The science of model flying: Reynolds Number (Re)

When a fluid (liquid or gas) flows around or through something it can flow in one of two ways. It can flow in smooth layers, called laminar flow, or in a chaotic way called turbulent. George Stokes studied fluid flow in the 1840’s and gave his name to a unit of viscosity. He also studied terminal velocity. In the 1880’s Osborne Reynolds studied the flow of water through tubes and gave his name to the number that predicts when a fluid will change from laminar to turbulent. It is just a number, not a measurable unit, but it has been used ever since including for open surfaces such as wings as well as for pipes. It is fundamental to how aircraft fly, or at least fly well.

It is a very strange number with a huge range. As you will see, only a small range of the lower values are important to us as model flyers. I have never really understood it, so when I found myself with some time on my hands decided to use one of my acquired skills. My degree in the mists of the past was a traditional one. As well as teaching job specific skills, it also trained us in the universal skills of research and synthesis, the latter being the ability to analyse complementary or contrary ideas and create something from them. I applied that to the Reynolds Number.

It seems that in a fluid the particles in a moving mass are subject to two types of influence. The viscous forces tend to keep them in an orderly pattern. The momentum that their masses (inertia) have, tends to disrupt that order. Reynolds Number (Re) is a measure of how likely disorder is.

In its simplest form:

Re = inertial force / viscous force

Re can vary between 0 and very large values in the millions. n our model’s wings turbulence starts to occur at around Re = 2000. A small aircraft like a Cessna will be from 1 000 000 and a large passenger jet will be ten times more. Despite that full-size aircraft will have mostly turbulent airflow. Our models are around 30 000 to 400 000 with small slow models being the lowest. To see more and to use a calculator look at https://rcplanes.online/design.htm

The wings on our models turn out to be in a tricky zone for Re. Its value is neither low enough to be completely smooth (laminar) nor high enough to be mostly turbulent. Gentle flow through pipes will be laminar. Flow over the wings of full size aircraft will be mostly turbulent. On our wings there will be a critical point on the upper surface where the flow changes from laminar to turbulent, where the Re is about 2000.

Fortunately for us, aircraft designers use scale wind tunnel models of full size aircraft so they have done a lot of work on the so-called ‘scale effect’ that informs us too.

At the leading edge of a wing Re will be at or near zero. As you move further back along the chord Re increases with distance. When it approaches 2000, commonly at around half chord and called the transition point, the flow becomes turbulent.

I like analogies. They can clarify complicated things. After all when we explain something in words or maths symbols we create analogies. The words and symbols are not the actual thing but represent it in ways that our hominid brains can cope with. And of course you can’t find an analogy if you don’t understand the phenomenon.

The nearest thing to an air particle is a sheep. It is brainless and follows the herd but responds rapidly to anything that upsets it. I upset my sheep owning friends when I say that, but no-one has ever convinced me that his or her sheep are clever. Indeed as Monty Python showed, ‘There is nothing more dangerous than a clever sheep.’

So to the analogy. Let’s imagine a flock of sheep moving slowly along a lane. They walk in orderly rows, controlled by their herd instinct. Through a gap in the hedge a dog starts barking at them. Instantly they panic and start moving in all directions, though they still drift along, pushed from behind by the remaining sheep.

The Re equation now becomes: Re = panic / herd instinct
It’s a shame that Joshua Reynolds didn’t paint rural pictures or I could have named it after him. I suspect that the ovine Re (Reo) would be closer to 1 than 2 000.

I did try to find a suitable aerial picture of sheep but I fell asleep … zzz. However I did love this picture from farmonline.com.au. Notice the laminar flow up the ramp with possibly some panic setting in near the top causing some turbulence.

Hope they all have their their baa-ding passes. Who would want to clean out that hold? I also hope that urine seepage doesn’t corrode the control linkages as has happened in other aircraft carrying animals.

Turbulators make our models more like full size aircraft with the whole wing being turbulent and so more predictable. It made sense therefore for it to be used on free flight gliders, which are trimmed close to stall, or were when I flew them.

As you would expect Martin Simons covers turbulators and Re in his excellent book Model Aircraft Aerodynamics, which is well worth a read.

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