ENGR 218

Project report

Hot-wire anemometer calibration

Ahmed Nasser Saleh / 202000466

Abdelrahman Fouda / 202001261

Yara Mahboub / 202001848

Introduction

In this project, we want to design a setup used to measure instantaneous flow velocity called hot-wire anemometer. It is simply a thermal transducer that measure flow velocity through electric voltage measurements. When a heated wire is put in a position of a flowing gas, heat is transferred from the wire to the gas, so the resistance of the wire starts gradually changing which indicates the flow rate.

Problem statement

In the following project, we want to calibrate of a hot-wire anemometer. This is done by estimating the Nusselt number, which is a ratio between convective and conductive heat transfer in a boundary, for 1 <= Re <= 100 and from the following we will get the convective heat transfer coefficient “h”. Moreover, it is required to determine power input to maintain wire temperature difference (between wire and the air flow) between 10 and 100k in the same range of Reynold’s number.

Analytical solution (governing equation)

Considering a wire as a cylinder of diameter ‘D’ = 5*10^-6 m. the flow across it generally contains flow separation which must be numerically handled by some calculations of heat transfer and heat transfer coefficients. One of the used equations will be Nusselt number for cross flow over a cylinder which equals Nu_cyl = hD/k = 0.3+((0.62Re^0.5*Pr^0.333)/((1+(0.4/Pr) ^ (2/3)) ^ (1/4))) * (1+(0.4/Pr) ^ (5/8)) ^ (4/5)

Design of Ansys:

- **Geometry**

We will first make a container by constructing its dimensions "we used L= 100 µm and w= 50 µm and h=20 µm" on x-y plane then we will add a hole of **diameter** =5*10^-6m inside the container then we will extrude it and then we will choose (show all bodies) to make it hollow as shown in figure (1).

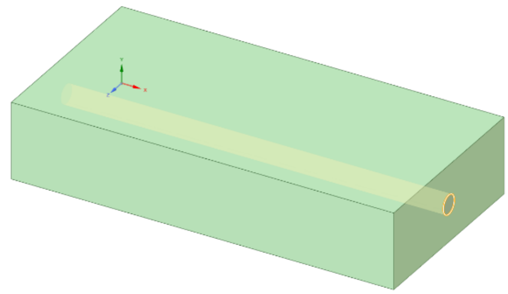

Fig 1. The geometry of the system

- **Meshing:**

<u>Design:</u>

we are going to activate advanced sized function for custom meshing. Then we will make a scope in the wire and add number of n divisions, about 30. Then apply meshing. a heat source is put in the cylinder. We can check the validity of it by doing the following:

If the measured surface temperature difference of the cylinder after applying the heat source and the flow is between 10K to 100k so it is valid.

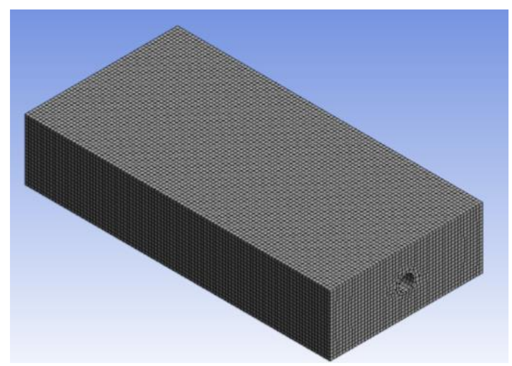

Fig 2. The mesh is shown.

Then we will add the given Reynold's number where its range is from 1 to 100.

We then do mesh analysis and named 7 sections:

- Inlet
- Outlet
- Heat source
- Fluid domain
- Wire wall
- Wall of box
- Contact surface (lateral area of the wire)

Quality:

The skewness and orthogonality of the mesh is shown in figures (2) and (3). The value of skewness (very low value) and orthogonality (value near to 1) shows that the mesh is excellent.

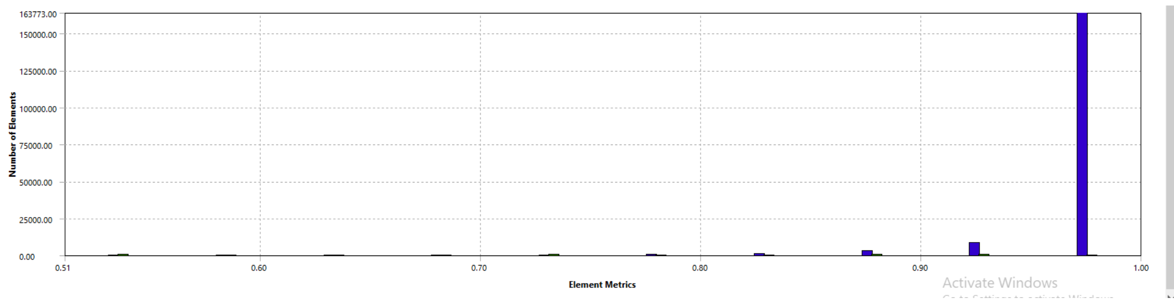

Fig 3. Orthogonality

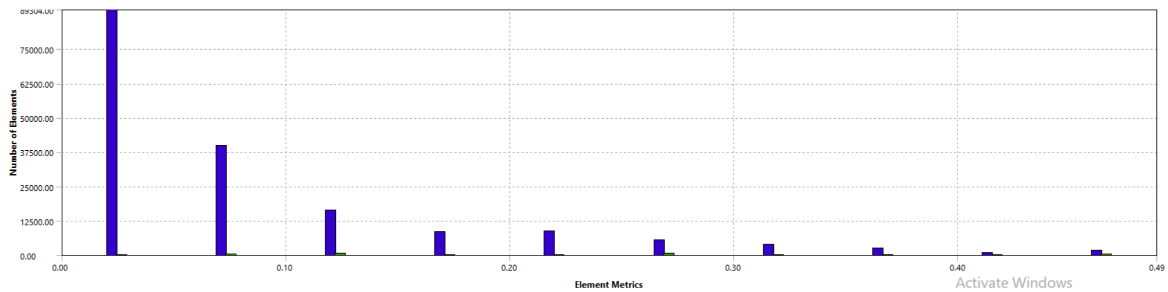

Fig 4. Skewness

- **Setup and solution**

the final system is shown in figure (5). Gravitational force on the y axis = 9.8 is applied. A heat source is added to the cylinder with value of 70000000 W/m3. The velocity of the flow is 1.65 m/s (inlet boundary condition). multiple graphs are formed with 30 iterations. The graphs are for Nusselt number, total heat transfer, and convective heat transfer coefficient “h”.

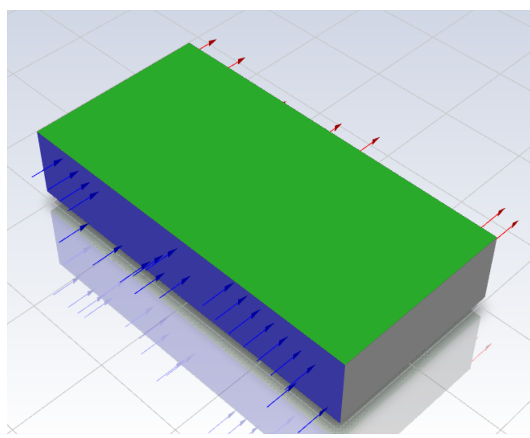

Fig 5. Final System with direction of the flow

Results

The following graphs show the Nusselt number, total heat transfer, and convective heat transfer coefficient, respectively.

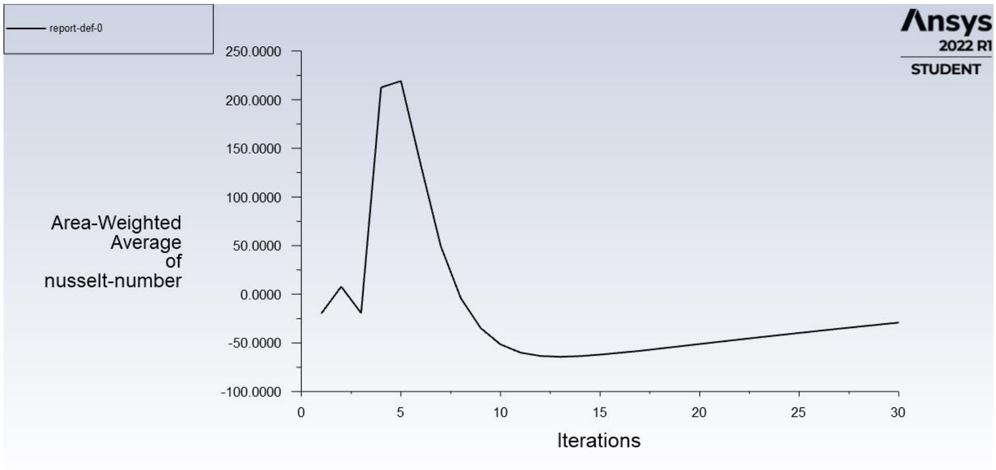

Fig 6. Nusselt number

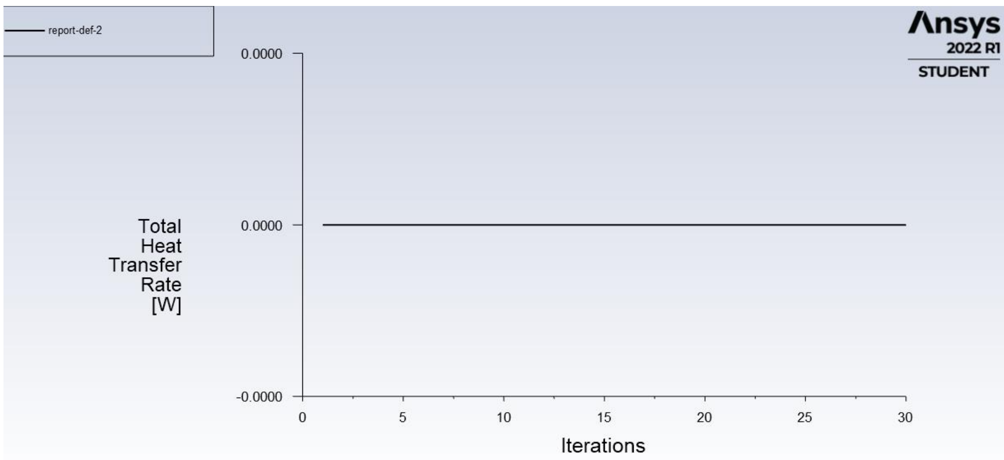

Fig 7. Total heat transfer

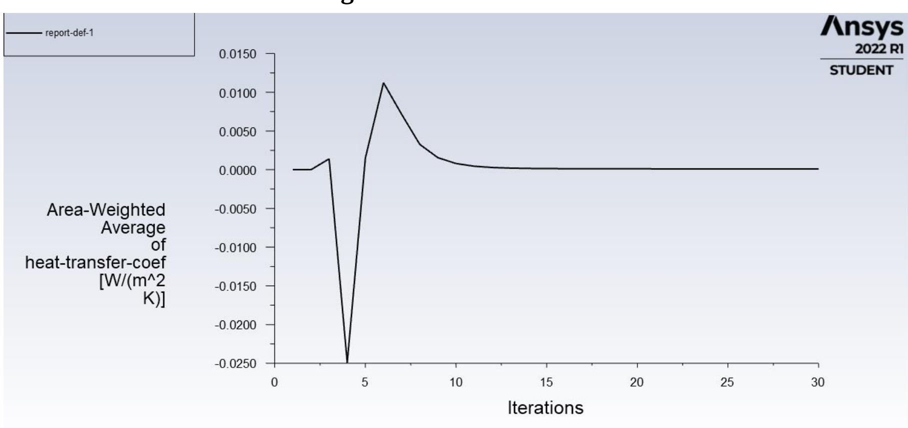

Fig 8. Convective heat transfer coefficient

The following figures show the contours of temperature, pressure, and velocity, respectively.

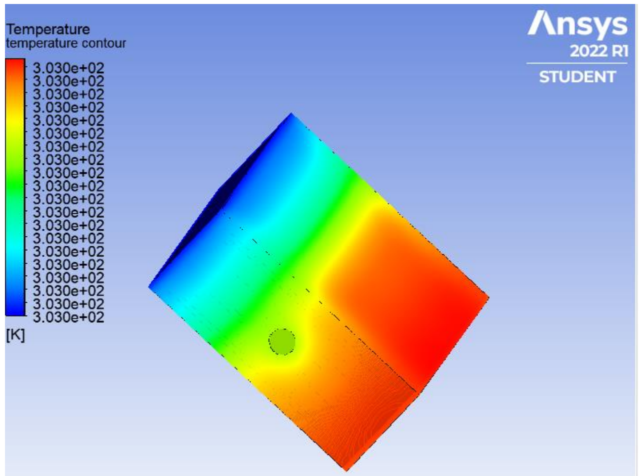

Fig 9. Temperature

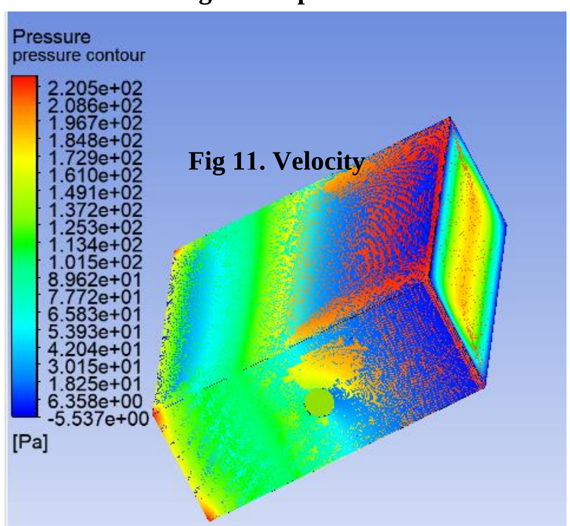

Fig 10. Pressure

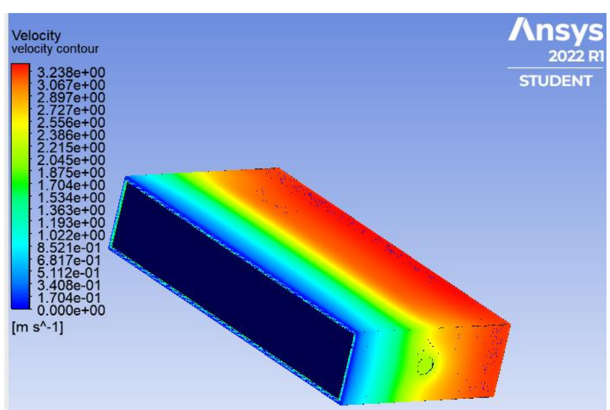

Fig 11. Velocity

The following figures shows the graphs of area weighted average of Nusselt number and Nusselt number vs position, respectively.

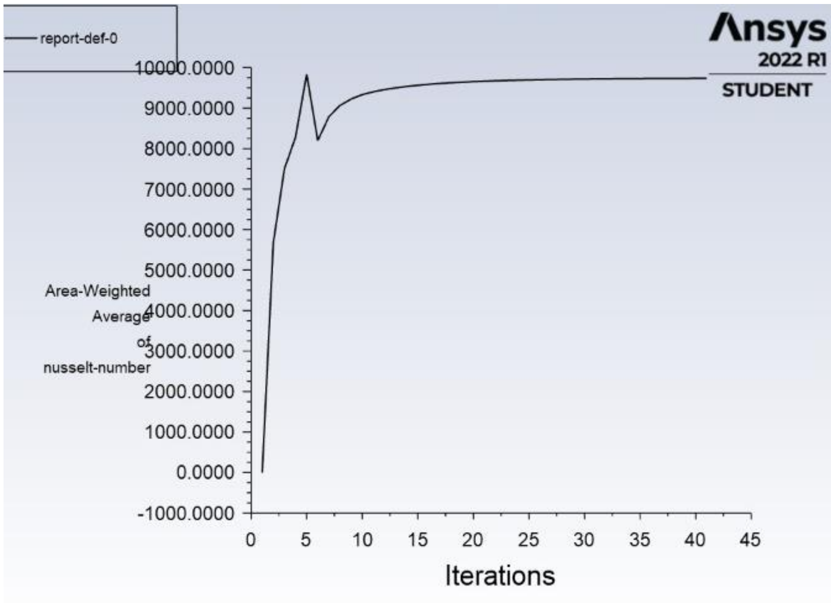

Fig 12. Area weighted average of Nusselt number graph

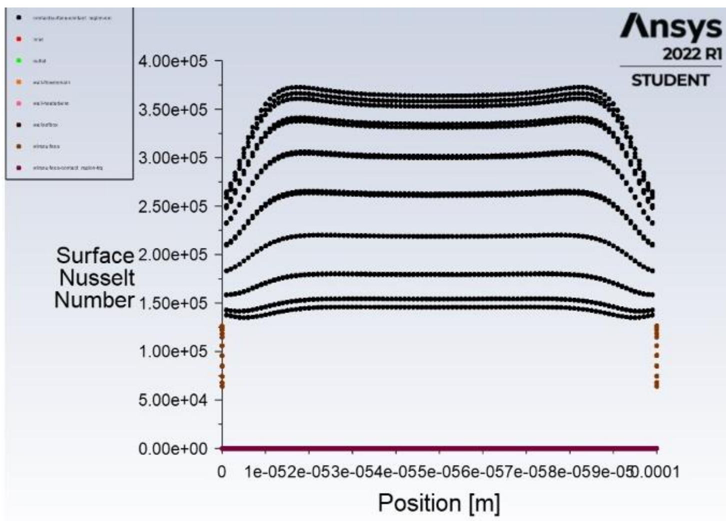

Fig 13. Nusselt number vs position

Comments and conclusion

Finally, it is seen that solving this system analytically and using a software like ANSYS giving different answers. Maybe there is something wrong in the calculations we’ve done or there is something wrong that we did while designing the system on ANSYS as the Nusselt number we got is negative, which looks illogical.

References

Çengel, Y. A., Cimbala, J. M., & Turner, R. H. (2017). Flow across cylinders and spheres. In Y. A. Çengel, J. M. Cimbala, & R. H. Turner, Fundementals of Thermal-Fluid Sciences (pp. 776 - 783). New York: McGraw-Hill Education.