Assessment of hard disk Head Gimbal Assembly (HGA) aeroelastic stability

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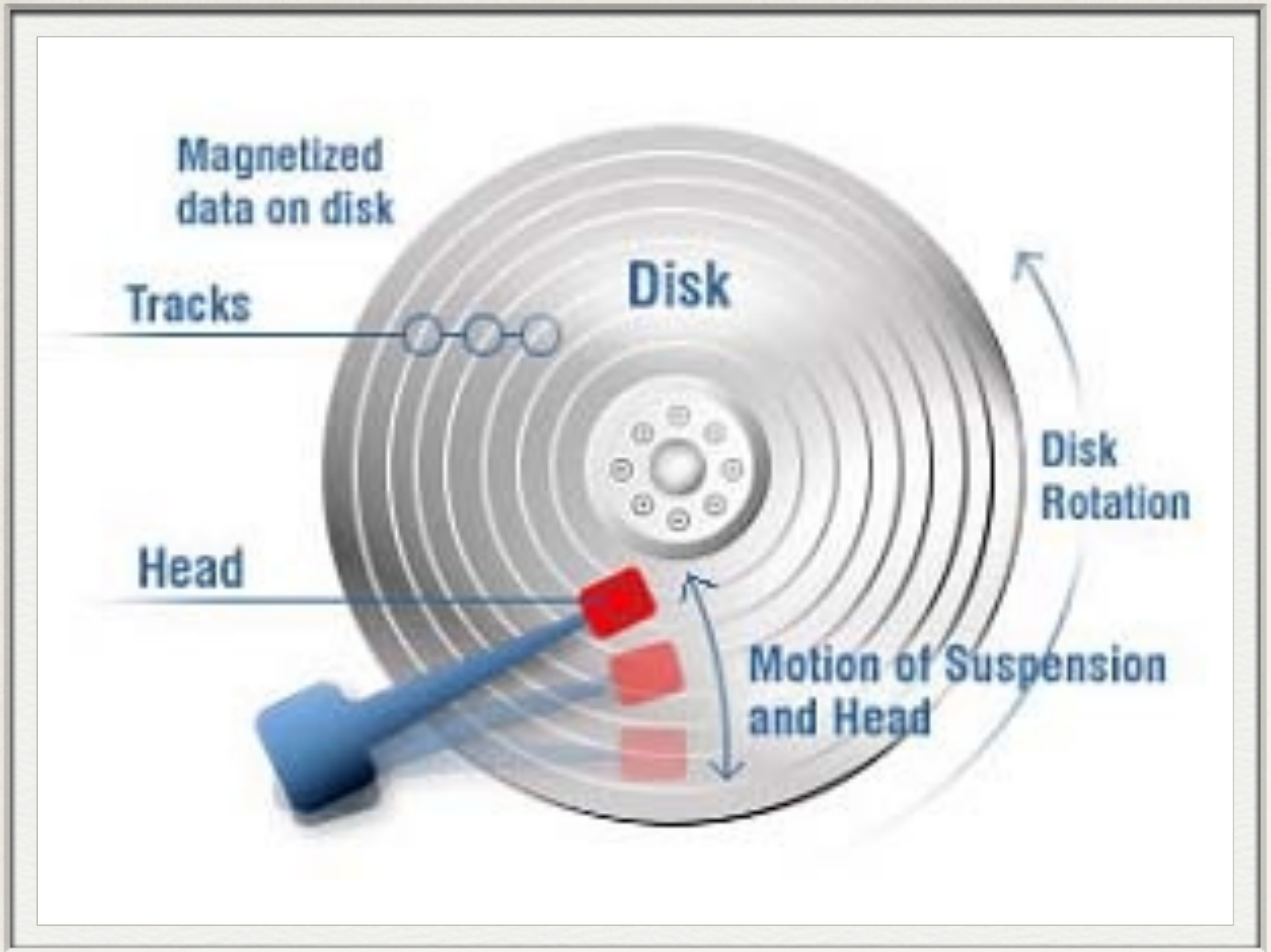
About the speaker

- 2007 - current: Full-time staff at Mechanical Engineering, KMUTT
- M.Eng and PhD in Aeronautical Engineering at Imperial College London
- Research interests: Wind energy, Aeroelasticity, Dynamic stall, Nonlinear dynamics... (Not CFD)

Introduction to today's topic

Head Gimbal Assembly Aeroelastic Stability

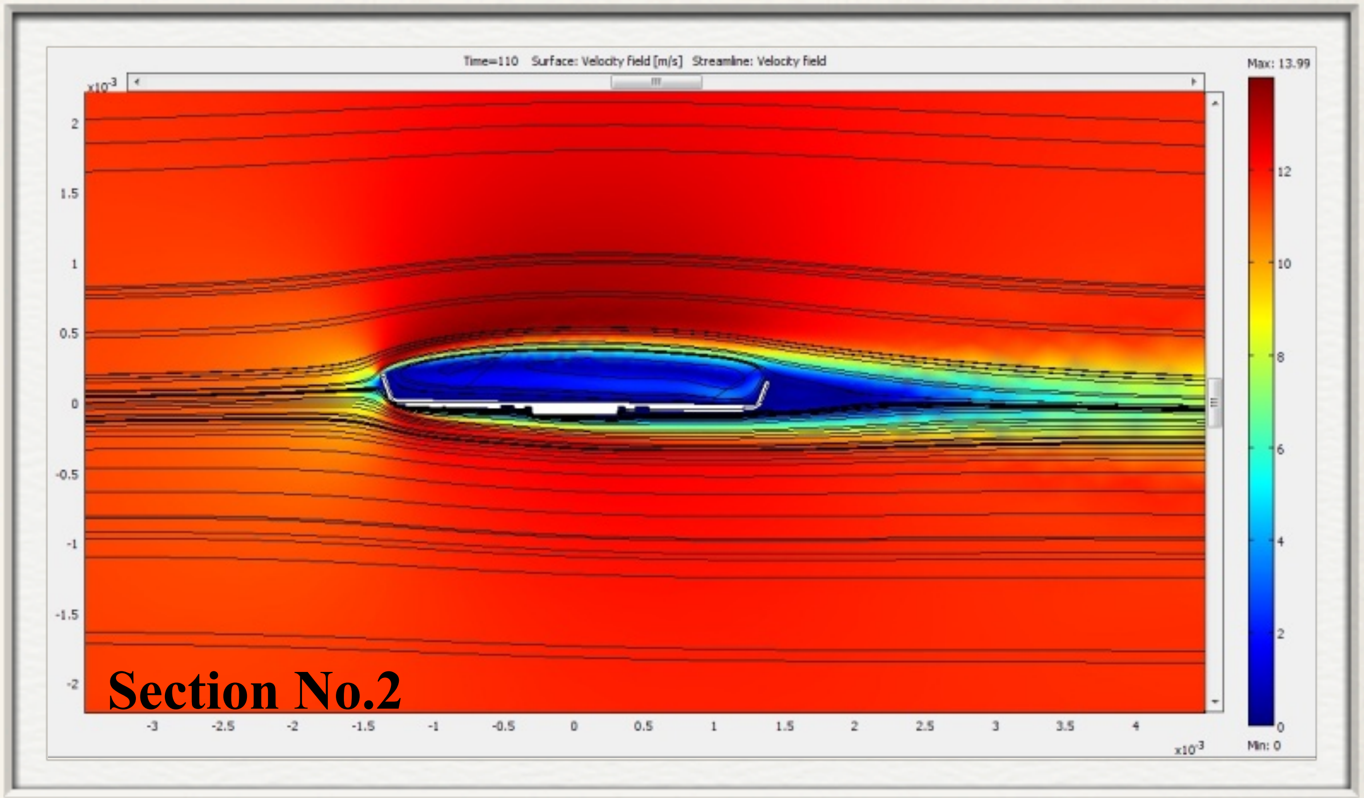


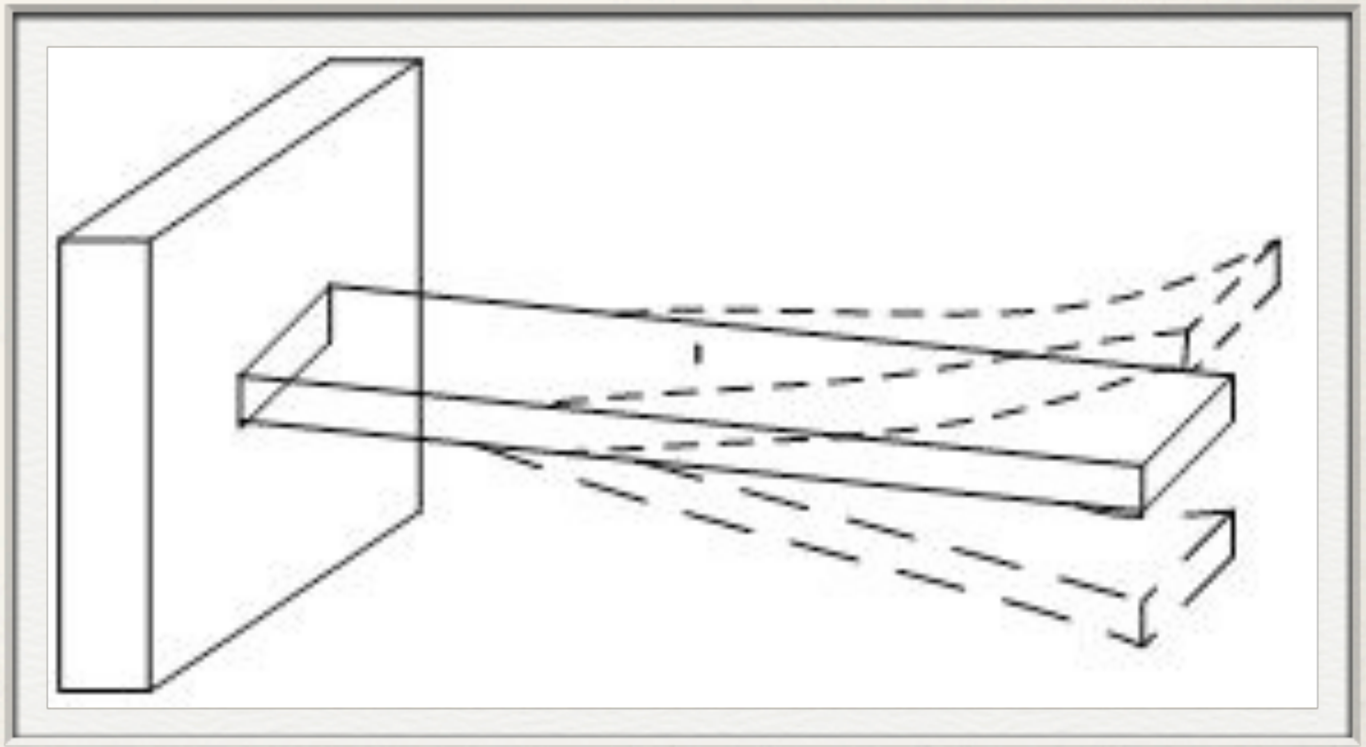
Operating conditions

Disc rotational speed, Seek time, HGA materials, HGA profile

Research Objectives

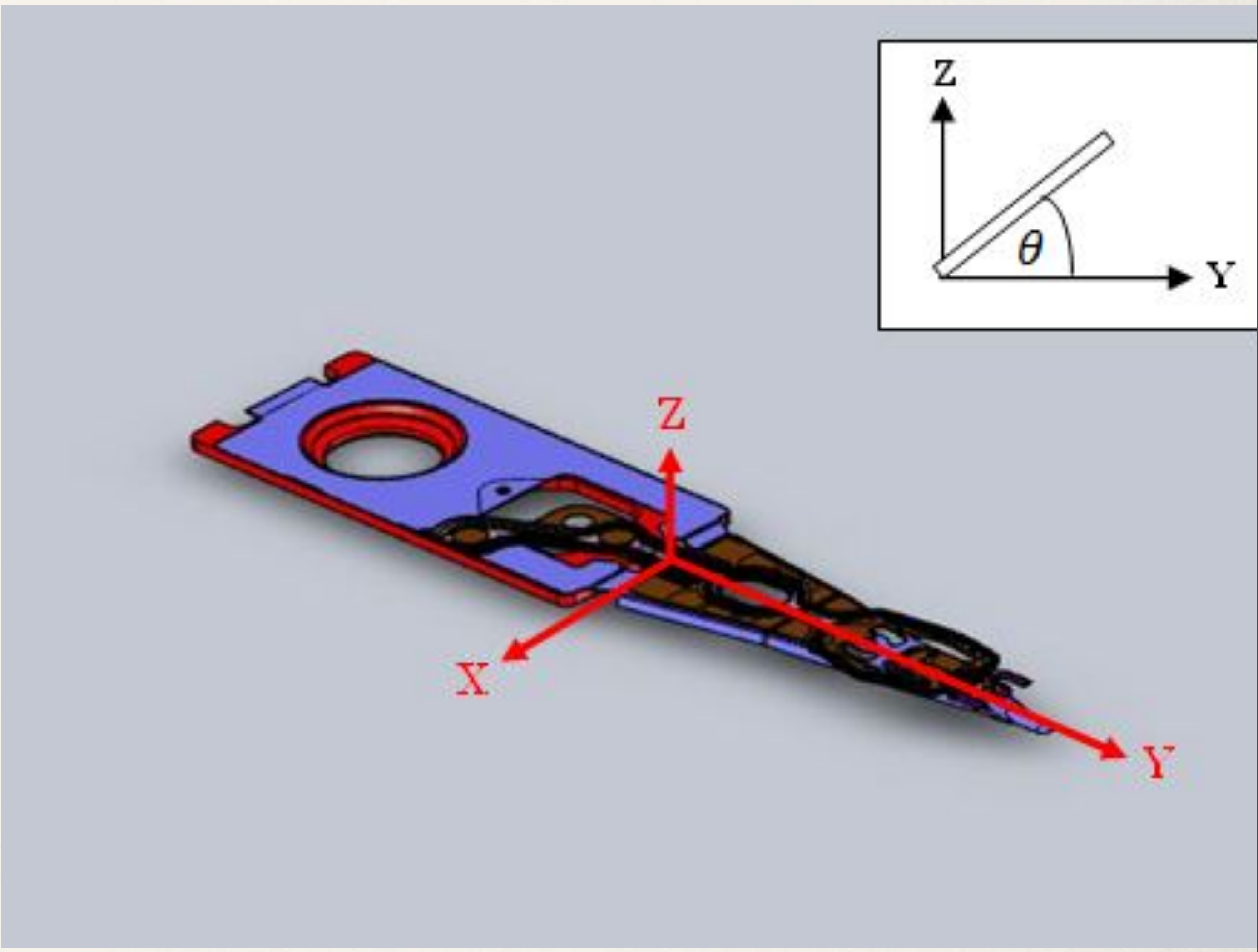
- Determination of HGA unsteady flow characteristics under actual working conditions and model it using a mathematical model
- Assess the HGA structural stability characteristics at different values of significant hard disk design parameters

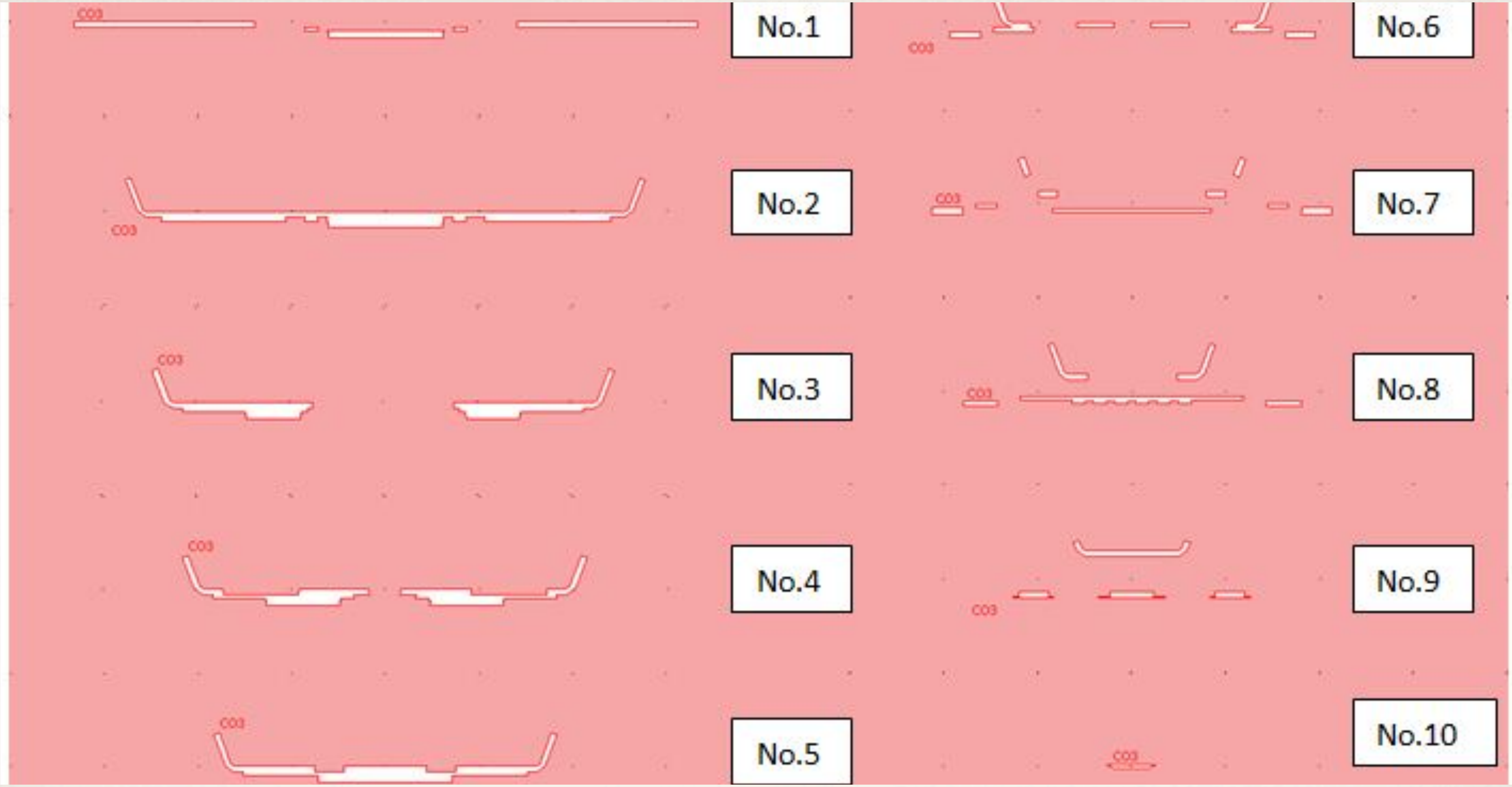




Aeroelastic system

- 1 degree-of-freedom
- Assume that the HGA is a rigid body with 1 degree-of-freedom in rotation about the X-axis
- Unsteady flows are caused by the HGA heaving motion which induces a change in the effective angle of attack



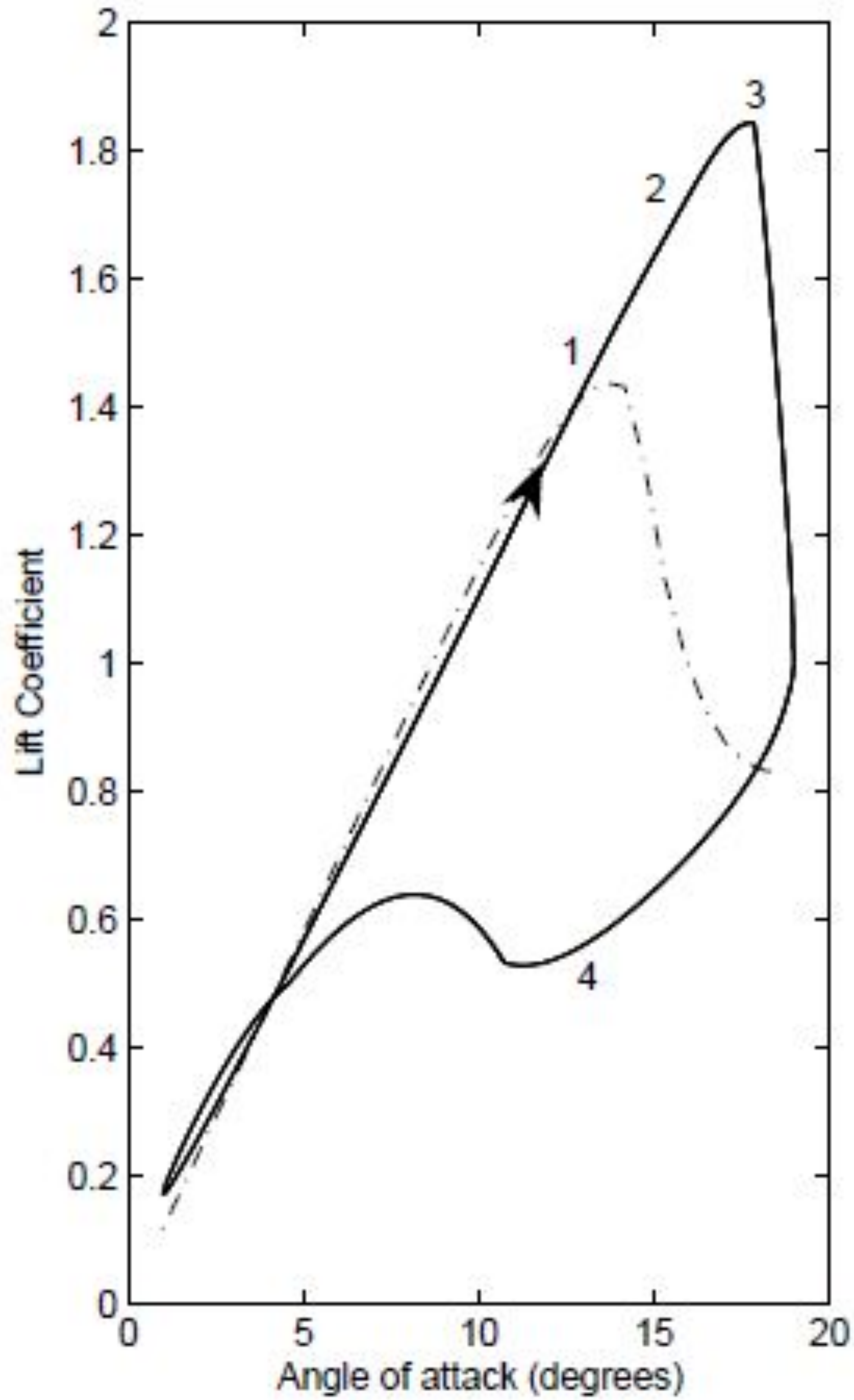


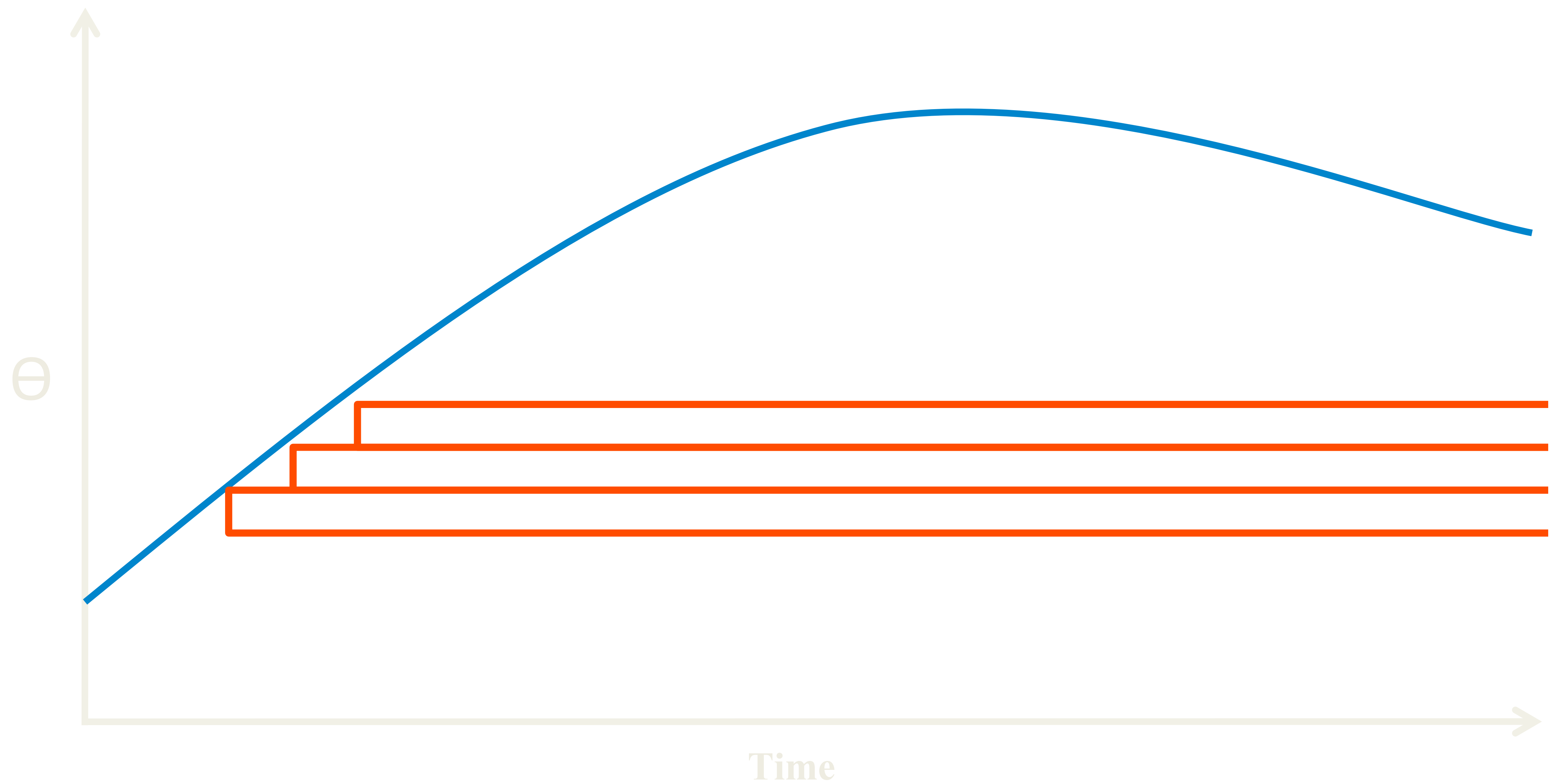
Aerodynamic forces on HGA

Break HGA down into elements and conduct calculations in two dimensions

Unsteady flows

- It is believed that flows around the HGA during operation are UNSTEADY. What are unsteady flows
- Consider an aerofoil oscillating in pitch in sinusoidal cycles
- Its lift responses will NOT follow the static curves
- Severe cases will include dynamic stalls



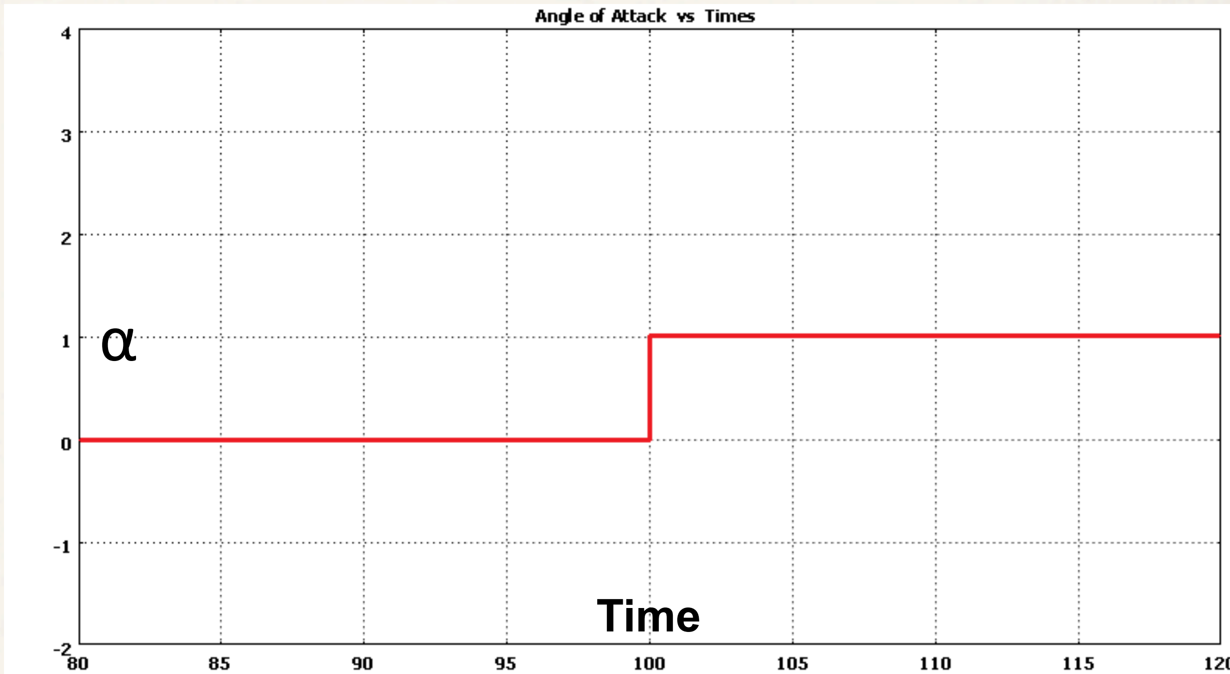


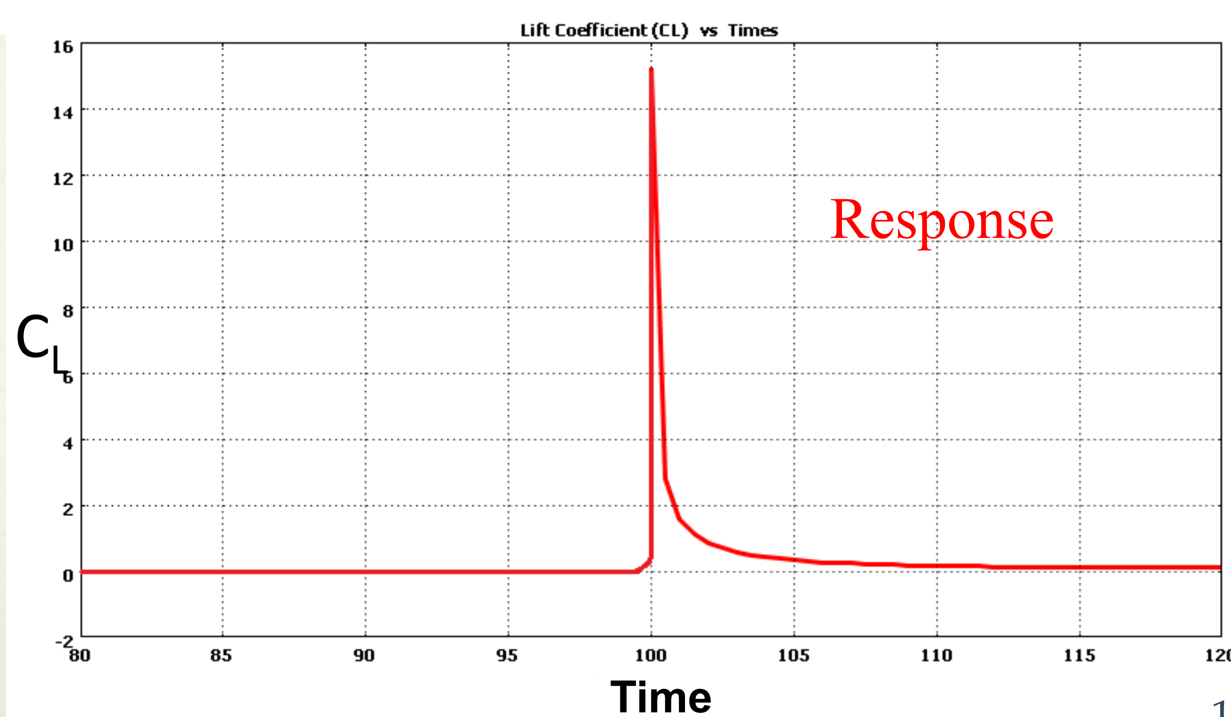
Modeling unsteady flows

Breaking continuous inputs into steps with each indicial response functions

Step input and indicial response

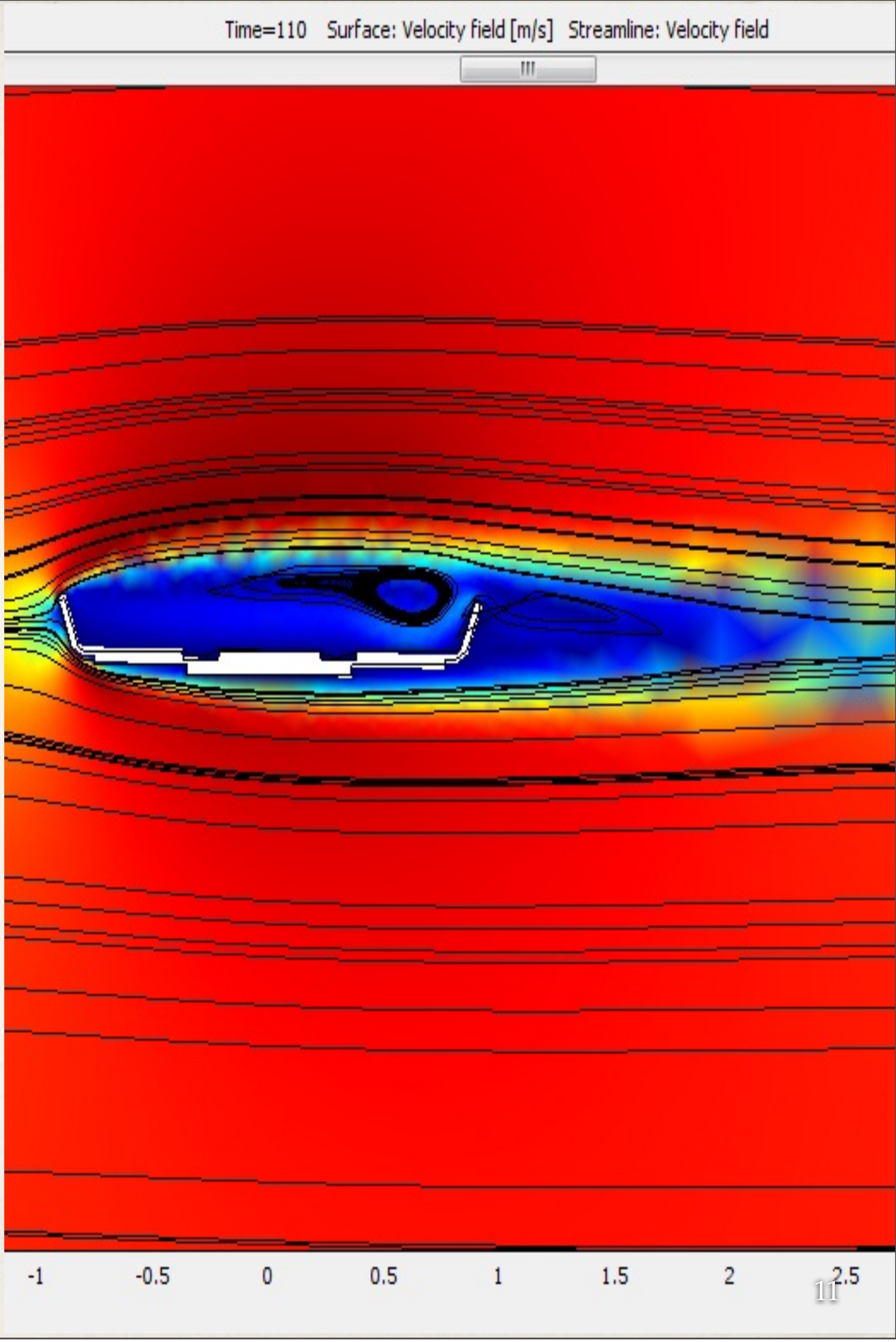
- Indicial responses are responses of step inputs
- The total response is the summation or superposition of all indicial responses of step inputs that make up the total continuous input
- Mathematical models represent indicial responses
- CFD vs wind tunnel testing





CFD vs wind tunnel testing

- Need to know the lift responses of the section due to a step change in the angle of attack
- CFD
- Wind tunnel tests were also conducted for verification



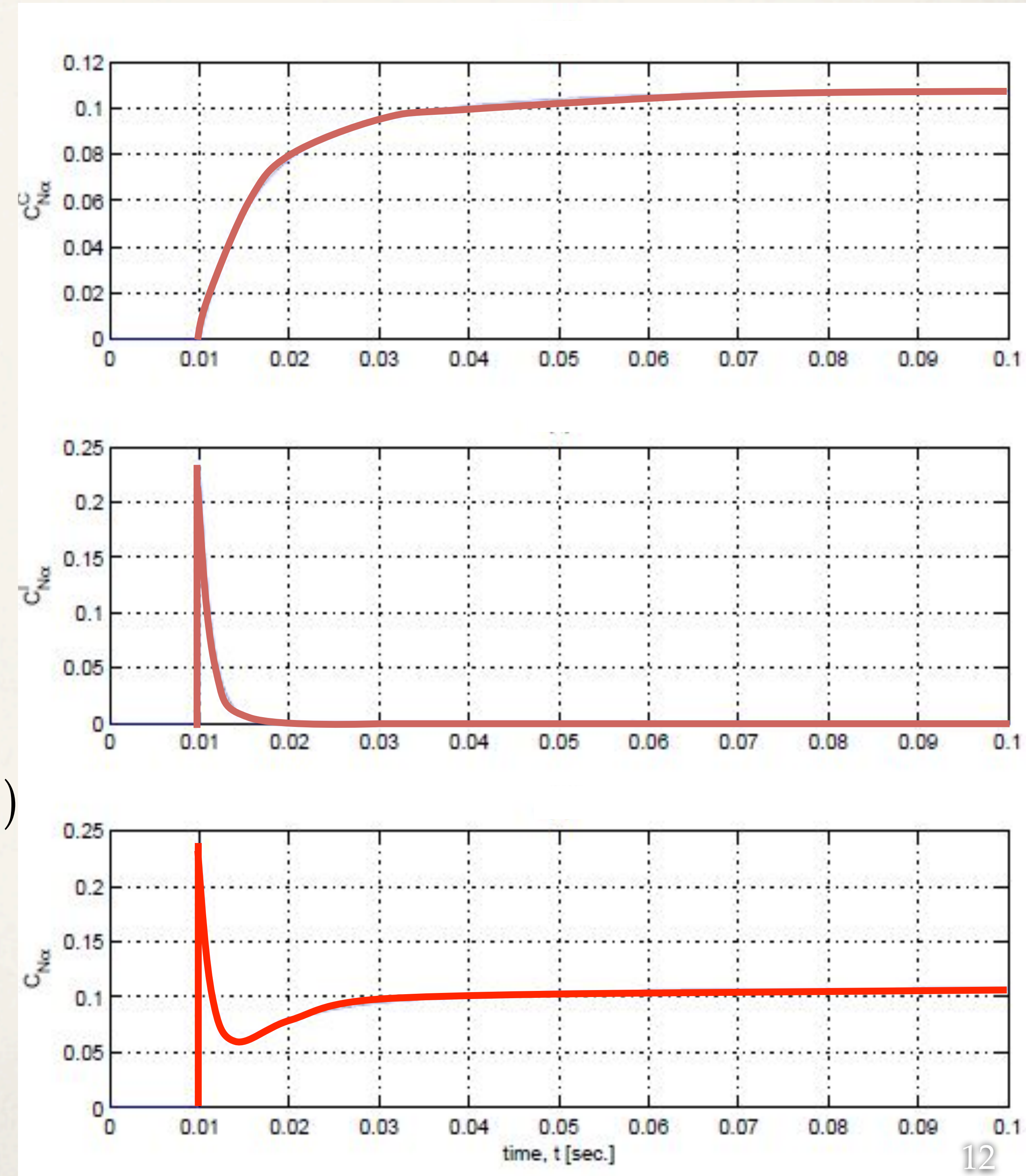
Indicial response verification using aerofoil examples

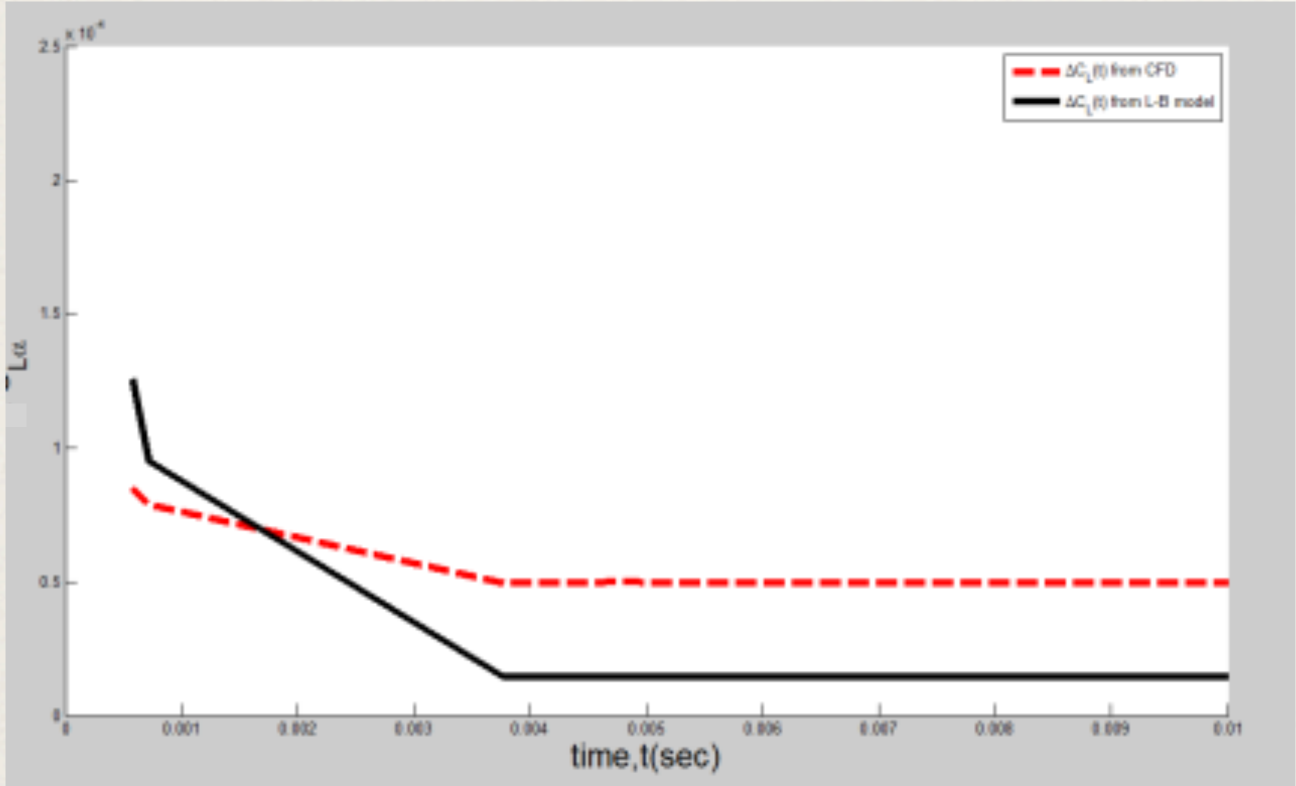
- Verified aerofoil CFD results with existing mathematical model and its data

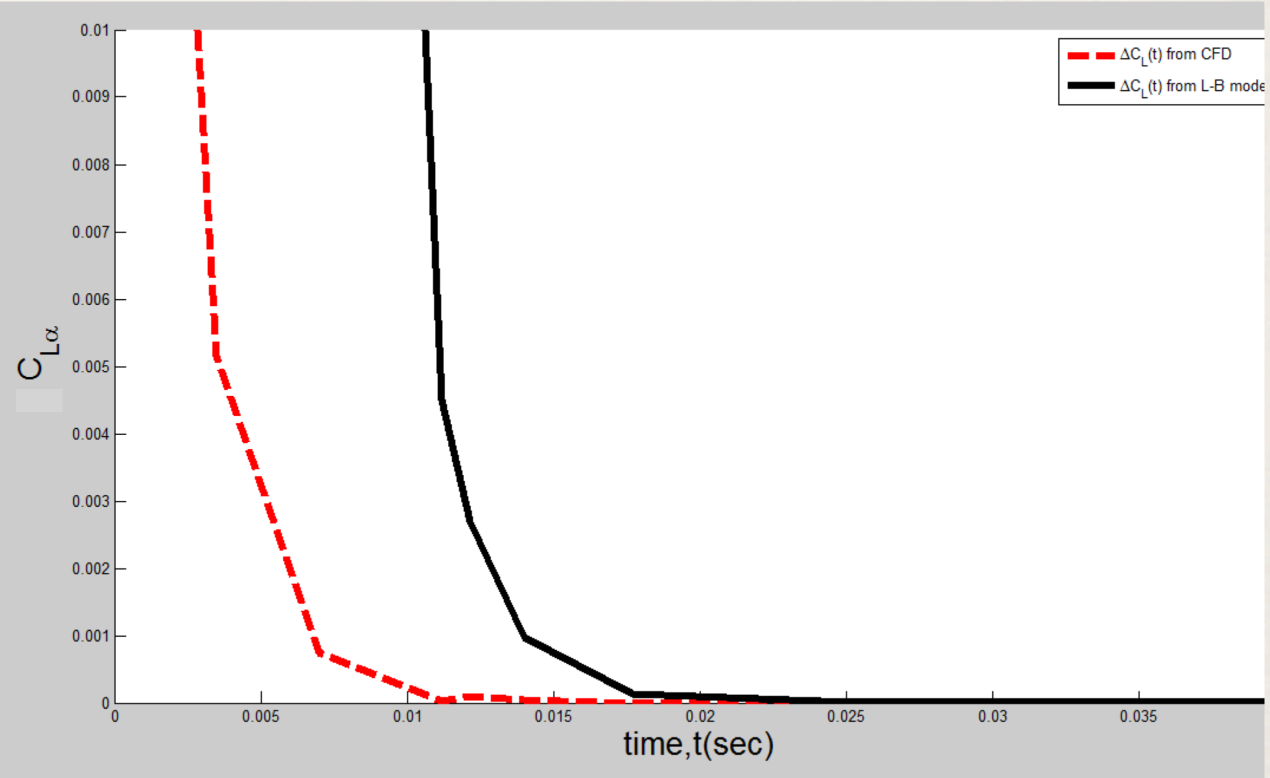
$$\frac{\Delta C_{L\alpha}(t)}{\Delta\alpha} = \frac{4}{M}\phi_\alpha^I(t,M) + C_{L\alpha}^S(M)\phi_\alpha^C(t,M)$$

$$\phi_\alpha^C = 1 - A_1\exp\left(-b_1\beta^2\frac{2V}{c}t\right) - A_2\exp\left(-b_2\beta^2\frac{2V}{c}t\right) = f\left(A_1, A_2, b_1, b_2\right)$$

$$\phi_\alpha^I = \exp\left(\frac{-t}{\left(\frac{0.75}{(1-M)+\pi\beta^2M^2(A_1b_1+A_2b_2)}\right)T_I}\right) = f(A_1, A_2, b_1, b_2)$$



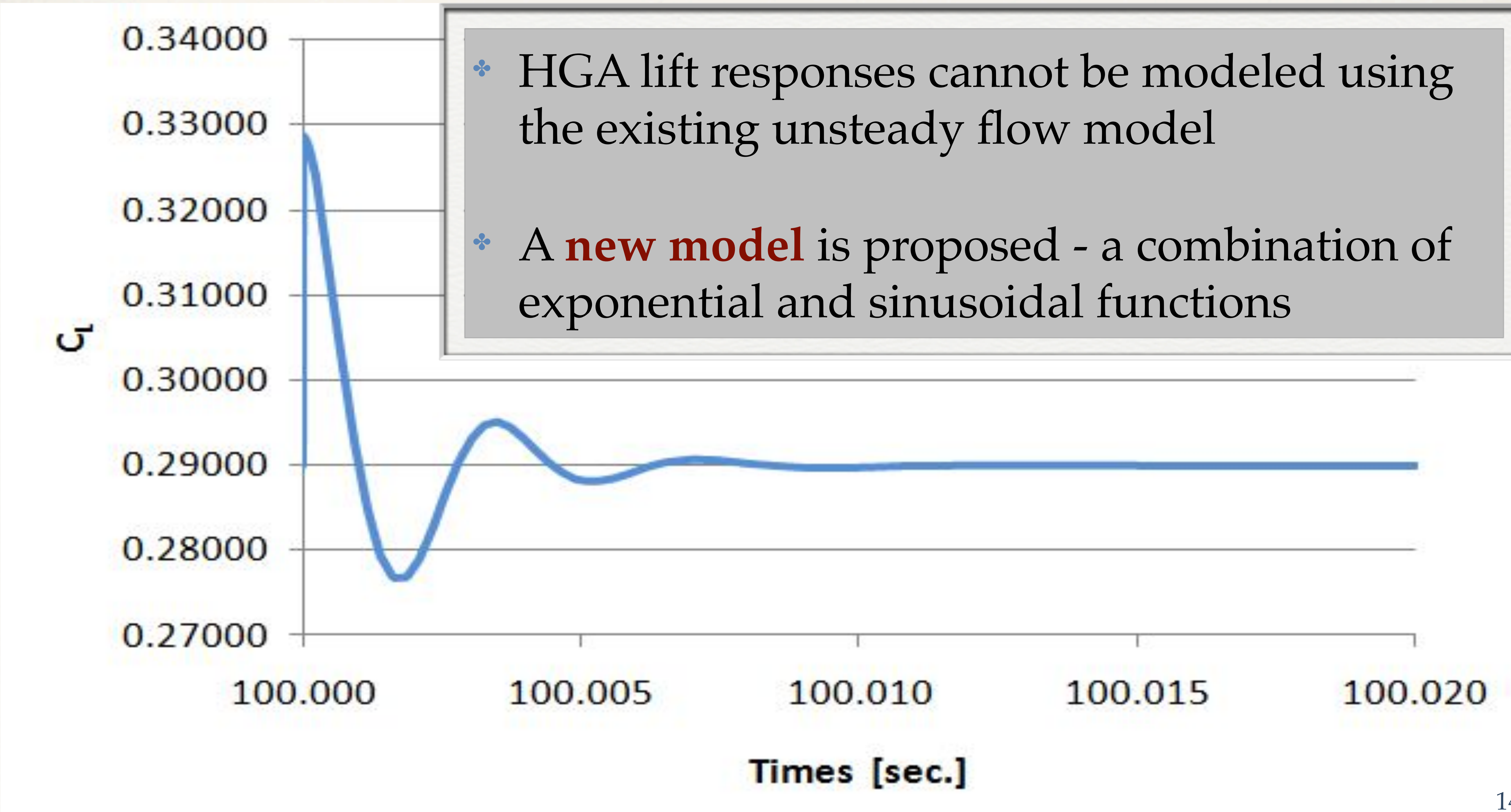




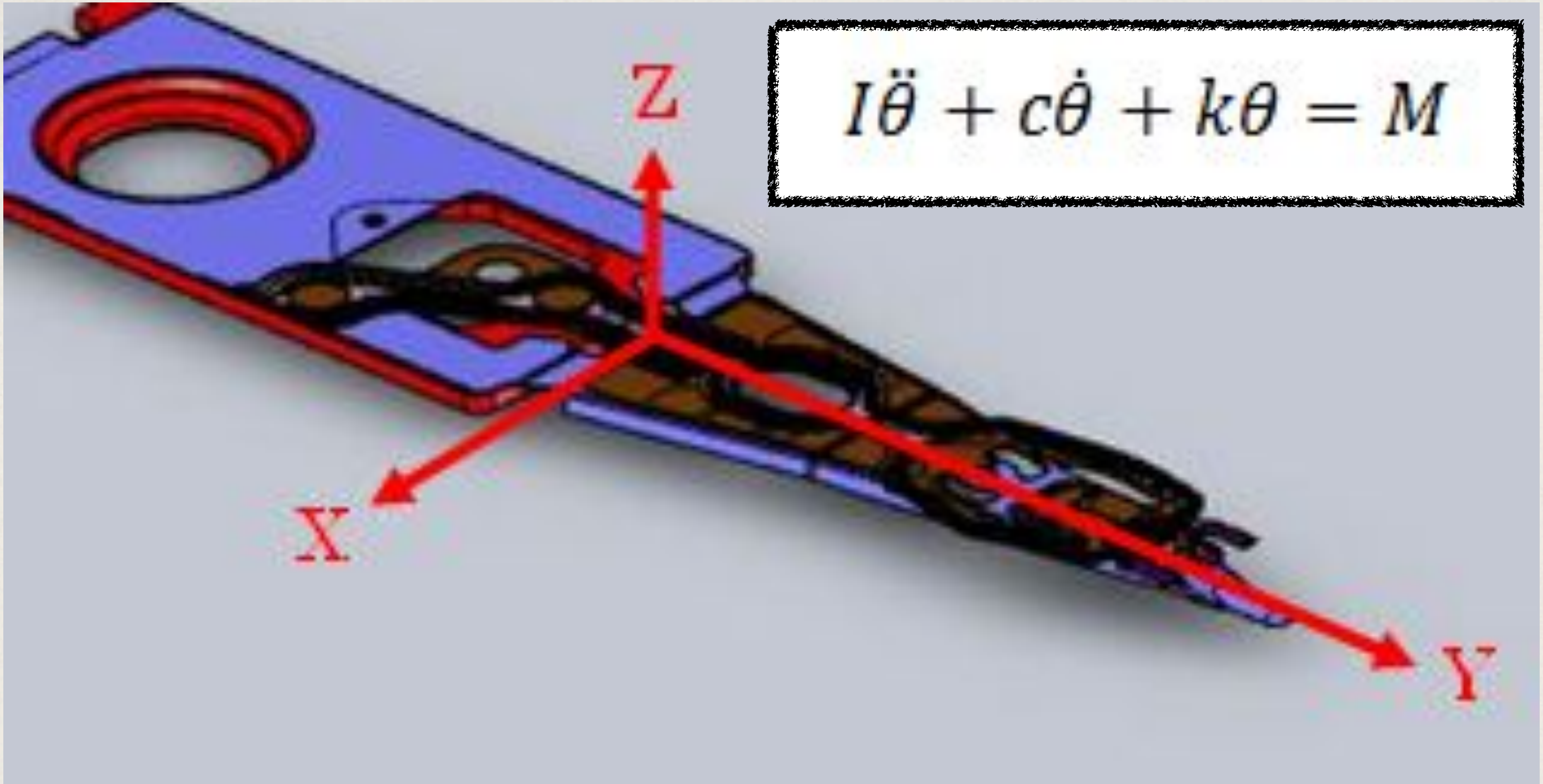
Determine model parameters

Using the curve fitting technique to determine the model parameters. Minimising the RMS error between the two curves.

Determine unsteady flow model constants for HGA cross sections

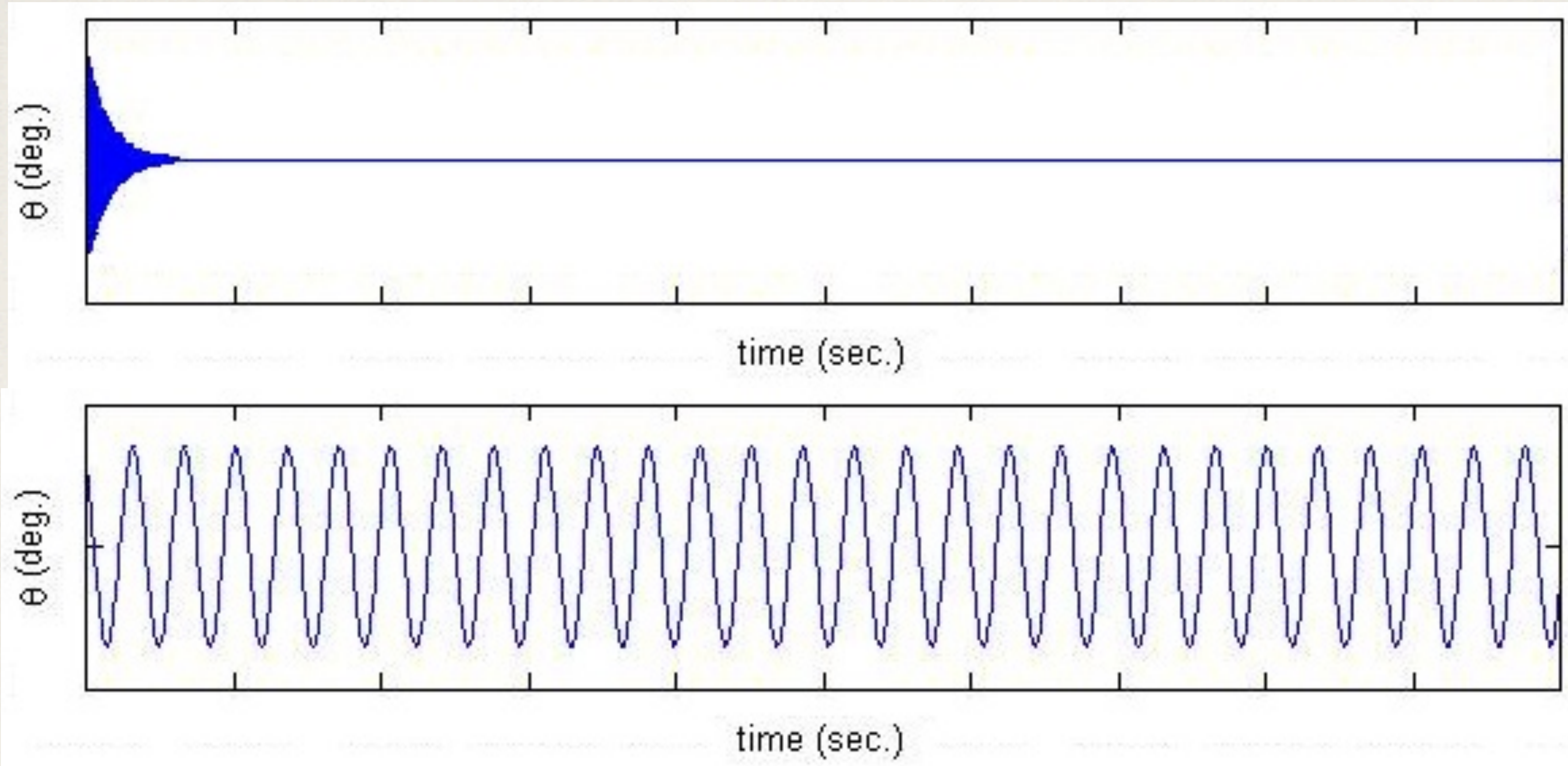


- HGA lift responses cannot be modeled using the existing unsteady flow model
- A **new model** is proposed - a combination of exponential and sinusoidal functions



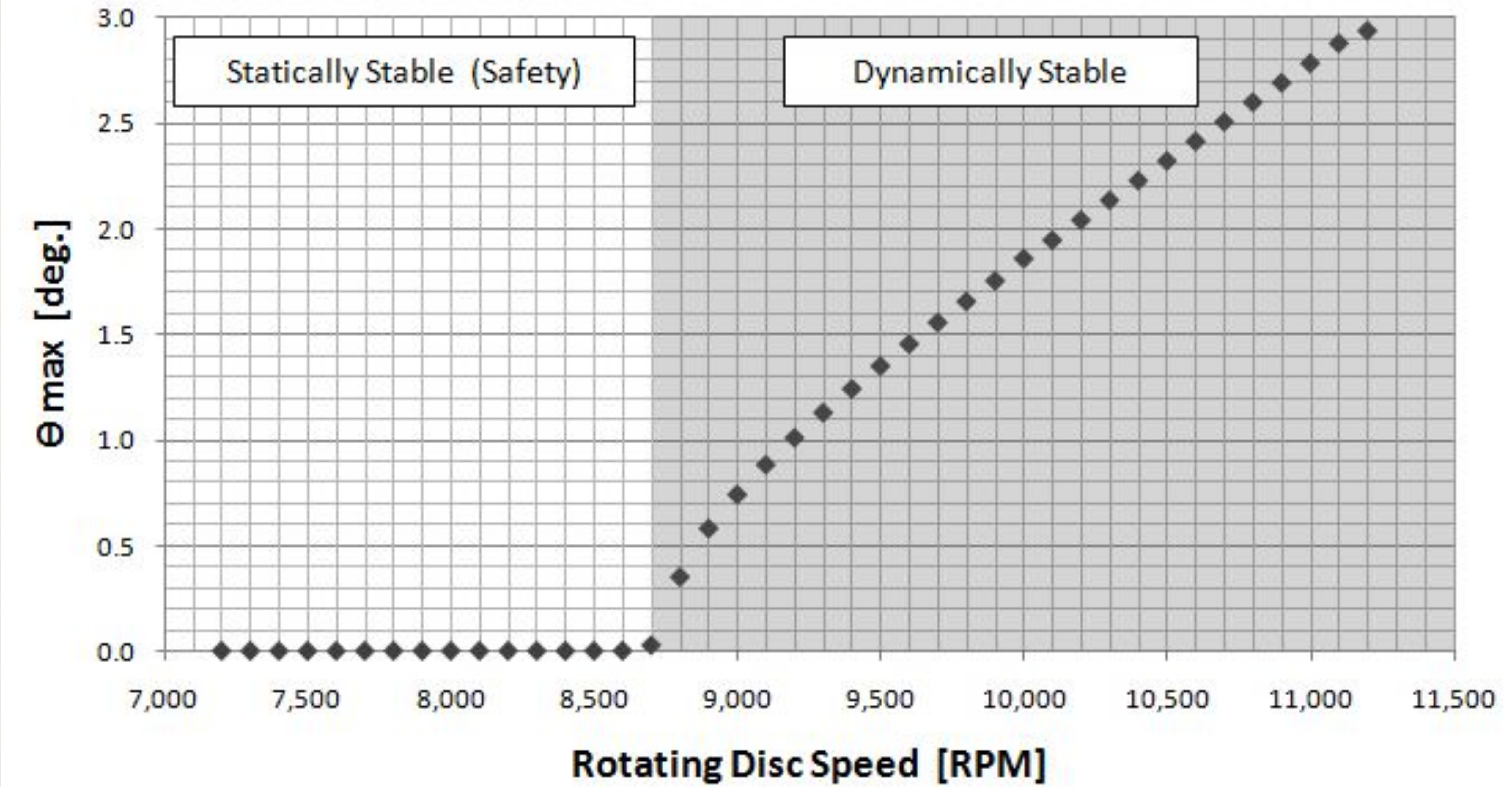
Complete aeroelastic model

System completed with structural and aerodynamic models is ready to be solved using numerical integration to determine its dynamics



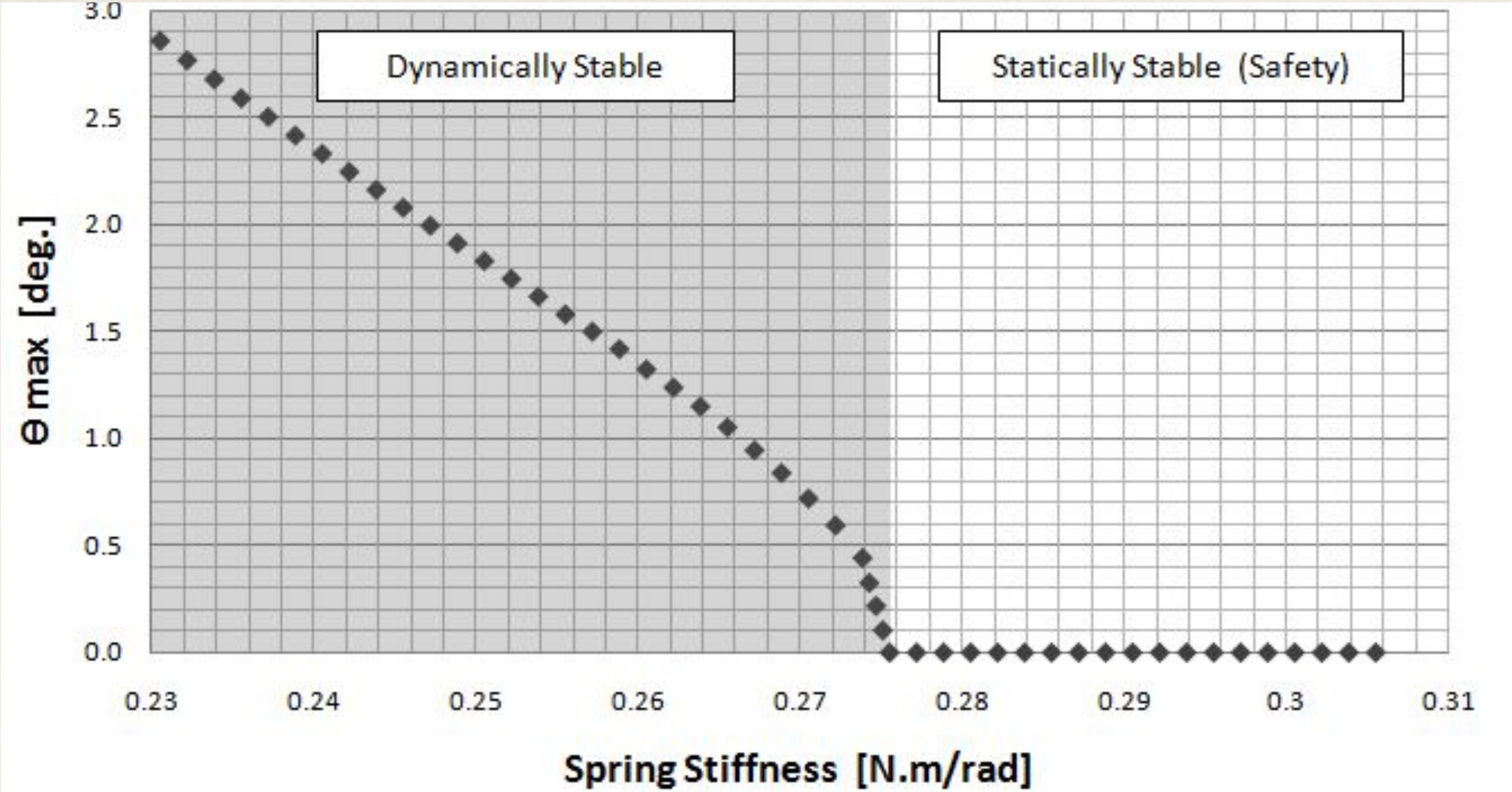
Static and dynamic stability

The system shows different dynamics depending on the system parameters, ie. change in disc RPM. There must be a critical value between the two examples shown here.



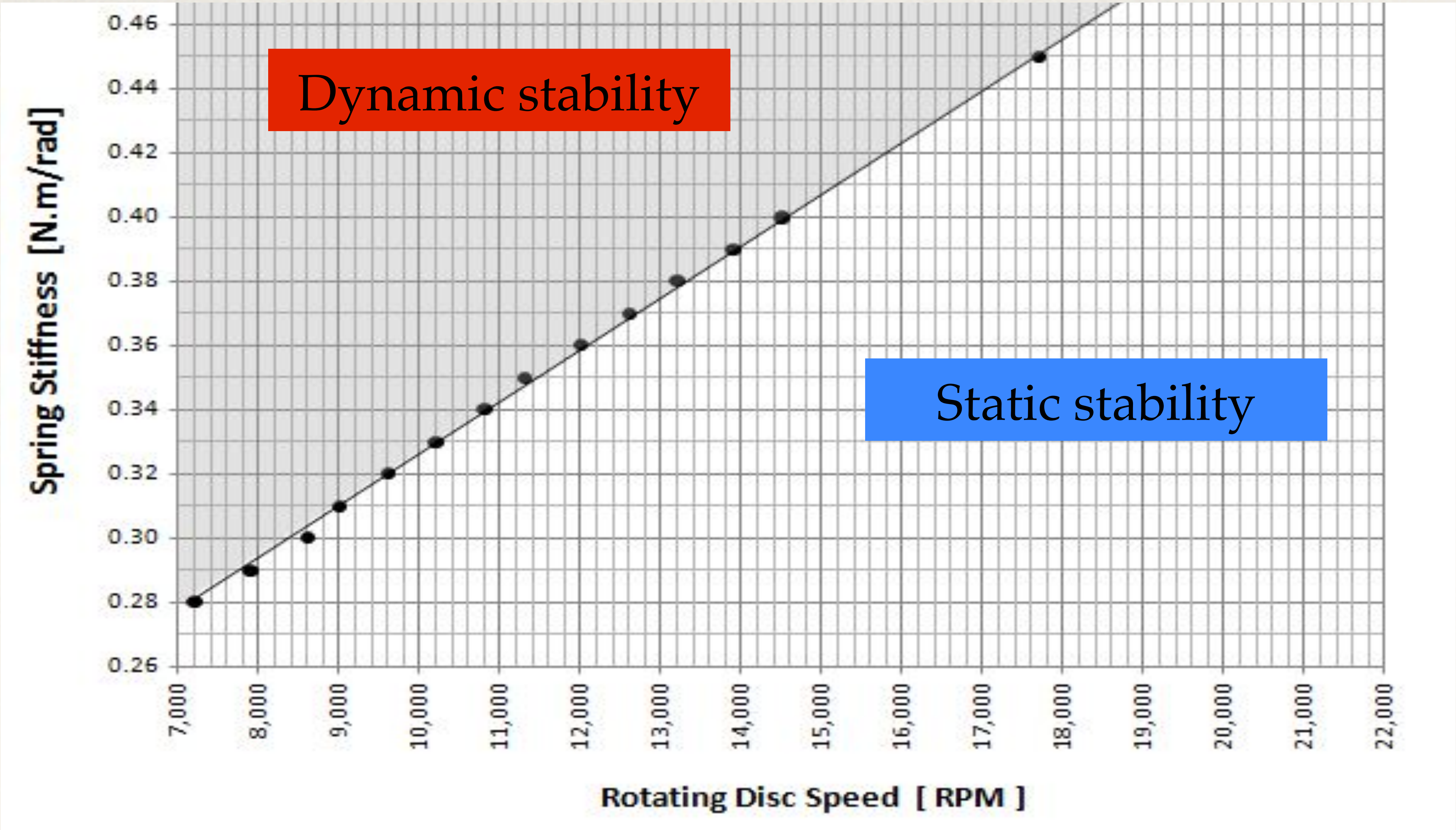
Bifurcation diagram in disc RPM

HGA becomes unstable (oscillation observed) if the disc speed exceeds 8700 RPM



Bifurcation in HGA stiffness

HGA becomes unstable if the stiffness falls below 0.276 N.m/rad



HGA stability assessment

This map may be used in the new hard disk preliminary design process.

Conclusions

Advanced Manufacturing
Industry / University Cooperative Research Center
KMUTT

Acknowledgement

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Q&A

Thank you very much for your attention