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«MIP: Engineering-2020: Modernization, Innovations, Progress: Advanced Technologies in Material Science, Mechanical and Automation Engineering»

«Numerical modeling of viscous currents near axial symmetric surfaces»

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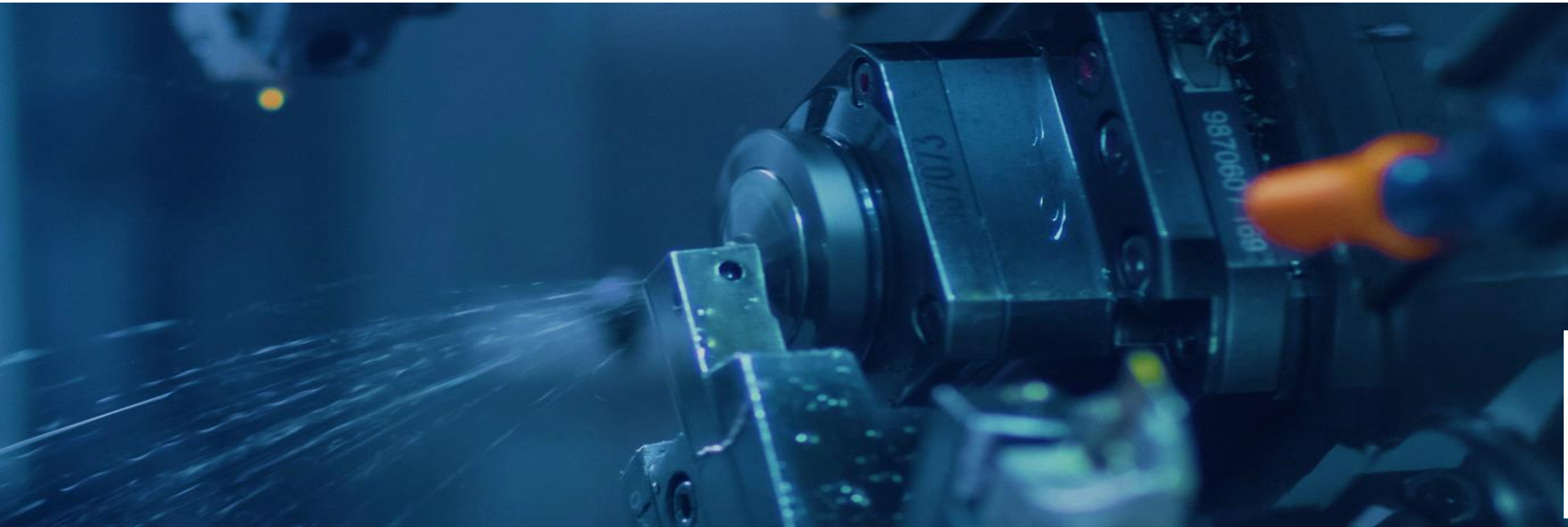
Problem statement

- Flow study near axial symmetric surfaces divides to subcritical and supercritical Reynolds numbers
- In the range of supercritical Reynolds numbers flow changes from laminar to turbulent
- Task: describe mathematical model for Reynolds number more than $2 \cdot 10^5$



Solution methods

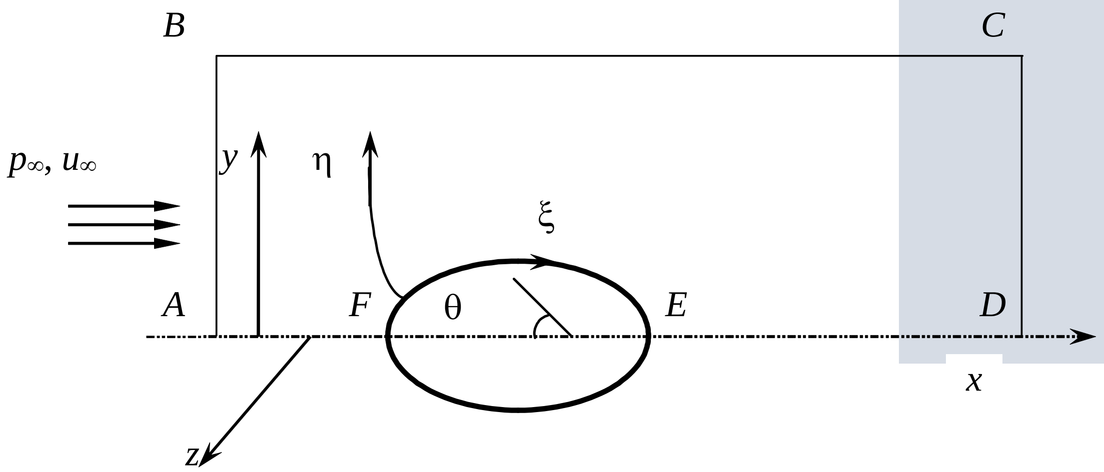


Figure 1. Range of integration

Solution methods

(ξ, η) - orthogonal curvilinear axial symmetric system of coordinates

$$\mathbf{F}_\xi + \mathbf{G}_\eta = \mathbf{P} + \mathbf{R}_\xi + \mathbf{H}_\eta + \mathbf{S},$$

$$\mathbf{F} = yDU\begin{bmatrix}\rho \\ \rho u \\ \rho v\end{bmatrix}, \ \mathbf{G} = yDV\begin{bmatrix}\rho \\ \rho u \\ \rho v\end{bmatrix}, \ \mathbf{P} = -y\begin{bmatrix}0 \\ p_\xi x_\xi - p_\eta y_\xi \\ p_\xi y_\xi + p_\eta x_\xi\end{bmatrix}, \ \mathbf{R} = y\mu\begin{bmatrix}0 \\ u_\xi \\ v_\xi\end{bmatrix}, \ \mathbf{H} = y\mu\begin{bmatrix}0 \\ u_\eta \\ v_\eta\end{bmatrix},$$

$$\mathbf{S} = \begin{bmatrix}0 \\ -\mu_\xi\left(vx_\xi + yv_\eta\right) + \mu_\eta\left(vy_\xi + yv_\xi\right) \\ \mu_\xi\left(-vy_\xi + yu_\eta\right) - \mu_\eta\left(vx_\xi + yu_\xi\right)\end{bmatrix}, \ U = \frac{1}{D}\left(ux_\xi + vy_\xi\right), \ V = \frac{1}{D}\left(-uy_\xi + vx_\xi\right), \ D = x_\xi^2 + y_\eta^2 .$$

Solution methods

One-equation turbulence model don’t give adequate results. Consider next two-equation turbulence model. Numerical algorithm based on *SIMPLE.*

$$\mathbf{F} = yDU\begin{bmatrix}\rho E\\ \rho\varepsilon\end{bmatrix},\ \mathbf{G} = yDV\begin{bmatrix}\rho E\\ \rho\varepsilon\end{bmatrix},\ \mathbf{R} = y\mu\begin{bmatrix}E_\xi\\ \varepsilon_\xi\end{bmatrix},\ \mathbf{H} = y\mu\begin{bmatrix}E_\eta\\ \varepsilon_\eta\end{bmatrix},\ \mathbf{S} = yD\begin{bmatrix}\mu_T Q - \rho\varepsilon\\ c_\mu c_1 Q E - c_2\rho\dfrac{\varepsilon^2}{E}\end{bmatrix},$$

$$c_1 = 1{,}44\ ,\ c_2 = 1{,}92\ ,\ c_\mu = 0{,}09\ ;\ \mu_T = c_\mu E^2/\varepsilon\ ,$$

Solution methods

Finite-difference grid was generate using method based on solving Laplace equation (conformal map)

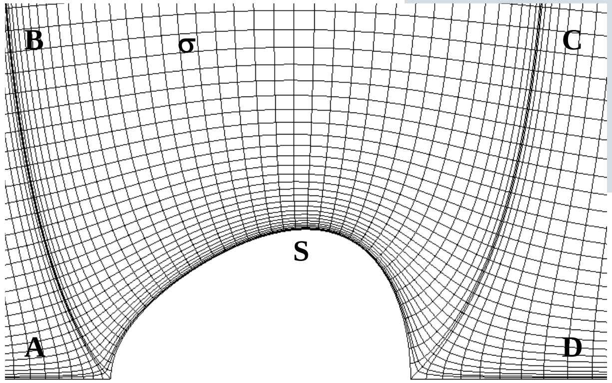


Figure 2. Curvilinear grid

Solution methods

Simulated results are very closely to experimental

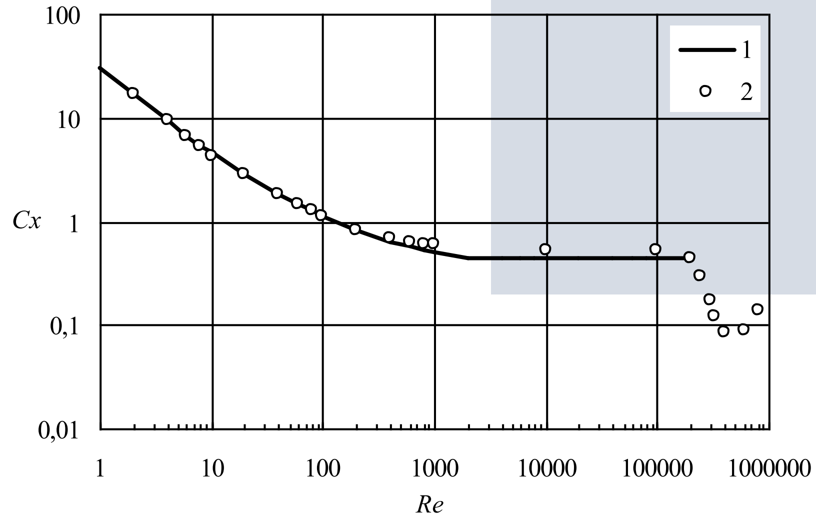


Figure 3. Drag coefficient as function of Reynolds number

Solution methods

Visual results shown at fig.4 and fig.5

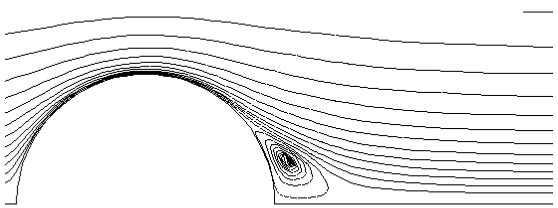


Figure 4. Sphere

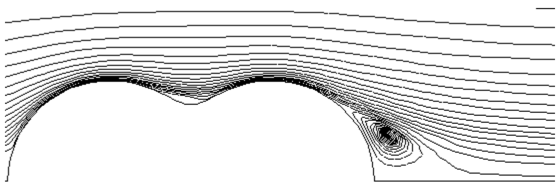


Figure 5. “dumbbell”

Conclusions

Results, implementation

Shown mathematical model adequately describe boundary layer physical processes near axial symmetric surfaces.

Could be used to:

- solve turbulent erosive burning;
- calculate flow parameters;
- modelling turbulent flows.

Contacts

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