattens out. There was turbulence in the second half of the flight. I had to record the turbulence in the second half of the flight. The main outcome was that there can be 2.34% of ice on any plane wing and there won't be any turbulence caused by ice.

Further Investigation

To further investigate this topic I will use a wind tunnel to get more accurate results. By using a wind tunnel, I can more accurately control the speed of the frisbee and the angle. The wind tunnel will simulate flight of the frisbee because air molecules are coming at it. The wind tunnel is basically the reverse of throwing the frisbee in the air. Also while I am using the wind tunnel I will be able to see the degree of turbulence.

Resources

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