Lecture 1 - Introduction to Aeroelasticity

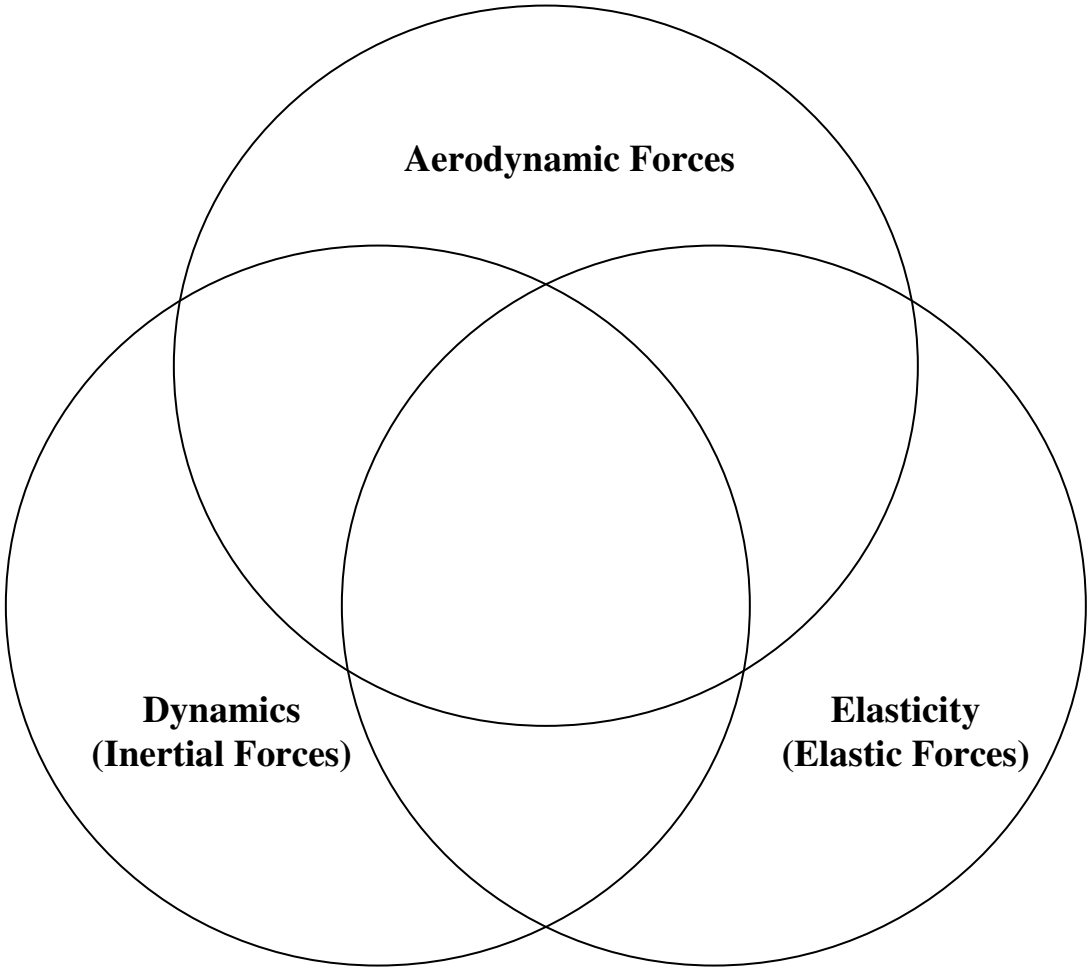

Figure 1 Collar's Triangle

Aerodynamic loads arise from the _____ around an object immersed in a fluid flow. These include _____ (perpendicular to the flow), _____ (in the direction of the flow) and _____.

Elasticity provides a _____ when an object is displaced from the equilibrium position under a given load.

Dynamics or the effects of inertial forces provide a means to determine the responses of a body under different types of loadings.

These three fields of study may exist separately or interact with one another to create a new area of study as shown in the figure above. _____ will not be covered in this course. Although _____ is not included in this course, some of the analytical techniques used will be referred to here.

Aeroelasticity

From the figure in the previous page, we can deduce that aeroelasticity is the study of the interplay between aerodynamic loadings, elastic forces and, possibly, inertial forces. In another words, it is the study _____ _____.

In aeronautical applications such as aircraft structures, i.e. wings, are _____ and they can deflect due to the aerodynamic and other forces acting on them. This deflection or a change in geometry (angle of attack) will in turn lead to changes in induced aerodynamic loads, which further result in another deflection and so on. This complex interaction gives rise to phenomena such as _____ and _____.

We normally classify aeroelasticity into two types namely, _____ and _____ aeroelasticity.

Static Aeroelasticity

Static aeroelasticity is the study of the phenomena involving interactions between _____ with a _____. In this analysis the accelerations of the structures are neglected, hence the _____ will not be considered. This is why this type of analysis is named static aeroelasticity. Two particular phenomena associated with static aeroelasticity are _____ and _____ .

1. Divergence

A divergence is a type of _____ of a lifting surface. Let us consider a flexible wing immersed in a fluid flow. Lift and moment are generated, which cause _____ to the wing, hence altering the effective _____. The new angle of attack may generate a _____, possibly greater, magnitude of lift and moment than the original position. If the larger aerodynamic loadings cause the deformation to increase and the _____, there will come a point where the deformation is so large that a catastrophic failure of the entire wing structure becomes inevitable.

Normally, the parameter for divergence to appear is the _____ or _____. The critical speed is called the _____.

2. Control Reversal

When an aircraft pilot wants to make his plane _____, he would apply opposite deflection of _____ on _____. [See figure 1 for illustration] This will create an unbalanced force on the wings and the _____ _____ about the aircraft _____ axis will result in a _____.

The aileron _____ deflection (nose up) would increase the _____ of the wing section, thus _____ the lift. However, for a flexible wing, the increase in lift due to the aileron deflection may cause a _____ on the entire wing section. Depending on the _____ of the wing, the reduction in lift could be greater than the increment, hence the positive control by the pilot would result in a _____ by the aircraft. This is called an _____.

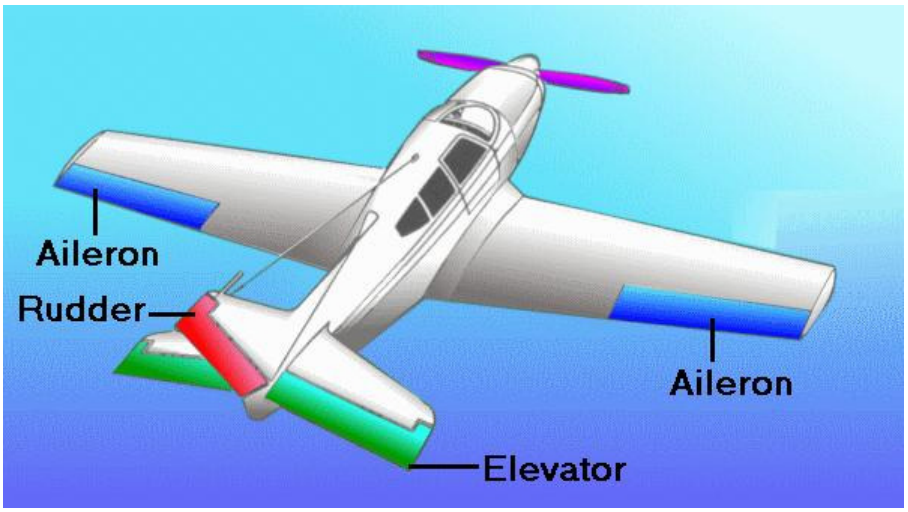

Figure 1. Ailerons are located at the outer trailing edges of each wing

Dynamic Aeroelasticity

Dynamic aeroelastic phenomena include _____, _____ and _____. It is clear that these phenomena share a common feature – _____, in another words, the geometry of the structure immersed in a moving fluid is a _____ _____ which is a distinct difference from the static aeroelastic phenomena.

We will learn more about dynamic aeroelasticity in lectures 5.

Typical Aerofoil Section

In this course, we will only consider _____ aeroelastic systems, i.e. we will only analyse the behaviour of an _____. The aerofoil usually has _____ in _____ (rotation, positive nose up) and _____ (vertical translation, positive downward).

Figure 2. A typical pitch and plunge aerofoil model

Figure 2 shows an illustration of a two degree-of-freedom aerofoil mounted on rotational and translation springs.

L	
M_{ac}	
θ	
α	
x_{ac}	
x_{cg}	
x_o	
I	
U	
k_α	
k_h	
c	

The two dimensional simplification of the aeroelastic system is only valid under certain conditions. For an aircraft wing, the assumption of a pure two dimensional flow is understood and accepted to be a good representation of a station at 70-75% from the root of a high aspect ratio straight wing. Three dimensional effects provide significant contributions in other parts of the wing and must be included in the calculation.

Divergence of the 1-DOF Typical Section

A divergence is a type of catastrophic structural failure which can be very dangerous or costly, which engineers must try to avoid at all cost. Let us consider a system of _____ _____ aerofoil (_____) as shown below.

Figure 3.

Considering the moment equilibrium of this system about the elastic axis, we obtain

_____

Assuming small angle of attack, i.e. $\sin\alpha \approx \alpha$, and $\cos\alpha \approx 1$, the above expression becomes

_____ [EQN.1]

Next, let us consider the aerodynamic loads. First, the lift force is given by

_____ [EQN.2]

where

L	
ρ	
U	
S	
C_L	
q	
a	

We can express the aerodynamic pitching moment about the aerodynamic centre as

_____ [EQN.3]

When the angle of attack is small, it is possible to assume that the moment coefficient is a constant. Now, we substitute equations 2 and 3 into equation 1 to obtain

_____

Rearranging the above equation, we obtain an expression for the elastic deflection as

_____ [EQN.4]

The deflection angle will increase to infinity if the denominator of the right hand side of equation 4 approaches zero. This situation is called a static divergence. Therefore, the condition at divergence is given by

_____

where q_D denotes the dynamic pressure at divergence. We can rearrange the above expression to obtain

_____

Finally, the air speed at which divergence occurs is given by

_____

It is worth noting that the aerodynamic centre is ahead of the elastic axis, i.e. _____, in order for divergence to be possible.

Exercise