Tutorial 2, Nov 17, 2022

Modeling and Similarity

- If we do an experiment on a smaller model, how does this scale to a larger prototype?
- 3 types of similarity:
  1. Geometric
     - All lengths scale by the same factor
     - The model is essentially a smaller scale version of the prototype
  2. Dynamic
     - The corresponding forces scale by a constant factor
  3. Kinematic
     - Velocities at corresponding points scale
- If we have all 3 types, then we have *complete similarity*
- Principle of similarity: suppose $\pi_1 = f(\pi_2, \pi_3, \cdots, \pi_n)$; to ensure complete similarity between model and prototype, geometric similarity must exist and all independent πs must be identical
  - Under these conditions, the solutions in dimensionless form are guaranteed to be equal
  - In short, if geometric similarity exists and $\pi_{2,m} = \pi_{2,p}, \pi_{3,m} = \pi_{3,p}, \cdots, \pi_{n,m} = \pi_{n,p}$, then $\pi_{1,m} = \pi_{1,p}$
- Example: Designing a large scale car prototype with length L_p, we would like to reduce drag; if we found $\pi_1 = f(\pi_2)$, where $\pi_1 = \dfrac{F_D}{\rho V^2 L^2}$ and $\pi_2 = \dfrac{\rho V L}{\mu} = \text{Re}$ for a smaller scale model with wind properties V_m, μ_m and ρ_m; if we match the Reynolds numbers between the model and prototype, then π_1 will also be the same between the two
- So long as corresponding independent πs are equal, similarity can be achieved, even in different fluids