Introduction to Fluid Mechanics Prof. Suman Chakraborty Department of Mechanical Engineering Indian Institute of Technology, Kharagpur

Lecture – 60 Principle of Similarity and Dynamical Analysis-Part-II

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V m - Jin	Ship 100 m long 10 m/s Asubmyed = 500 m ² } politin Model 1:25
$ = \frac{2 \text{ m/s}}{2 \text{ m/s}} $	Find (a) Vm neglectry frictions office (b) FD, n= 60 N towing tents at made spect of Estimate FD, p considering frictional Final alfects who
N 57 12 N	$\frac{d_{1}}{d_{p}} \frac{d_{1}}{d_{m}} = \frac{h_{n}}{d_{p}} \frac{p}{d_{p}} = \frac{h_{n}}{d_{p}} \frac{p}{d_{p}}$

Estimate the total drag force on the prototype considering fictional effects also. There are some other data given for the problem.

One of the important resistance is the frictional resistance. The other important resistance is called as wave making resistance, so because of formation of the water waves and there it is sort of a gravity dependent phenomena.

Considering the wave making resistance the important forces are inertia force and gravity force. So, then the similarity will be determined by the Froude number which is the ratio of the inertia force and gravity force.

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$$F_{rm} = F_{r,p}$$

$$\frac{F_{rm}}{V_{glm}} = \frac{V_{p}}{\sqrt{gl_{p}}} \rightarrow \frac{V_{m}}{V_{p}} = \int \frac{I_{m}}{l_{p}}$$

$$\frac{R_{em}}{R_{em}} = \frac{R_{ep}}{V_{m}} \frac{V_{p}l_{p}}{V_{m}} \rightarrow \frac{V_{m}}{V_{p}} = \int \frac{I_{m}}{l_{p}}$$

$$\frac{V_{m}l_{m}}{V_{m}} = \frac{V_{p}l_{p}}{V_{m}} \rightarrow \frac{V_{p}}{V_{p}} = \int \frac{I_{m}}{l_{p}}$$

$$\frac{I_{m}}{I_{p}} = \int \frac{I_{m}}{I_{p}} \frac{V_{p}}{V_{p}} \frac{V_{m}}{V_{p}} = \frac{V_{m}}{I_{p}}$$

$$Fr_{m} = Fr_{p}$$

$$\frac{V_{m}}{\sqrt{gl_{m}}} = \frac{V_{p}}{\sqrt{gl_{p}}} \rightarrow \frac{V_{m}}{V_{p}} = \sqrt{\frac{l_{m}}{l_{p}}} = 2m / s$$

 $\begin{aligned} \mathbf{R}\mathbf{e}_{m} &= \mathbf{R}\mathbf{e}_{p} \\ \frac{V_{m}l_{m}}{v_{m}} &= \frac{V_{p}l_{p}}{v_{p}} \longrightarrow \frac{V_{m}}{V_{p}} = \frac{l_{m}}{l_{p}} \end{aligned}$

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$$H_{m} = F_{n,p}$$

$$H_{m} = \frac{V_{p}}{V_{p}} - \frac{V_{m}}{V_{p}} - \frac{V_{m}}{V_{p}} - \frac{V_{m}}{V_{p}}$$

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$$H_{m} = \frac{V_{p}}{V_{p}} - \frac{V_{m}}{V_{p}} - \frac{V_{m}}{V_{$$

 $\operatorname{Re}_{m} = 8 \times 10^{6} \rightarrow C_{D,M} = 0.003$ $\operatorname{Re}_{p} = 10^{9} \rightarrow C_{D,P} = 0.0015$

$$\rho = 1000 Kg / m^{3}$$

$$F_{f} = C_{D,f} \times \frac{1}{2} \rho V^{2} \times A$$

$$F_{f} \Big|_{m} = C_{D,f} \Big|_{m} \times \frac{1}{2} \rho_{m} V_{m}^{2} \times A_{m} = 2.88N$$

$$F_{wave} \Big|_{m} = (60 - 2.88) N = 57.12N$$

$$\frac{F_{wave} \Big|_{m}}{\frac{1}{2} \rho V_{m}^{2} l_{m}^{2}} = \frac{F_{wave} \Big|_{p}}{\frac{1}{2} \rho V_{p}^{2} l_{p}^{2}} \rightarrow F_{wave} \Big|_{p} = 8.92 \times 10^{5} N$$

$$F_{f} \Big|_{p} = C_{D,p} \times \frac{1}{2} \rho V_{p}^{2} \times A_{p} = 0.225 \times 10^{5} N$$

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 $F_{total}\big|_p = F_{wave}\big|_p + F_f\big|_p$

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Buckingham pi theorem m physical farameters n fundamentel dimensions (m-n) no of non dim parameters $(\pi + \text{terms})$ $f[\pi_1, \pi_2, \dots, \pi_{m-n}] = 0$

Buckingham pi theorem

m physical parameters

n fundamental dimensions

(m-n) no. of non. Dimensional parameters $(\pi \ terms)$

 $f[\pi_1, \pi_2, ..., \pi_{m-n}] = 0$

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Frample MLT-21-2 to of fundamental dim - = 3 (M, L no of vaintle -> m=6 no of Theme

Example

 $\frac{\Delta p}{l}$ $D, \mu, \rho, \overline{V}, \overline{\varepsilon}$ $D \rightarrow [L]$ $\mu \rightarrow [ML^{-1}T^{-1}]$ $\rho \rightarrow [ML^{-3}]$ $\overline{V} \rightarrow [LT^{-1}]$ $\overline{\varepsilon} \rightarrow [L]$

$$\frac{\Delta P}{L} = \frac{MLT^{-2}L^{-2}}{L} \to ML^{-2}T^{-2}$$

No. of fundamental dimensions $\rightarrow 3(M, L, T)$

No. of variables $\rightarrow m = 6$

No. of π terms 6-3=3

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EXAN

Repeating variables \rightarrow no. of repeating variables=no. of fundamental dimensions=3

First of all out of the 3 repeating variable one choose none of those should be the dependent variable that is the first thing, none of those should be dimensionless and none of those should be having same dimension and may be the most important thing is collectively there should content all the dimensions.

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113= p23 D, M, C, V [L] [ME'T-] T13 = OME tol d variable riell not find din = 3

$$\pi_{1} = \rho^{x_{1}} \overline{V}^{y_{1}} D^{z_{1}} \frac{\Delta p}{L}$$
$$\pi_{2} = \rho^{x_{2}} \overline{V}^{y_{2}} D^{z_{2}} \mu$$
$$\pi_{3} = \rho^{x_{3}} \overline{V}^{y_{3}} D^{z_{3}} \overline{\varepsilon}$$

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$$\pi_{2}$$

$$M^{x_{2}}L^{-3x_{2}}$$

$$L^{y_{2}}T^{-y_{2}}$$

$$L^{Z_{2}}ML^{-1}T^{-1}$$

$$x_{2} + 1 = 0$$

$$-3x_{2} + y_{2} - 1 = 0$$

$$-y_{2} - 1 = 0$$

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 $x_2 = -1, y_2 = -1, z_2 = -1$

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OVD 0

$$\pi_{2} = \frac{\mu}{\rho \overline{V} D}$$

$$\pi_{3} = \frac{\overline{\varepsilon}}{D}$$

$$\pi_{1} = \frac{\overline{V}^{2}}{2gD}$$

$$h_{f} \rightarrow \frac{\Delta p}{L} = \frac{h_{f} \rho g}{L}$$

$$h_{f} = f\left(\operatorname{Re}_{D}, \frac{\overline{\varepsilon}}{D}\right) \times \frac{l}{D} \frac{\overline{V}^{2}}{2g} \rightarrow \frac{\Delta p}{\rho g} \frac{D}{L} \frac{2g}{\overline{V}^{2}}$$