Introduction to Aircraft Design
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Lecture - 80
Effect of Gust

Let us look at the effect of gusts on the V-N diagram.

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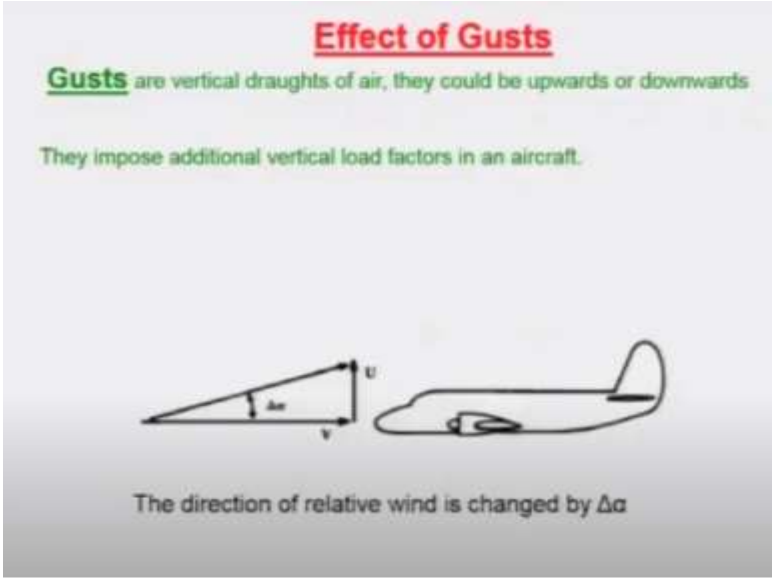

What is meant by a gust? A gust is a vertical draft of air and it depends whether they are vertically upwards or vertically downwards. And because they are acting either vertically up or down, when they add to the free stream velocity of the aircraft, they give an effective angle of attack and thus they impose an additional vertical load on the aircraft.

So you can see that if there is an aircraft flying at a velocity V and a vertical gust of U acts on it, then effectively it will create a small increase in the angle of attack delta alpha. And because of that, the relative wind direction is changed by delta alpha.

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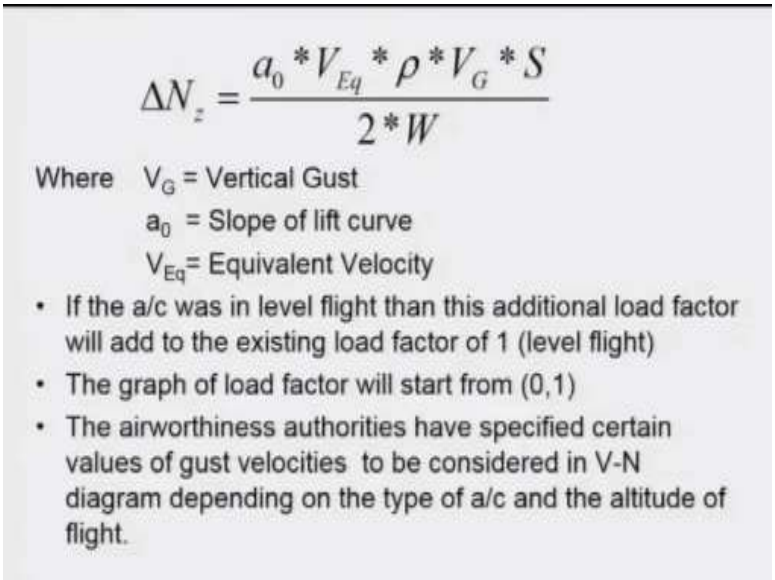

So there will be additional load factor delta N_z which will be a function of the speed, density, gust velocity. So the gust velocity U in the previous slide is replaced by V_G in this particular slide. So if the aircraft was in level flight, the load factor was 1. So this delta N_z will act as above the 1.

And hence, the graph for the load factor due to vertical gust will always start from 0, 1 because it would correspond to level flight at vertical load factor equal to 1. Now certain values of gust velocities have to be considered based on the historical information available with the airworthiness agencies.

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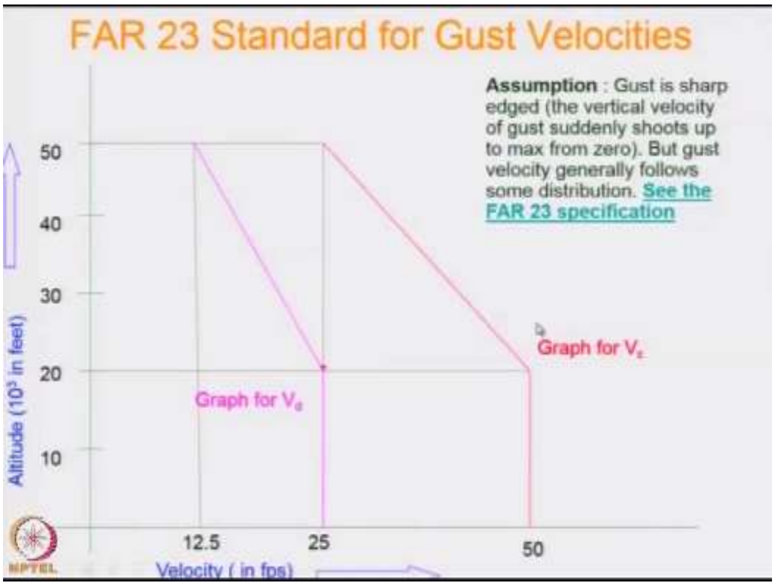

And these values depend upon the altitude at which you are flying. For example, if we look at the FAR 23 standard for gust velocities, we see that for altitude up to around

20,000 feet the value of gust velocity acting on the design diving speed is expected to be 25 feet per second. But about 20,000 feet at higher altitudes the weather disturbances are less. So the gust velocity to be considered is linearly reduced.

And at the height of 50,000 feet or above it is assumed that there will be no gust velocities acting at all, there will be no gust present. But when you are flying the aircraft at the cruising speed V_c you are expected to encounter a larger value of gust velocity the double of the previous values. Where it was 25 earlier at up to 20000 feet it is supposed to be 50 feet per second.

And again there is a linear reduction to 25 feet per second 25 feet per second when you reach a height of 50,000 feet, okay. Now in this particular discussion, we are assuming that the gust velocity is sharp. That means, the gust velocity suddenly reaches a value of 25 feet per second from zero. But that is not true.

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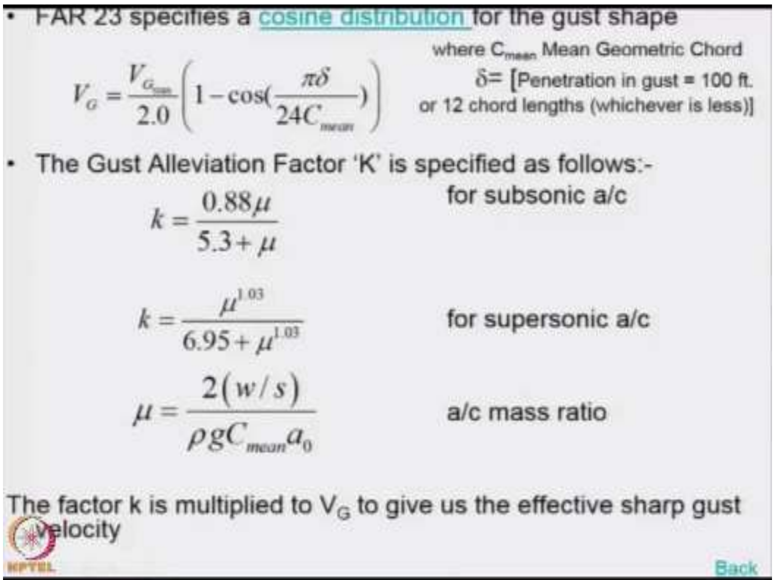

Actually, the gusts are actually going to increase very slowly. So to take care of that, the airworthiness regulations normally describe or prescribe a distribution that has to be considered for the gusts.

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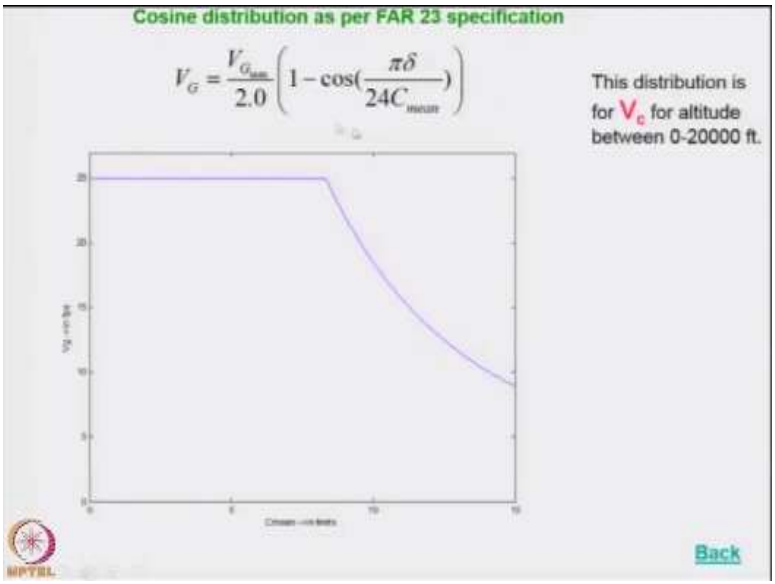

So for example, there is a formula for a cosine distribution. So for velocities, cruise velocity between 0 to 20,000 feet, this particular formula is to be used to look at the variation of the gust speed. So there is something called as a gust alleviation factor. That gust alleviation factor k takes care of the fact that the gusts are not are usually not sharp and they will be increasing slowly from zero value to the value.

So this factor k is multiplied by the gust velocity to achieve the effective sharp gust velocity. And there is a separate formula for subsonic flight and a different formula for supersonic flight.

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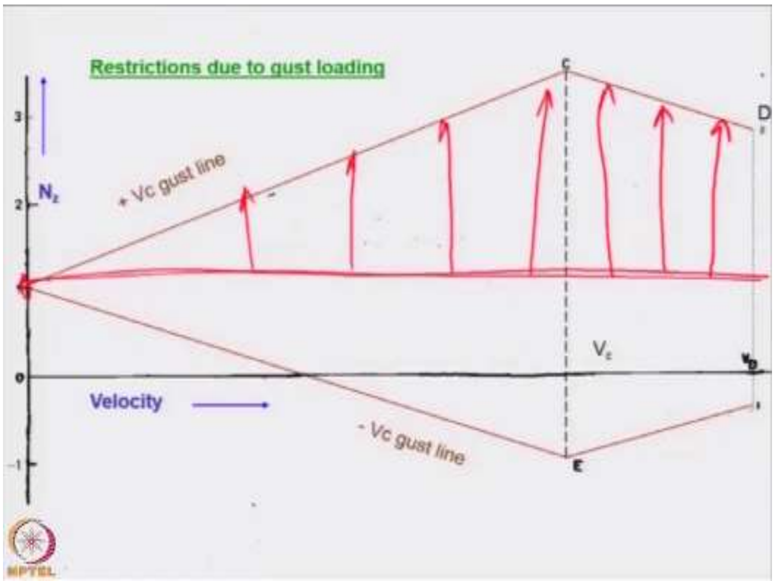

So let us see what happens to the V-N diagram. This is the restriction due to the gust loading. Notice that they are starting from the point 1, 0 because the aircraft is supposed to be in level flight. And in level flight at various velocities, you know due to gust, additional load factors are created. We also remember that at speeds beyond V_c, the numerical value of the gust velocity is lower.

So therefore, you can see that the load factors introduced also are lower. So basically what it means is that if the aircraft is in level flight at any point along this line at various speeds in level flight, then the lines indicate both what kind of additional load factor will be created.

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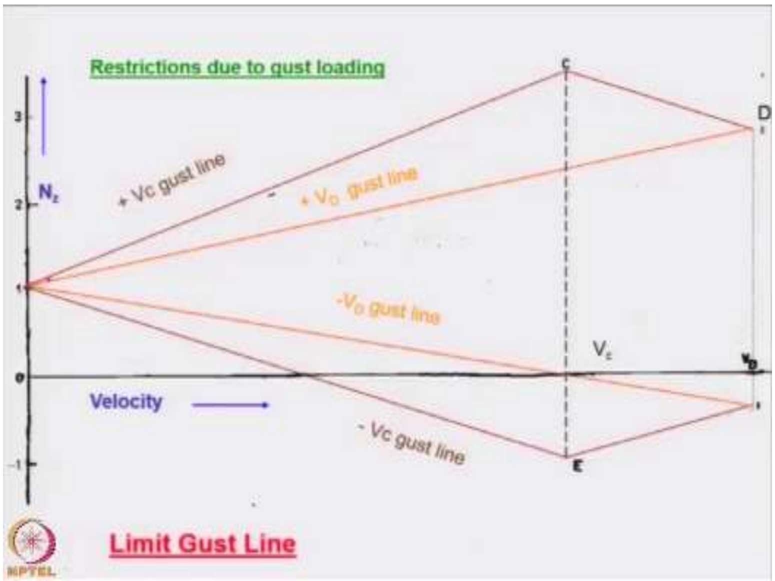

It can be observed that the highest value of the delta N_z happens at V_c. And there is a symmetricity here. The same kind of velocity is expected to be acting also in a vertical downward gust. So at design diving speed, the numerical value of the gust velocity is lower and hence the lines are inside the lines because of the gust due to the gusts acting at the cruise speed. So this is the limit gust line.

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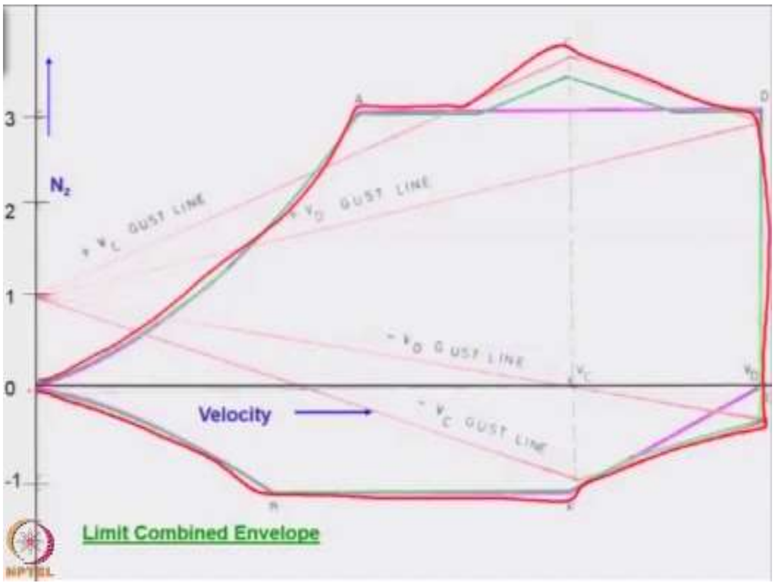

Now what you do is, this is the limit maneuver envelope which was obtained earlier by specifying the limits on the upper and the lower maximum values, the design diving speed. This is the upper and the lower value. This is a cut provided as I mentioned. And this corresponds to the $C_{L_{max}}$ both positive and negative. So what you are getting here is basically the limit envelope in which the aircraft can be maneuver.

On this particular graph, we have to superimpose the loading that can be created because of the additional load factor due to the gusts. So when you superimpose we notice that there are certain areas which are beyond the limit maneuver envelope. So in other words, now this area anyway you cannot fly because this area falls below the stall.

So if you now, if you now look at the combined envelope, it will actually be something like this. It will follow the outer contour of the V-N diagram and you will get the limit combined envelope. Thanks for your attention.