

MEMO No CFD/TERMO-20-97

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TITLE

Pipeflow manual

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ABSTRACT

MAIN RESULT

a Program for pipeflow calculations

PAGES

8

KEY WORDS

Pipe flow

APPROVED BY

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1 About the Pipeflow

The Pipeflow is a program that calculates the distributions of velocity and turbulence quantities in fully developed turbulent pipe flow. The distributions have been read from Hinze [1], and experiments are made by Laufer in 1954.

2 Theory

2.1 Velocity

The velocity profile is determined according to figures 1 and 2. Then those values are interpolated to calculation points (NPNTS=65 in main program). First the correction function

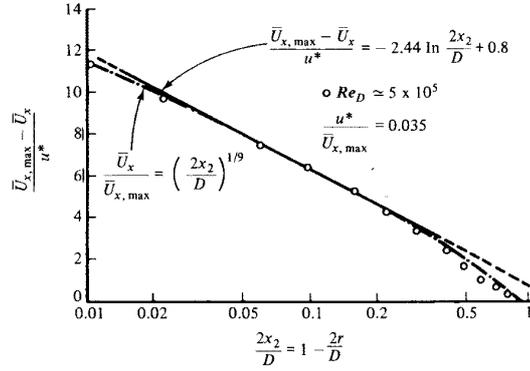


Fig. 1: Velocity profile in pipe.

h has been read from Hinze [1] Fig.7-54 (fig. 2) in 11 points. Then the profile is calculated

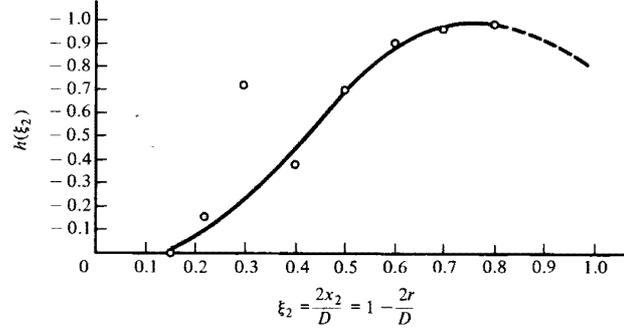


Fig. 2: Velocity profile correction function.

from the Eq.(1) as

$$\frac{U_{max} - U}{u^*} = -2.44 \ln(x_{wall}) + 0.8 + h(x_{wall}) \quad (1)$$

where $x_{wall} = 1 - 2r/D$ and u^* is the shear velocity (sometimes noted as u_τ). The shear velocity is calculated from (ref. [2])

$$u^* = u_\infty \sqrt{\lambda/8} \quad (2)$$

where λ is a friction factor. If the flow is laminar ($Re < 2000$) $\lambda = 64/Re$ and if it is turbulent, the Blasius's equation $\lambda = 0.3164/Re^{0.25}$ is used (ref. [2]). The Reynolds number

is calculated from

$$Re = \frac{U_\infty D}{\nu} \quad (3)$$

Because this log-profile is not a very good approximation near the wall and in the centerline the following equation is used.

$$\frac{U}{U_{max}} = (x_{wall})^{1/9} \quad (4)$$

The final profil is calculated so that it is the maximum of the given two profiles. The average velocity is used as U_{max} here. This gives too low velocities and because of that the profile has to be scaled. After the scaling the profile is written to file VELOCITY.DAT.

2.2 Turbulence kinetic energy

The distribution for turbulence kinetic energy is calculated from fluctuating velocities in three directions. Those fluctuating velocities have been read from Hinze [1] (Fig. 7-56) (fig. 3) (measured by Laufer).

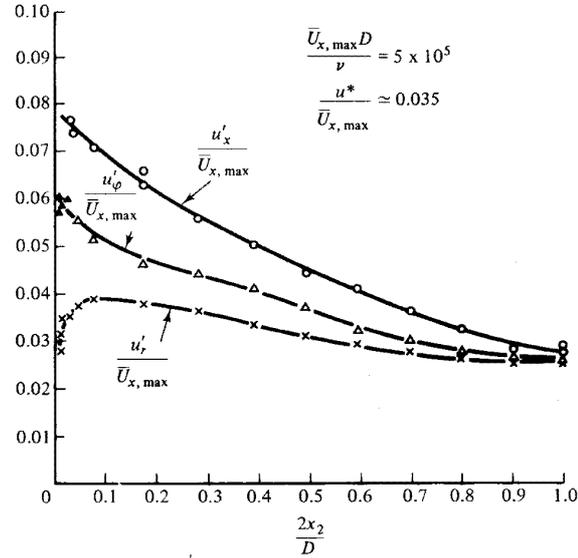


FIGURE 7-56

Fig. 3: Fluctuating velocities.

The Turbulence level as a function of dimensionless distance from wall is calculated first. That distance is defined so that it is zero at the wall and one at the rotation axis. The turbulence level in measured data is calculated from equation

$$Tu = \frac{1}{U_\infty} \sqrt{\frac{1}{3} (u'^2 + v'^2 + w'^2)} \quad (5)$$

And after that the average turbulence level is calculated by integrating the local turbulence level over the whole area (from 0 to 1).

When the turbulence level of the measured data is calculated, the fluctuating velocities are interpolated to calculation points and the local turbulence level in user's case can be obtained. After that the kinetic energy of turbulence is calculated from equation

$$k = (Tu \cdot U_\infty)^2 \cdot \frac{3}{2} \quad (6)$$

The kinetic energy of turbulence is written to file TURBK.DAT.

2.3 The dissipation of turbulence kinetic energy

The dissipation distribution is divided to two parts. Near the wall the gradients are so great that it is convenient to present this data in two regions (figures 4 and 5). This data have been read in and values are interpolated to calculation points. These non-dimensional values are converted to dimensional form. Because of differences between the user's case and measured data also dissipation level has to be scaled. The scaling has been done so that the turbulent viscosity remains the same i.e. k^2/ϵ is constant. The dissipation of turbulent

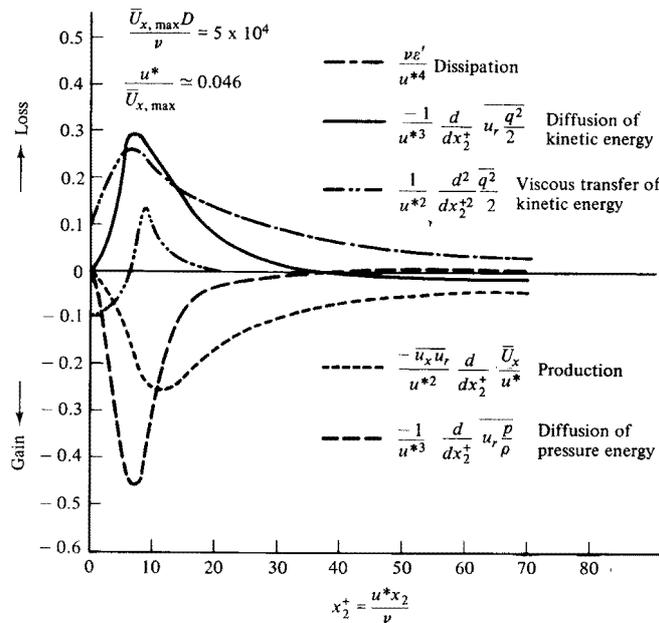


Fig. 4: Dissipation of k near the wall.

kinetic energy is written to file TURBEPS.DAT.

3 Using Pipeflow

This is the first version of the program and not much effort have been put on it. So if this program proves to be useful it can be further developed. If you have suggestions, comments or own modifications, please e-mail¹ me.

3.1 Input

All inputs are supposed to be in SI-units. Below are the explanations for inputs:

Give the Average velocity:

This is the average velocity of the flow. The velocity is calculated so that the massflow remains the same.

Give the diameter of the pipe:

Are you using water(1) or air(2):

The value of kinematic viscosity depends on medium.

Do you want to change (y/n):

You can change the automatically chosen kinematic viscosity.

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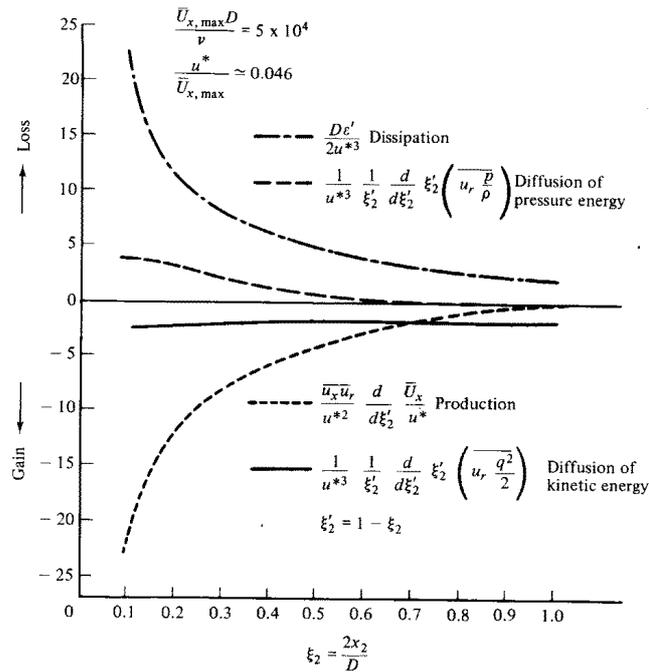


Fig. 5: Dissipation in core region.

Calculate distribution for k(1) or use uniform(2):

If you choose 1, program will calculate the k -distribution. If you choose 2, program will set a uniform distribution for k .

Give the turbulence level:

Turbulence level is between 0 and 1.0.

3.2 Output

The output files:

VELOCITY.DAT

The velocity profile. The first column is distance from rotation axis, the second is y^+ , the third is dimensionless distance from wall ($1 - 2r/D$) and the final column is velocity. See appendix fig. 6 and 7.

TURBK.DAT

The distribution of k . The first column is distance from rotation axis and the second is y^+ . See appendix fig. 8

TURBEPS.DAT

The distribution of ϵ . The first column is distance from rotation axis and the second is y^+ . See appendix fig. 9 and 10.

FLUCT.DAT

The distribution of fluctuating velocities. The first column is distance from rotation axis. The second one is the longitudinal component, the third one is the circumferential (tangential) component, and the fourth one is the radial component.

YPLUS.DAT

The dimensionless distance from the wall in calculation points. If the y^+ of the first point is too great you can change the code. The y^+ -values can be modified by changing the number of calculation points (NPNTS) or by modifying the function that calculates the distribution for calculation points. The existing routine is

```
X = REAL(I-1) / REAL(NPNTS-1) ! BETWEEN 0...1
POW      = 2.2
DWALL(I) = X**POW * DIAM/2.      ! CLUSTER NEAR THE WALL
DWALLO(I) = X**POW
```

References

- [1] J. O. Hinze. *Turbulence*. McGraw-Hill, inc, New York, USA, 1987. ISBN 0-07-029037-7.
- [2] Paul A. Wuori. *Virtausmekaniikan perusteet*. Otatiето, Otaniemi, Finland, 1990. ISBN 951-672-153-2.

A Examples of velocity, k and ϵ -profiles

Here is an example run of pipeflow.

```

Give the Average velocity:
4.5
Give the diameter of the pipe:
0.25
Are you using water(1) or air(2)
1
Using value 0.1791E-05 for kinematic viscosity
Do you want to change (y/n):
n
The Reynolds number is 628140.69
The flow is turbulent
The shear velocity is 0.1687
Calculate distribution for k(1) or use uniform(2):
1
Give the turbulence level:
0.05

```

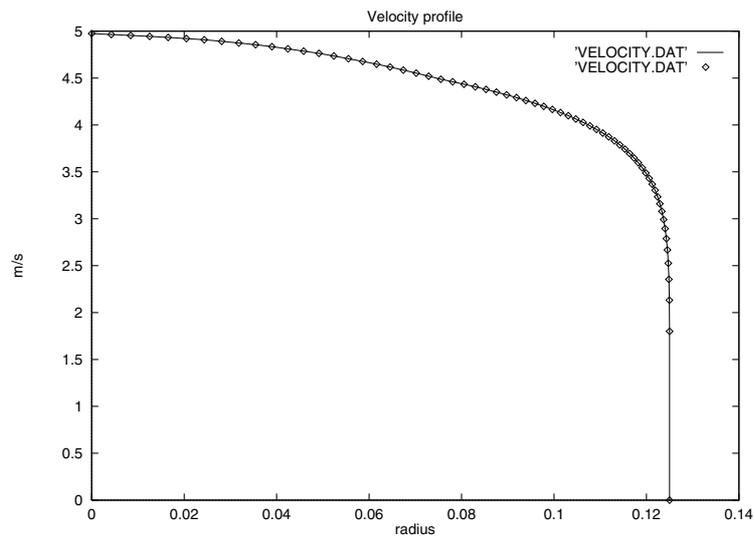


Fig. 6: Velocity profile

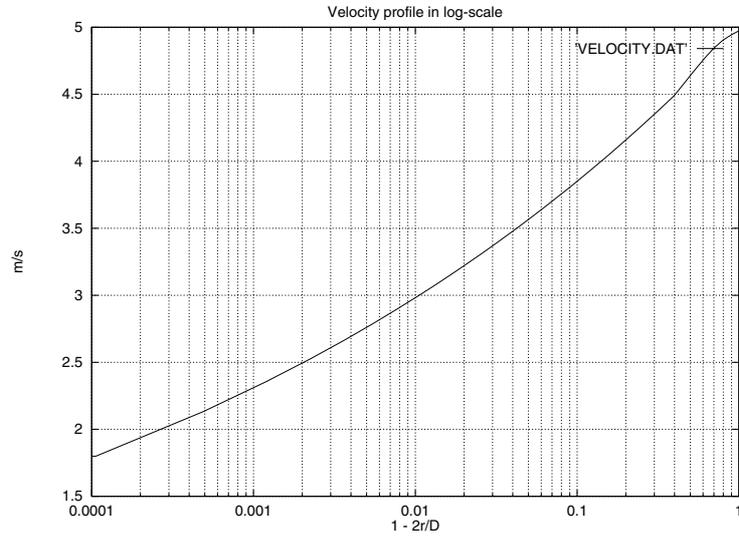


Fig. 7: Velocity profile in log-scale

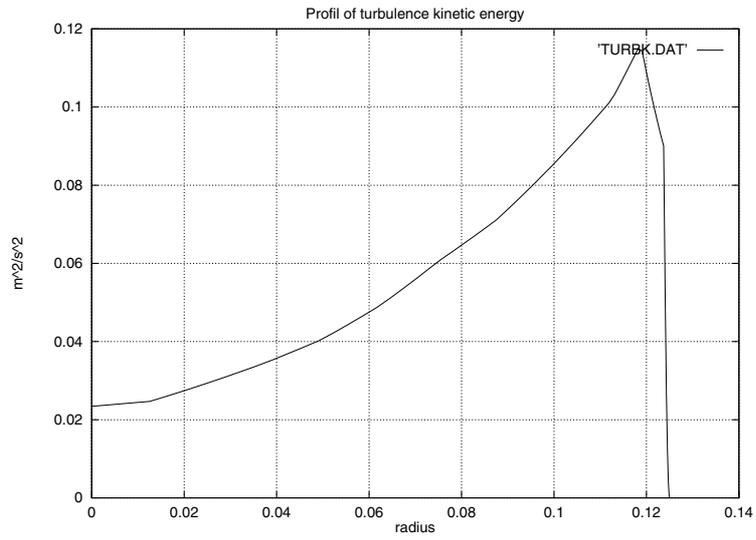


Fig. 8: The profile of turbulent kinetic energy.

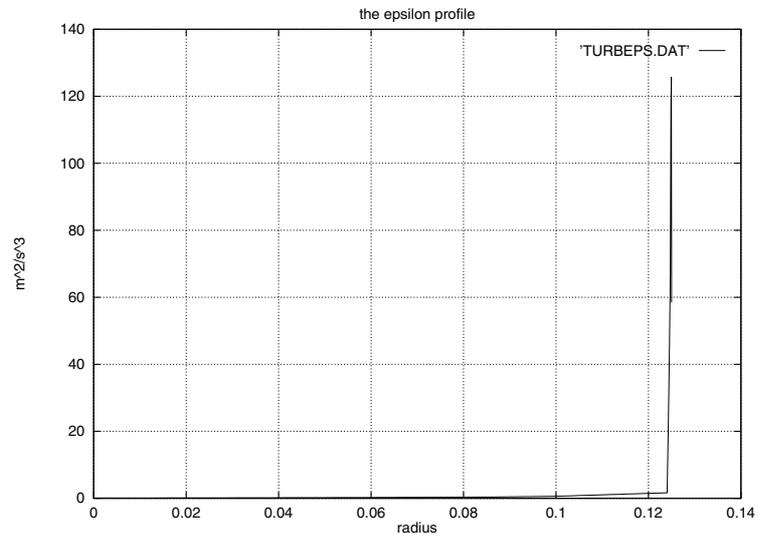


Fig. 9: The profile of dissipation.

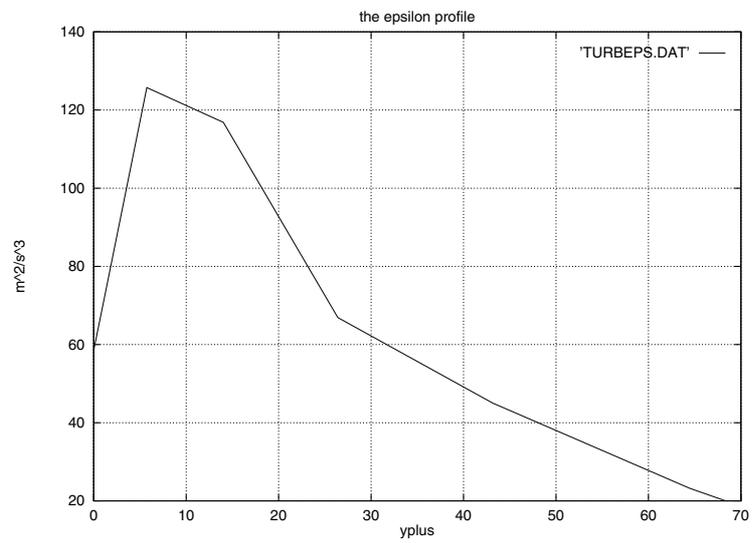


Fig. 10: The profile of dissipation near the wall.