A generalized approach towards a new log law of the wall in Taylor-Couette flows at intermediate Reynolds numbers

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Introduction

- Classical log-law is optimal at high Re N° even in Taylor-Couette system [1].
- However, at intermediate Re N° in the TC system, significant deviations from the classical log-law can be observed near the cylindrical walls [1,2].
- Singh et al [3] presented a new law of the wall, which behaves nonlinearly with the radial distance, based on the turbulent mixing length.

Objective

To create a generalized approach towards the estimation of the two constants of integration: Mixing Length, C_{lm}, and log law, C_U.

Log Law

Simplified RANS equation: $r^2(\nu+\nu^t)r\,\partial(\overline{U_\theta}/r)/\partial r = -r_i^2 U_i^{*2}$

Turbulent viscosity: $\nu^t(r) = l_m^2(r) r\,\partial(\overline{U_\theta}/r)/\partial r$

Mixing length as introduced by prandtl: $l_m(r) = r_i/r^2\, U_i^*/(\partial(\overline{U_\theta}/r)/\partial r)$

Mixing length profiles near inner and outer cylinder:

$$l_{mi}(r) = C_{lm}\delta_i^2 U_i^*/\nu,$$
$$l_{me}(r) = C_{lm}\delta_e^2 U_e^*/\nu,$$

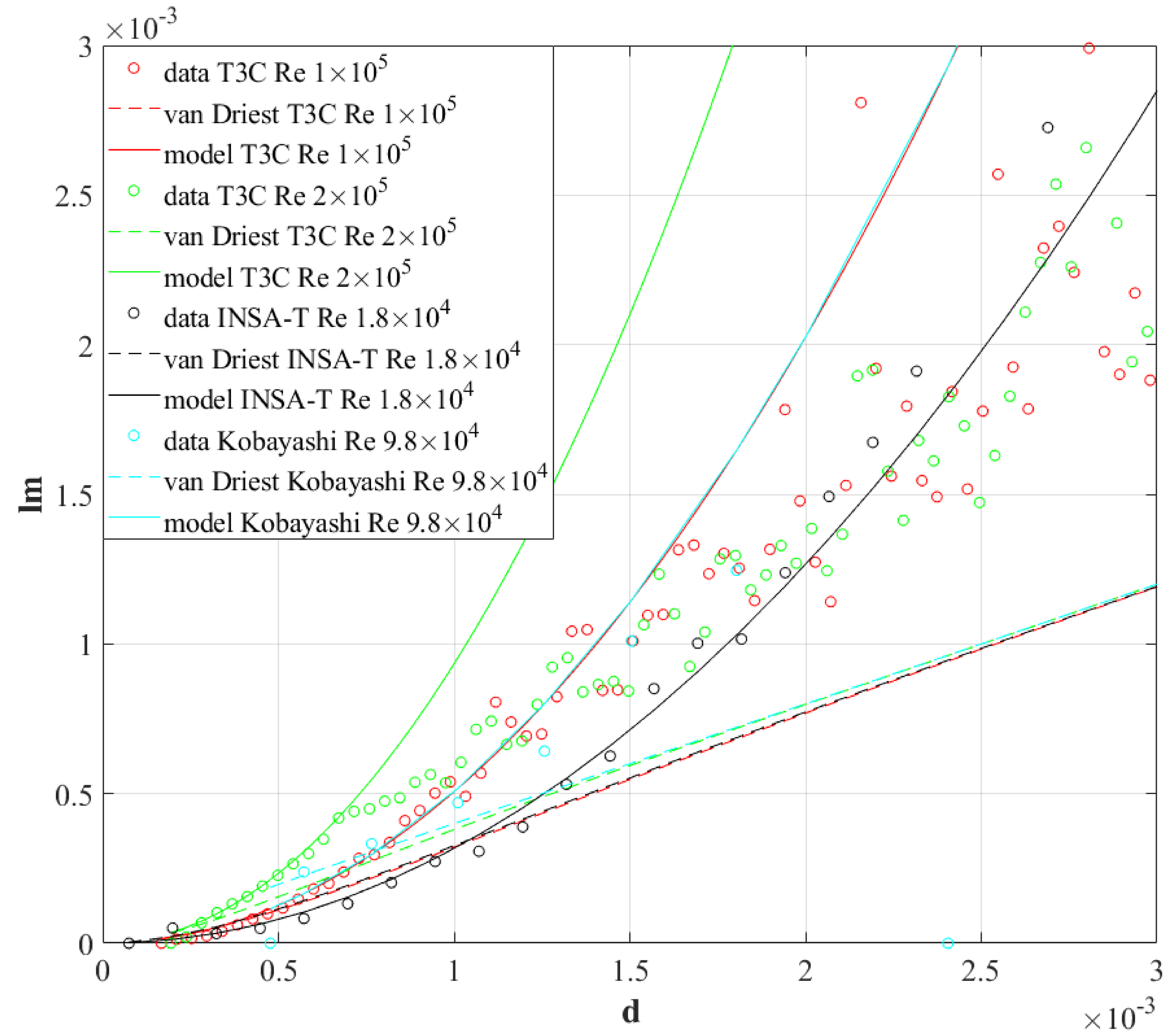
Inserting the mixing length in RANS, we get:

$$\partial(\overline{U_\theta}/r)/\partial r = (-r_i\nu)/(C_{lm}r^2(r-r_i)^2)$$

Upon integration, we get:

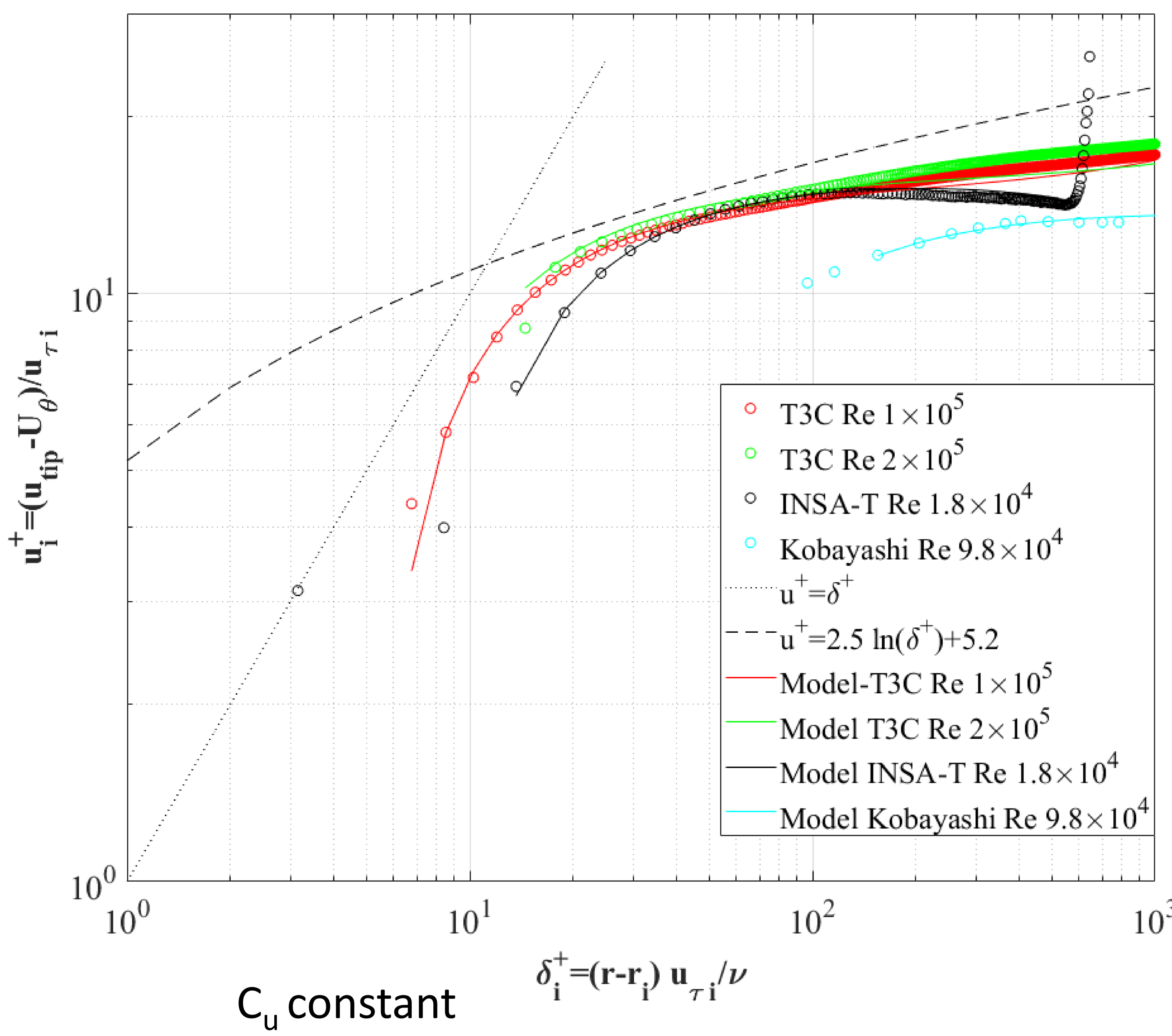
$$\frac{U_{tip}-\overline{U_\theta}(r)}{U_i^*} = -\frac{1}{C_{lm}r_i^+}\frac{r_i-2r}{\delta_i} + \frac{2}{C_{lm}r_i^+}\frac{r_i+\delta_i}{r_i}log\left(\frac{\delta_i}{r_i+\delta_i}\right) + \frac{C_U(r_i+\delta_i)}{U_i^*}$$

Mixing length profile

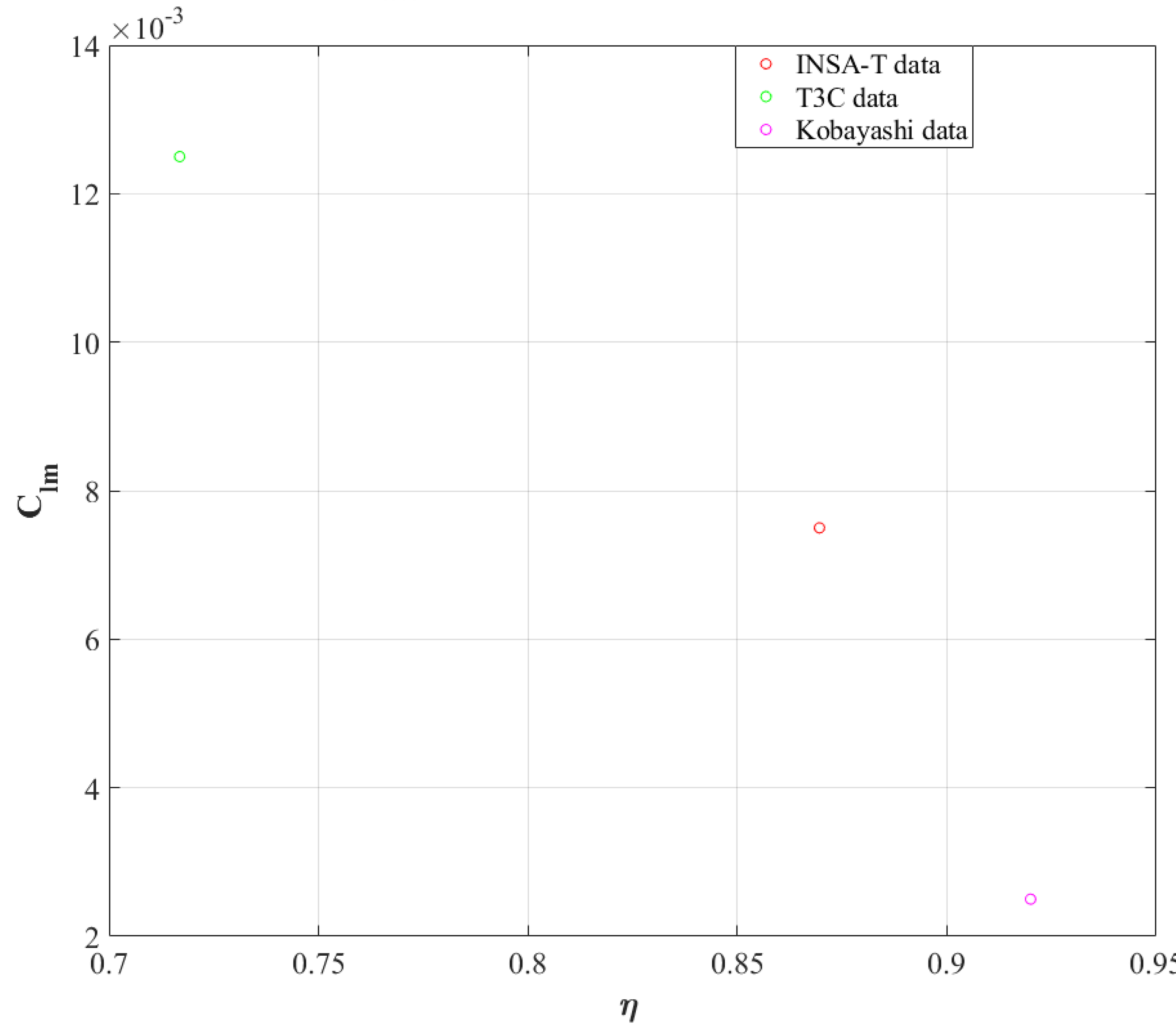


Results

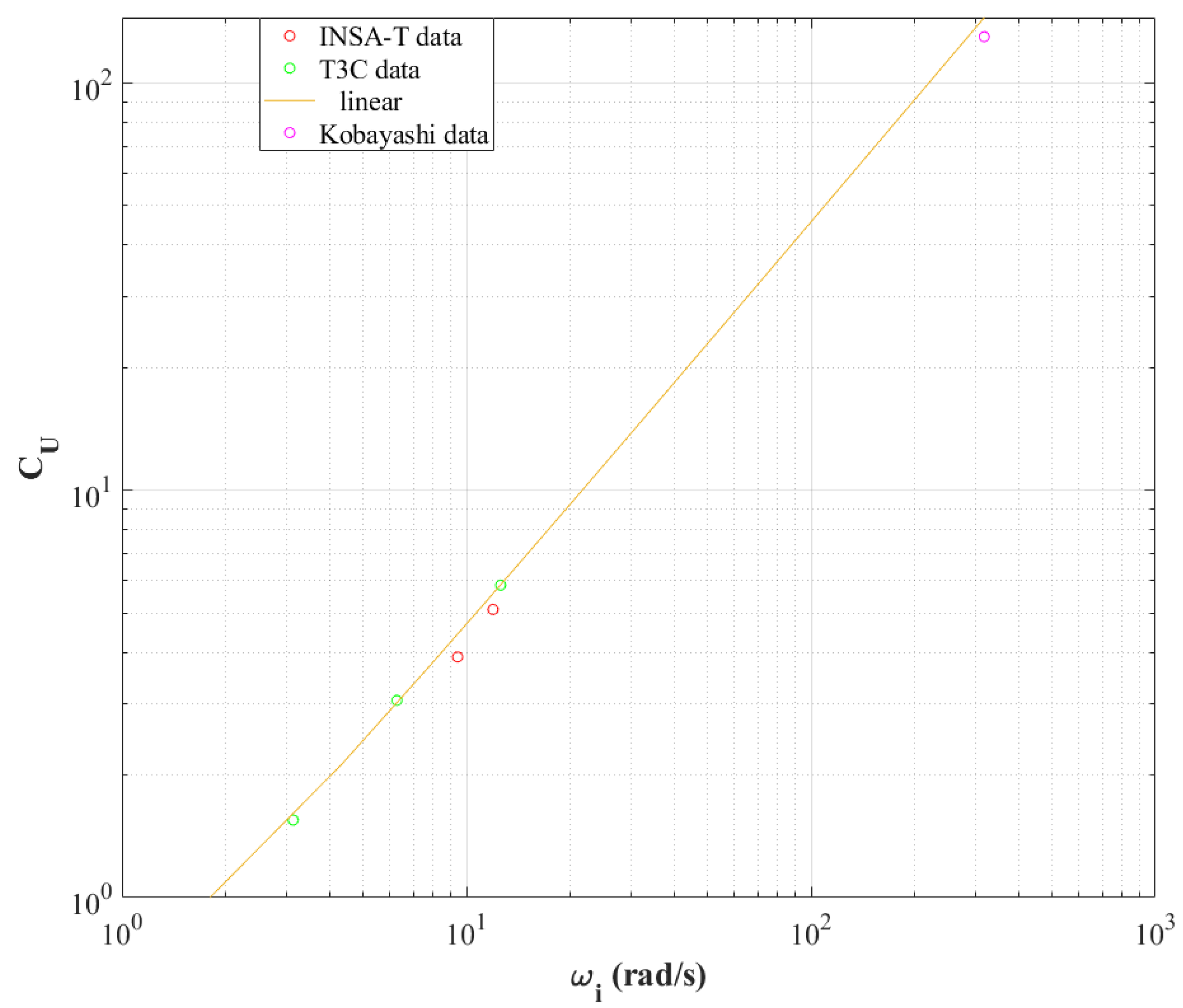
Velocity profile



C_{lm} constant



C_u constant



References

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4. Kobayashi, M. et al**. An experimental study on turbulent taylor vortex flow between concentric cylinders,** JSME Journal II, v.33, n.3, p.436-445 (1990).