YILDIZ TECHNICAL UNIVERSITY

DETERMINING HEAT TRANSFER COEFFICENTS OF 0.08 mm, 0.1 mm DIAMETER WIRES IN WIND TUNNEL

MECHANICAL ENGINEERING DEPARTMENT

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LIST OF ABBREVIATIONS

TLC : Thermocromic Liquid Crystal

CFD : Computational Fluid Dynamics

LIST OF SYMBOLS

Q : The heat transferred

I : Current

V : Voltage

Re: Reynolds Number

ρ : Density of fluid (kg/m^3)

V : Bulk velocity (m/s)

η : Viscosity

λ : Fluid conductivity

c_p : Specific heat

μ : Dynamic viscosity of the fluid (Pa·s or N·s/m² or kg/(m.s))

υ : Kinematic viscosity ({\bold \nu} = \mu /{\rho}) (m²/s)

ε: Emissivity

σ: Stefan–Boltzmann constant

Nu: Nusselt Number

h : Convection heat transfer coefficient (W/m^2*K)

D : The characteristic distance such as a diameter

L : Characteristic Linear Dimension (m)

k : Constant thermal conductivity (W/m*K)

k = Heat conduction coefficent (W/m)

Pr : Prandtl number

T_S : Wire temperature (°C)

T_{SURR} : Air temperature (°C)

α : Heat conduction according to material (W/m*K)

A : Cross sectional area

D_h : Hydraulic diameter

DETERMINING HEAT TRANSFER COEFFICENTS OF 0.08 mm, 0.1 mm DIAMETER WIRES IN WIND TUNNEL

ABSTRACT

We aimed to determine the number of heat transfer for wires of different diameters for detailed research in parallel and cross flow by using a wind tunnel. These correlations were found experimentally by passing air over certain diameters of wires at lab. The wire diameters used in the experiment are 0.08 mm, 0.1 mm and air velocities are 1m/s, 1.5m/s, 2m/s, 2.5m/s, 3m/s, 3.5m/s, 4m/s, 4.5m/s, 5m/s. Wires of various diameters are placed in the air turbine. These wires are heated and the heat transfer coefficients with the specified air flows are found. A power supply is used for the heating operation. A multimeter was used to determine the voltage and current values and the resulting wire resistances were calculated. The power that given is equal to the power that taken. Electrical power is equal to exertion on convection heat transfer and radiation heat transfer. The heat transfer coefficient is obtained from the formulas of convection heat transfer coefficient and radiative heat transfer coefficient. Fand-Keswani, Churcil, Hilpert correlations in the literature are used in cross-flow. Andrews, PEEK, Kese Matsuo correlations were applied in calculations in parallel flow situations. In the experiments, it was also observed that the heat transfer coefficient change in the wires of different diameters takes place depending on the diameter. The results of the tests are detailed with formulas, tables and graphics. In summary: we are determinig correlations by finding the heat transfer coefficients. We model the cooling with these experiments.

ÖZET

Bir rüzgar tüneli kullanarak paralel ve çapraz akış içerisinde farklı çaplardaki tellerin ısı transfer sayısının belirlemesi amaçlanmıştır. Bu korelasyonlar deneysel olarak laboratuardaki belirli çaplardaki teller üzerinden hava akışı geçirilerek bulunmuştur. Deneyde kullanılan tel çapları 0.08 mm, 0.1 mm ve hava hızları 1m / s, 1.5m / s, 2m / s, 2.5m / s, 3m / s, 3.5m / s, 4m / s, 4.5m / s, 5m / s'dir. Hava türbinine çeşitli çaplardaki teller yerleştirilmiştir. Bu teller ısıtılır ve belirtilen hava akışlarına sahip ısı transfer katsayıları bulunur. Isıtma işlemi için bir güç kaynağı kullanılır. Voltaj ve akım değerlerini belirlemek için bir multimetre kullanılır ve elde edilen tel dirençleri hesaplanır. Verilen güç, alınan güce eşittir. Elektrik gücü; konveksiyon ısı transferi ve radyasyon ısı transferlerinin toplamına eşittir. Isı transfer katsayısı; konveksiyon ısı transfer katsayısı ve radyasyon ısı transfer katsayısı formüllerinden elde edilir. Deney sonuçları literatürde yer alan Fand-Keswani, Churcil, Hilpert korelasyonları çapraz akışta kullanılmıştır. Andrews, PEEK, Kese Matsuo korelasyonları ise paralel akış durumlarında ki hesaplamalarda uygulanmıştır. Deneylerde ayrıca farklı çaplardaki tellerde ısı transfer katsayısı hesaplamasında çapa bağlı olarak ısı transfer katsayısı değişimi ne yönde gerçekleştiği gözlenmiştir.Testlerin sonuçları; formüller, tablolar ve grafikler ile detaylandırılmıştır. Özet olarak: ısı transfer katsayılarını bularak, korelasyonlar belirlenmiştir. Bu deneyler ile soğutmayı modellenmiştir.

1. INTRODUCTION

The transfer of energy as heat is always from the higher-temperature medium to the lower-temperature one, and heat transfer stops when the two mediums reach the same temperature. Heat can be transferred in three different modes: conduction, convection, and radiation. All modes of heat transfer require the existence of a temperature difference, and all modes are from the high-temperature medium to a lower-temperature one.

Conduction is the transfer of energy from the more energetic particles of a substance to the adjacent less energetic ones as a result of interactions between the particles. Conduction can take place in solids, liquids, or gases.

Convection is the mode of energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion. The faster the fluid motion, the greater the convection heat transfer. In the absence of any bulk fluid motion, heat transfer between a solid surface and the adjacent fluid is by pure conduction. The presence of bulk motion of the fluid enhances the heat transfer between the solid surface and the fluid, but it also complicates the determination of heat transfer rates.

Radiation is the energy emitted by matter in the form of electromagnetic waves (or photons) as a result of the changes in the electronic configurations of the atoms or molecules. Unlike conduction and convection, the transfer of energy by radiation does not require the presence of an intervening medium. In fact, energy transfer by radiation is fastest (at the speed of light) and it suffers no attenuation in a vacuum. This is how the energy of the sun reaches the earth. The heat transfer mechanisms used in this thesis are convection and radiation heat transfer mechanisms. These mechanisms are formed on the wires in the wind tunnel environment. The heat transfer with the radiation of the environment in which the wire is located is a size that can not be negligible, so the results obtained by making only the convection heat transfer coefficient are not healthy.

2. LITERATURE RESEARCH

2.1.CONVECTION HEAT TRANSFER

Heat transfer by convection is one of the three mechanisms of heat transfer. Others are conduction and radiative. Convection is a type of heat transfer between the solid surface and the fluid.There are 2 types of convection heat transfer. They are natural and forced convection heat transer. Natural convection is the transport caused by the movement of the fluid due to the temperature differences existing in the fluid. Forced convection occurs when the fluid movement is due to an external effect such as a pump or fan. The regional convective heat flux of a fluid over a surface and total heat transfer are expressed as:

$Q_{Conv.} = h.\pi.D.L.(T_S-T_\infty)$ (D=diameter)

2.2.RADIATIVE HEAT TRANSFER

Radiation is the emission or transmission of energy in the form of waves or particles through space or through a material medium such as alpha radiation (α), beta radiation (β), and neutron radiation, electromagnetic radiation.Its equation is expressed as:

$Q_{Rad.} = \varepsilon.\,\sigma.\,\pi.D.L\,(T_S^4 - T_{SURR}^4)$ (D=diameter)

2.3.NATURAL CONVECTION

Natural convection is type of heat transport, in which the fluid motion is not generated by any external source like a pump, fan, suction device but only by density differences in the fluid occurring due to temperature gradients.

2.4.FORCED CONVECTION

Forced convection is type of transport in which fluid motion is generated by an external source like a pump, fan, suction device. It should be considered as one of the main methods of useful heat transfer as significant amounts of heat energy can be transported very efficiently.

2.5.TYPES OF FLOWS

There are two types of flows, namely the laminar and the turbulent. The flow type is determined by reynold number rangers. The reynold number ranges differ depending on whether the flow is internal flow or external flow. The dimensions of the cylinder, the speed of the flow is important while selecting the type of flows.

2.5.1. THE LAMINAR FLOW

The laminar flow is a fluid flow that occurs in laminar or layers that slip smoothly upon the adjacent laminas and layers, exchanging kinetic momentum on the molecular level. In the case of the laminar flow, the viscous forces of the fluid help to keep the instability and tendency for turbulence under control. Laminar flow causes less wear and attrition to the pipes or open channel walls. Laminar flow helps improve the performance of pumps and make it more predictable. Laminar flow helps retain the fluid’s kinetic energy as well as heat since the outermost layers act as insulating elements to up to a point.

2.5.2. THE TURBULENT FLOW

The turbulent flow occurs when the inertial forces overwhelm the viscous forces, so the fluid flow becomes “messy” with characteristics of vertical momentum switching. It is the most common flow type in real environment.

2.6. CROSS FLOW AND PARALLEL FLOW HEAT TRANSFER ON THE CYLINDER OBSTACLES

The position of the cylinder inside the wind turbine is very important. The heat transfer formulas vary depending on the position.Cross and parallel flow in this experiment.. The cylinder is positioned longitudinally at 0 degree angle with the parallel flow. The cylinder position for cross flow is 90 degrees. When a fluid flows across a solid object or ensemble of solids at a different temperature, crossflow heat transfer results. Heat transfer is a function of Reynolds Number,

$$\mathrm{Re} = \frac{\rho V D}{\eta}$$

and Prandtl Number,

$$\mathrm{Pr} = \frac{\eta c p}{\lambda}$$

where ρ is the density, V is a bulk velocity, η is viscosity, λ is the fluid conductivity, and c_p is specific heat. D is a characteristic length, such as a diameter. Another popular choice for crossflow heat exchangers is a hydraulic diameter, D_h.

2.7. REYNOLDS NUMBER

Reynolds number is the ratio of the inertia forces to the viscosity forces . The basic formula with which we can determine the Reynolds number for a given flow situation is: “Re = VDρ/µ” or “Re = V.D/v” where “V” is the fluid velocity, “D” is the characteristic distance, “ρ” is the fluid density, “ν” is the kinematic viscosity, and “µ” is the dynamic viscosity both of which can be acquired from data tables.

Re = ***V.D.ρ / µ***

Re = ***V.D / v***

2.8. NUSSELT NUMBER

In heat transfer at a boundary (surface) within a fluid, the Nusselt number (Nu) is the ratio of convective to conductive heat transfer across (normal to) the boundary. In Table 1 equations give the nusselt number for various flow conditions.

$Nu = h.D_h / k$

2.9.ARTICLE RESEARCH

In a study by Ravi and others in 2014, air flow and heat transfer in a two-dimensional circular cylinder unsteady flow regime were investigated. The effects of the Reynolds number on the drift and lift coefficients, the number of Strouhal, and the effect of a long circular cylinder on the heat transfer characteristic were investigated in the crossflow of Reynolds number 50 to 180. At the same time CFD (Computational Fluid Dynamics) solver was also simulated using the Fluent program. Detailed flow analyzes, instantaneous flow line, vortex size, velocity and pressure variation are analyzed in detail. The results obtained are consistent with the experimental / numerical data available for the circular cylinder in the literature. Nusselt number increases with increasing number of Reynolds. At the same time, as the number of Reynolds increases, the drift coefficient increases. As a result; the relative drift coefficient for the specified operating range and the Nusselt number were obtained as a function of the Reynolds number [1].

In Manohar and Ramroop's experiment in 2010, the flow was made through two steel pipes of 34 mm and 49 mm in diameter along the air flow of 1.1 m / s and 2.5 m / s, with the horizontal axis at 30 and 60 degrees and heat transfer characteristics. These experimental studies are compared with those given for the cross-flow horizontal pipes in the literature. Relations of Churchill, Zhukaukas, Hilpert, Fand and Morgan were used to compare experimental data. 30 ° slope and Nu values at an air velocity of 1.1 m / s were observed to agree well with the literature, however, considerable differences were observed at 60 ° slope and air velocity 2.5 m / s. The experimentally determined Nusselt number for 30 degrees of inclination varied from 2% to 18% in the air velocity of 1.1 m / s and from 12% to 41% in the air velocity of 2.5 m / s. The experimentally determined Nusselt number for 60 degrees of inclination varied from 19% to 45% and the air velocity of 1.1 m / s and from 29% to 65% for the air velocity of 2.5 m / s [2].

In Nakamura and Igarashi's experiment in 2014, the Nusselt number and flow regime in the separated stream behind the circular cylinder in the crossflow were investigated by varying Reynolds numbers. The Nusselt number at the stagnation point behind the circular cylinder increases with the number of Reynolds in the laminar flow regime (Re <150), Nur / Re ^ 0,5. In contrast, the number of Nusselt in the areas of fluctuation decreases with the number of Reynolds [3] in the Nur / Re ^ 0.5, a complex flow regime (300 <Re <1500) [3].

Experiments by Yuge in 1960 to find convection heat transfer for the sphere were carried out in the range of 1.44x105 to 3.5 x 105 Reynolds number and 1 to 105 Grashof number. Empirical formulas for forced, natural and combined convection heat transfer have been obtained and compared with other experiments in the literature. The results obtained are consistent with literature studies [4].

In Wiberg and Lior's 2003 experiment, local heat transfer coefficient distributions on a two-dimensional cylinder with a diameter of 150 mm were found to be close to the closed-loop airflow at Reynolds number 8,9x104 <Re <6,17 x105 tunnel. The cylinder with a diameter of 150 mm is positioned parallel to the flow line. Experiments were carried out in a different flow direction air flow conditions, using a turbulence grating, changing the flow turbulence level (Tu) and adjusting the flow modification inserts in front of the cylinder. This turbulence builder increased the heat transfer rate by up to 22%. The surface temperature of the cylinder was measured by Thermocromic Liquid Crystal (TLC) technique. As a result of the work done, the relation between the number of dimensionless Nusselt and Reynolds number is given [5].

2.10. PRESENTLY USED CORRELATIONS

There are many correlations to predict the heat transfer coefficient in the literature. Table 1 also shows the people who have done similar studies in the literature and the correlations they found.

Table 1 (Relationships for heat transfer (NUSSELT number) in melt spinning.)

Equation for Nu-number	References and conditions
Only parallel flow	
$0.76Re^{0.38}$	Andrews (1959) [24]
$0.42Re^{0.334}$	Kase, Matsuo (1965) [25]
$0.10 + 0.15Re^{0.36}$	Sano (1966) [189]
$0.53Re^{0.33}$	Copley (1967) [190]
$0.325Re^{0.3}$	Glicksman (1968) [192]
$0.76Re^{0.41}$	Conti (1970) [193]
$0.25 + 0.15Re^{0.36}$	Zieminski (1985) [194]
$0.16Re^{0.50}$	Slow melt spinning opf PEEK, Oshoshi (1993) [202]
$0.42Re^{0.344}Ra^{0.13}$	Melt spinning of PEEK, Golzar (2004) [204]
$3.0Re^{-0.22}$	Melt spinning of PEEK, Golzar (2004) [204]
Only transverse flow	
$0.891Re^{0.33}$	$1 < Re < 4$, Hilpert (1933) [205]
$0.821Re^{0.385}$	$4 < Re < 40$, dito
$0.615Re^{0.466}$	$40 < Re < 4000$, dito
$0.32 + 0.67Re^{0.52}$	$0.1 < Re < 10^3$, McAdams (1954) [206]
$0.38Re^{0.6}$	$10^3 < Re < 5.10^4$, dito
Parallel and transverse flow	
$0.42(Re^2 + 64Re^2)^{0.167}$	(*) Kase, Matsuo (1965) [25]
$0.28(Re^2 + 1024Re^2)^{0.17}$	(**) Brünig (1999) [207]

here with parameters a = 0.42, b = 64, c = 0.167. Re's are the REYNOLDS numbers related to the parallel and cross air flow, defined as follows.

These equations give the nusselt number for various flow conditions. The nusselt number is written in the equation and the heat transfer coefficient h is found. The equation is as follows.

$D_H = 4A/P$ (P,wetted perimeter, the area that contacts the fluid flow)
(A, cross sectional area, the area that contacts the fluid flow)

$A = \pi.D^2 / 4$

$P = \pi.D$

$Nu = h.D_h / k$

$h = Nu.k / D$

3. THEORITICAL STUDIES

The power that given is equal to the power that taken. Electrical power is equal to exertion on convection heat transfer and radiation heat transfer.Equations are equalized to find the heat transfer coefficient h.The value of h depends on the measured power (voltage and current) and measured temperature values. To find the temperature of wire, the wire resistance is measured by using current and voltage values. The wind turbine forms a forced flow. The heat transfer coefficient h is found by the following equation.

$$Q = I^2 * R$$

I=current (amper)

R=resistance(ohm)

Q=power(w)

$$R_{final} = R_0 \left(1 + \alpha(T_{wire} - T_{first})\right)$$

R_{final}=final resistance(ohm)

R_0=first resistance value(ohm)

α=heat conduction according to material(W/m*K)

T_{wire}=last temperature of wire(K)

T_{first}=first temperature of wire(K)

Q_{Total}= I.V (Voltage and Current)
$Q_{Conv.}$ = h.π.D.L.(T_S-T_∞) (D:Diameter)

$Q_{Rad.}$ = ε. σ. π.D.L (T_S^4 - T_{SURR}^4)

Q_{Total}= $Q_{Conv.}$ + $Q_{Rad.}$ = h.π.D.L.(T_S-T_∞) + ε.σ.π.D.L(T_S^4 - T_{SURR}^4)

h = (Q_{Total} - ε.σ.π.D.L(T_S^4 - T_{SURR}^4)) / (π.D.L.(T_S-T_∞))

4. EXPERIMENTAL STUDIES

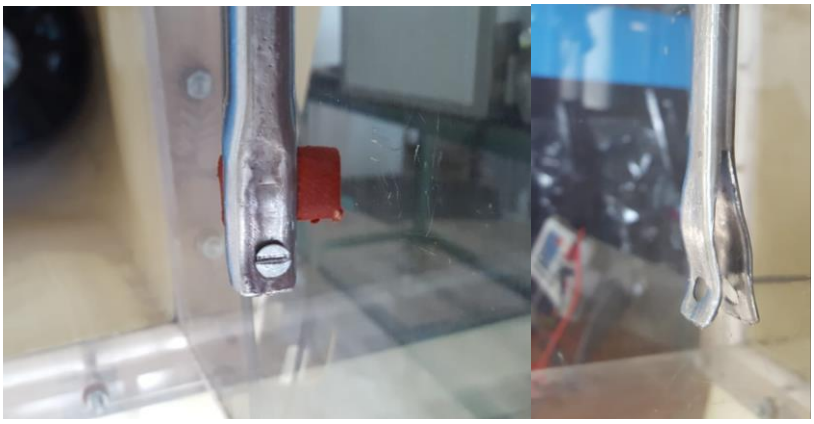
4.1.DEVICES

4.1.1. POWER SUPPLY DEVICE

A power supply is an electrical device that supplies electric power to an electrical load. power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load. It is suppling current to wire to generate heat in wire.N5767A 60V/25A/1500W used in this experiment.

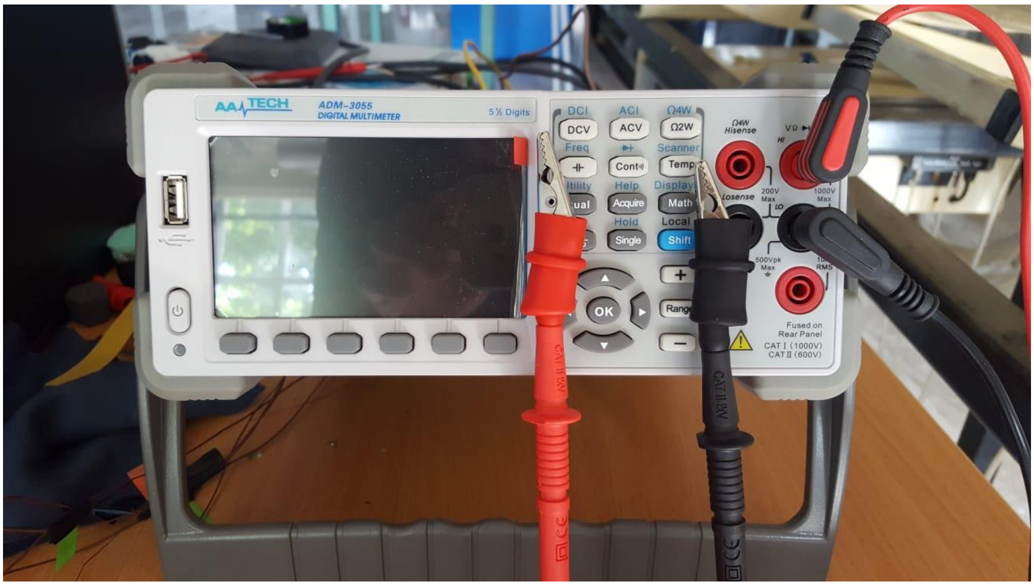
4.1.2. WIRES AND WIRES HOLDER

It is used to keep the wires stable during air flow. Insulation material is used to prevent current flow. Fixing systems are used.



4.1.3. DIGITAL MULTIMETER

Digital multimeter is used to read voltage and current values.It enables us to find wire resistance and wire surface temperature with a specific electrical resistance temperature relation formula. ADM-3055 used in this experiment.



4.1.4. WIND TUNNEL

The wind tunnel moves air around an object. A wind tunnel consists of a tubular passage with the object under test mounted in the middle. Air is made to move past the object by a powerful fan system or other means.

4.1.5. FREQUENCY CONVERTER

It allows to control the airflow. The air speed is changed to the desired value with the frequency converter.

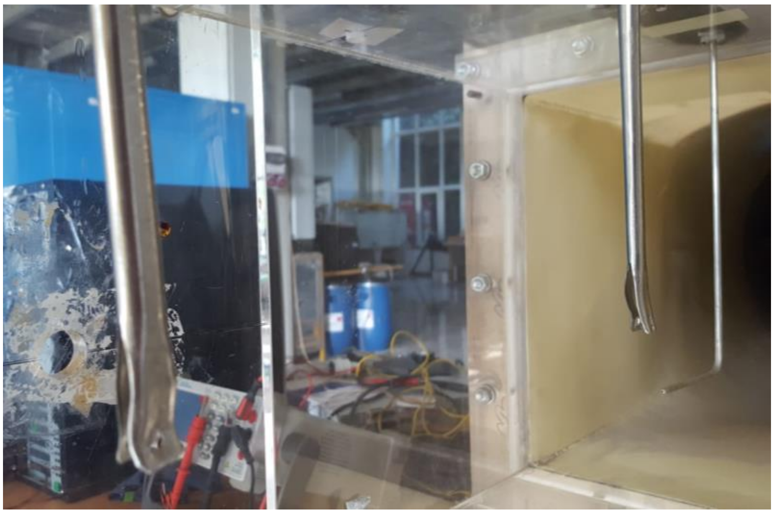
4.2.CYLINDER

There are a lot of wires for detailed research. The wire thicknesses used in the experiment are 0.08 mm, 0.1 mm. Its main material is Ni-Cr. Values were used according to the properties of Ni-Cr.

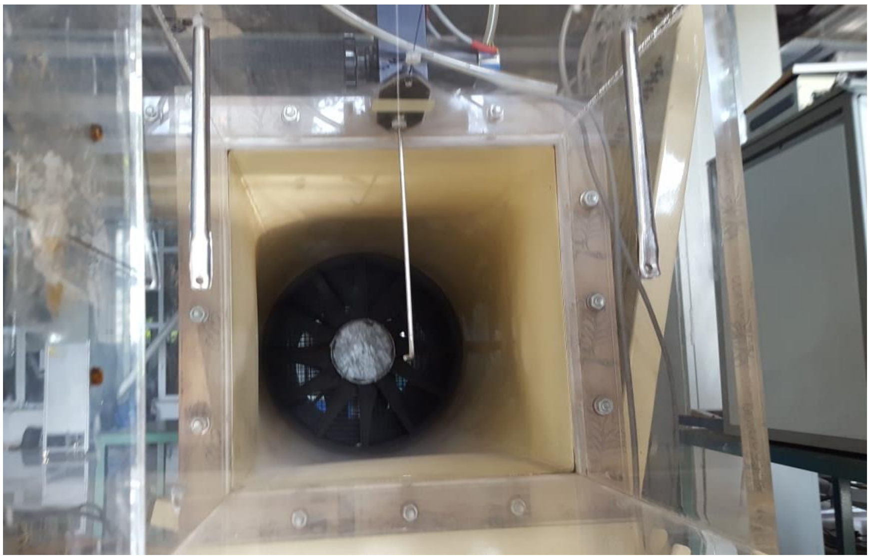
4.3.EXPERIMENT PROCEDURE

Wire is carefully positioned with the wind tunnel by fixing systems. There is a controlled air flow with frequency converter. The first resistance of the wire is measured by the multimeter. The current is transmitted through the power supply. The voltage value is measured by the multimeter. As a result of the measurements, the heat transfer coefficient is found by the experimental method. These experiments are applied for cross and parallel flow and have experimental results.

(Parallel Flow)



(Cross Flow)



5. RESULTS AND DISCUSSIONS

5.1.Cross Flow 0,08 mm

0.08mm Ni-Cr is placed carefully into the wind turbine.Cross flow type use for this experiment. Air flow rate is controlled by frequency. Voltage is measured with the multimeter. The current is measured from the power supply. Resistance is found by voltage / current. The values measured are shown in Table 1.

Table 2 (Diameter, frequency, speed, voltage, current, resistance, power values.)

Diameter (mm)	Frequency	Speed (m/s)	Voltage	Current	Resistance	Power (W)
0,08	7,2	5	19,86	0,39	50,92307692	7,7454
0,08	6,4	4,5	19,88	0,39	50,97435897	7,7532
0,08	5,8	4	19,89	0,39	51	7,7571
0,08	5,1	3,5	19,9	0,39	51,02564103	7,761
0,08	4,3	3	19,9	0,39	51,02564103	7,761
0,08	3,7	2,5	19,85	0,385	51,55844156	7,64225
0,08	3	2	19,83	0,38	52,18421053	7,5354
0,08	2,2	1,5	19,83	0,38	52,18421053	7,5354
0,08	1,6	1	19,8	0,375	52,8	7,425

The effect of radiation is measured. By measuring the temperatures, the values Nusselt and heat transfer coefficient are found.

Table 3 (Nusselt, heat transfer coefficient, radiation, Reynolds number, T surfaces and Tf values.)

Nu	Heat transfer coefficient h (W/m^2*K)	Radiation (W)	Re	T surface (K)	T surface (C)	Tf (C)
2,622540582	981,977539	0,066284157	18,4937	423,00	150,00	86,5
1,943022943	758,8063212	0,100798451	14,9953	459,78	186,78	104,89
1,829746085	721,2927682	0,109939146	13,3251	468,18	195,18	109,09
1,72733641	687,2628946	0,11957352	11,4423	476,57	203,57	113,285
1,72733641	687,2628946	0,11957352	9,80773	476,57	203,57	113,285
0,692258717	328,2452874	0,46808065	5,77534	650,95	377,95	200,475
0,313714265	176,8613189	1,439569175	3,34378	855,75	582,75	302,875
0,313714265	176,8613189	1,439569175	2,50784	855,75	582,75	302,875
0,132278766	86,23831504	3,382388228	1,27939	1057,30	784,30	403,65

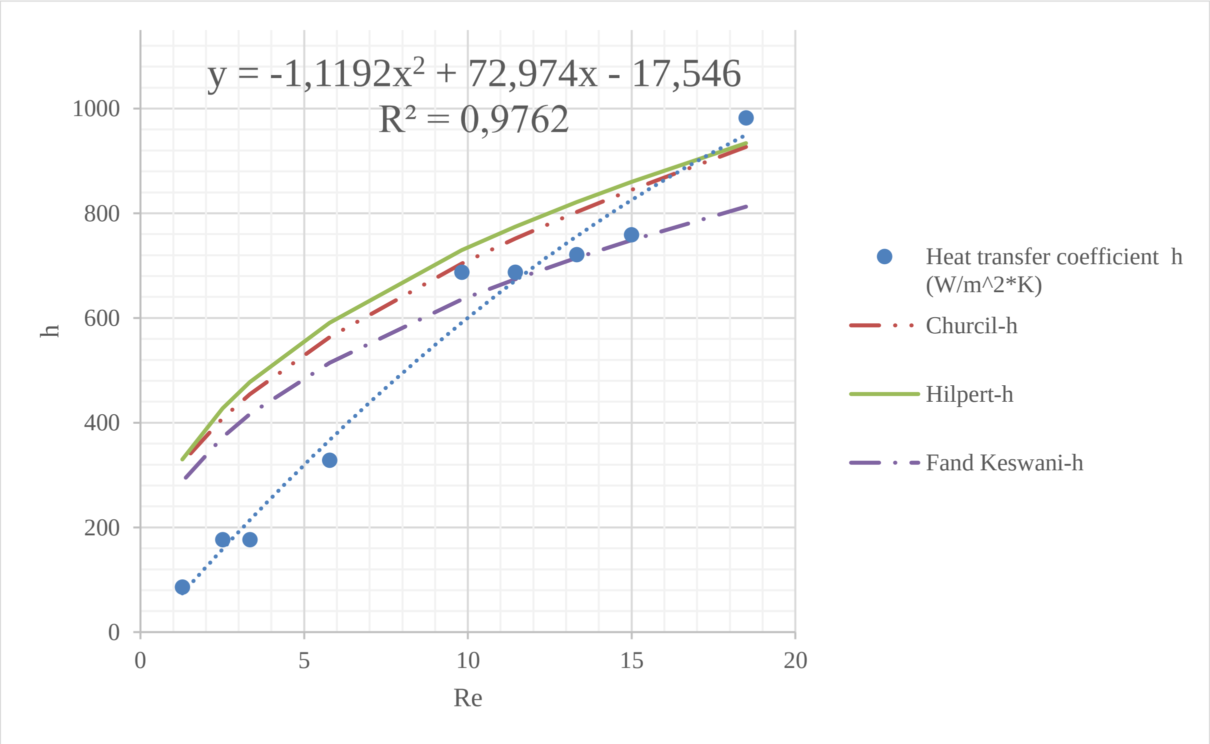
Other formulas in the literature have been searched. The following values are available for comparison with the literature.

Table 4 (Churcil-Nu,h ; Hilpert-Nu,h ; Fand Keswani-Nu,h values.)

Churcil-Nu	Churcil-h	Hilpert-Nu	Hilpert-h	Fand Keswani-Nu	Fand Keswani-h
2,475108074	926,7732793	2,494158283	933,9063921	2,170229883	812,6154517
2,254989682	844,352699	2,29636176	859,8439565	1,998541184	748,3287648
2,142678736	802,2992692	2,194298726	821,6277292	1,909940472	715,1533356
2,006608775	751,3495731	2,068327932	774,4595401	1,800568439	674,2003451
1,879804153	703,8691677	1,949148298	729,8342159	1,697079027	635,4500281
1,503937903	563,1307487	1,577451105	590,656848	1,374178283	514,5438807
1,213930114	454,5409569	1,275027818	477,4182286	1,111332906	416,124715
1,091399849	408,6610308	1,141348432	427,3636535	0,995102229	372,6035908
0,865150347	323,9447332	0,880812795	329,8093408	0,768467251	287,7429565

The heat transfer coefficient-Reynolds numbers values found are shown in a single graphic.

Figure 1 (The heat transfer coefficient-Reynolds numbers)



Nu= 0,0982Re^{1,1433}

5.2.Parallel Flow 0,08 mm

0.08mm Ni-Cr is placed carefully into the wind turbine.Parallel flow type use for this experiment. Air flow rate is controlled by frequency. Voltage is measured with the multimeter. The current is measured from the power supply. Resistance is found by voltage / current. The values measured are shown in Table 5.

Table 5 (Diameter, frequency, speed, voltage, current, resistance, power values.)

Diameter (mm)	Frequency	Speed (m/s)	Voltage	Current	Resistance	Power (W)
0,08	7,2	5	20,18	0,38	53,10526316	7,6684
0,08	6,4	4,5	20,2	0,38	53,15789474	7,676
0,08	5,8	4	20,21	0,38	53,18421053	7,6798
0,08	5,1	3,5	20,25	0,38	53,28947368	7,695
0,08	4,3	3	20,27	0,38	53,34210526	7,7026
0,08	3,7	2,5	20,29	0,38	53,39473684	7,7102
0,08	3	2	20,31	0,38	53,44736842	7,7178
0,08	2,2	1,5	20,35	0,38	53,55263158	7,733
0,08	1,6	1	20,19	0,375	53,84	7,57125

The effect of radiation is measured. By measuring the temperatures, the values Nusselt and heat transfer coefficient are found.

Table 6 (Nusselt, heat transfer coefficient, radiation, Reynolds number, T surfaces and Tf values.)

Nu	Heat transfer coefficient h (W/m^2*K)	Radiation (W)	Re	T surface (K)	T surface (C)	Tf (C)
2,596243853	972,1310577	0,066284157	18,4937	423,00	150,00	86,5
1,927139043	752,3823031	0,10052128	14,9953	459,52	186,52	104,759
1,81642005	715,7193378	0,109489211	13,3251	467,78	194,78	108,8885
1,464537204	598,2351639	0,150414233	10,829	500,81	227,81	125,4065
1,328829227	552,4040266	0,17415944	8,97599	517,33	244,33	133,6655
1,21242488	512,7756285	0,200291433	7,15564	533,85	260,85	141,9245
1,111519168	478,1317105	0,228965037	5,57491	550,37	277,37	150,1835
0,945367056	420,3232512	0,294580697	3,91295	583,40	310,40	166,7015
0,624757776	302,4271605	0,5397437	2,21237	673,59	400,59	211,7955

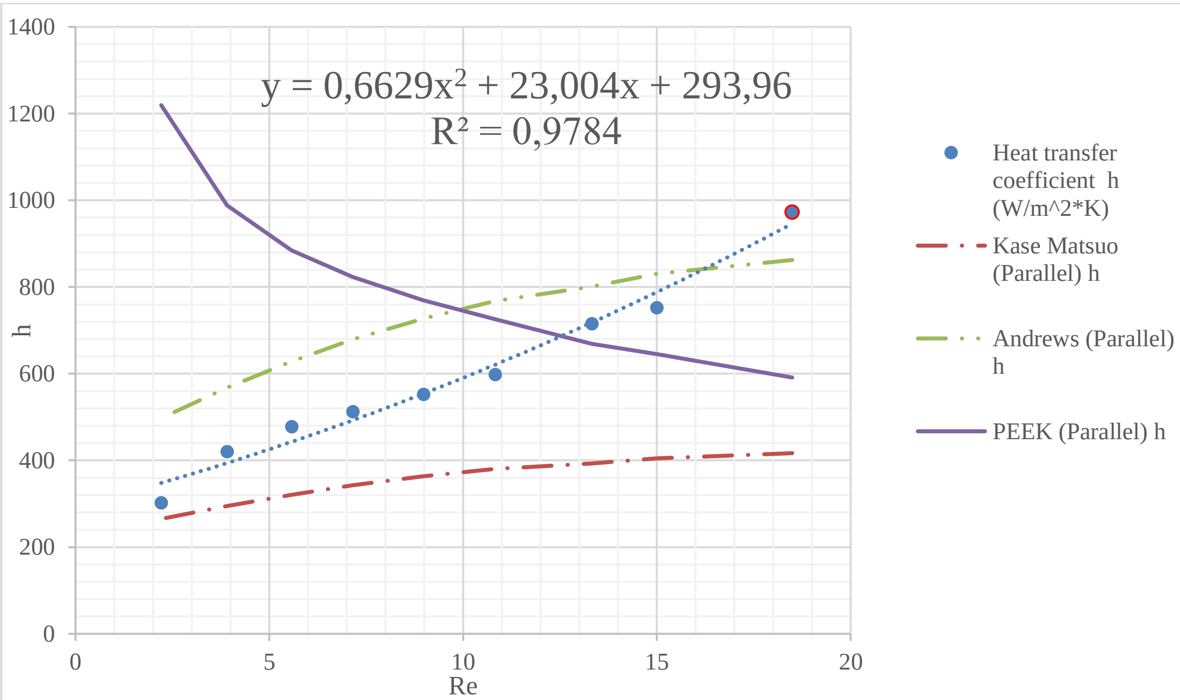
Other formulas in the literature have been searched. The following values are available for comparison with the literature.

Table 7 (Kase Matsuo-Nu,h ; Andrews-Nu,h ; PEEK-Nu,h values.)

Kase Matsuo (Parallel) Nu	Kase Matsuo (Parallel) h	Andrews (Parallel) Nu	Andrews (Parallel) h	PEEK (Paralel) Nu	PEEK (Parallel) h
1,112846223	416,6913578	2,302939567	862,3069342	1,57897798	591,2285675
1,03757249	405,0829559	2,126555425	830,2372755	1,65352601	645,5599104
0,997446029	393,021103	2,033239667	801,1522158	1,697046076	668,6827165
0,930684201	380,1665223	1,879134137	767,5900044	1,776280142	725,5761334
0,874135557	363,3845431	1,749785748	727,3987308	1,851156532	769,5393067
0,810404388	342,7475186	1,605387592	678,9728955	1,94580204	822,9457183
0,74557753	320,7180498	1,460104922	628,0795545	2,055648595	884,2589561
0,66243874	294,5294139	1,276336596	567,47688	2,222134342	987,9916219
0,547559867	265,0578864	1,027683406	497,4717983	2,519142075	1219,443781

The heat transfer coefficient-Reynolds numbers values found are shown in a single graphic.

Figure 2 (The heat transfer coefficient-Reynolds numbers)



$Nu = 0,3848Re^{0,6032}$

5.3.Cross Flow 0,1 mm

0.1mm Ni-Cr is placed carefully into the wind turbine.Cross flow type use for this experiment. Air flow rate is controlled by frequency. Voltage is measured with the multimeter. The current is measured from the power supply. Resistance is found by voltage / current. The values measured are shown in Table 8.

Table 8 (Diameter, frequency, speed, voltage, current, resistance, power values.)

Diameter (mm)	Frequency	Speed (m/s)	Voltage	Current	Resistance	Power (W)
0,1	7,2	5	14,71	0,48	30,64583333	7,0608
0,1	6,4	4,5	14,714	0,48	30,65416667	7,06272
0,1	5,8	4	14,715	0,48	30,65625	7,0632
0,1	5,1	3,5	14,722	0,48	30,67083333	7,06656
0,1	4,3	3	14,775	0,48	30,78125	7,092
0,1	3,7	2,5	14,792	0,48	30,81666667	7,10016
0,1	3	2	14,8	0,475	31,15789474	7,03
0,1	2,2	1,5	14,82	0,47	31,53191489	6,9654
0,1	1,6	1	14,84	0,47	31,57446809	6,9748

The effect of radiation is measured. By measuring the temperatures, the values Nusselt and heat transfer coefficient are found.

Table 9 (Nusselt, heat transfer coefficient, radiation, Reynolds number, T surfaces and Tf values.)

Nu	Heat transfer coefficient h (W/m^2*K)	Radiation (W)	Re	T surface (K)	T surface (C)	Tf (C)
2,383079484	713,8514596	0,082855196	23,1171	423,00	150,00	86,5
1,934514941	596,0927285	0,110421597	19,5652	447,53	174,53	98,765
1,917484589	591,6034376	0,111806011	17,3611	448,66	175,66	99,33
1,804817774	561,8515043	0,121819807	14,919	456,59	183,59	103,295
1,218284569	404,8652012	0,21639916	11,2054	516,64	243,64	133,32
1,093395814	370,7322516	0,254637947	8,96218	535,90	262,90	142,95
0,463585506	187,2968889	0,896255645	5,08404	721,48	448,48	235,74
0,195652119	92,97613677	2,46488573	2,8169	924,89	651,89	337,445
0,175259511	84,70506872	2,723749495	1,81653	948,04	675,04	349,0175

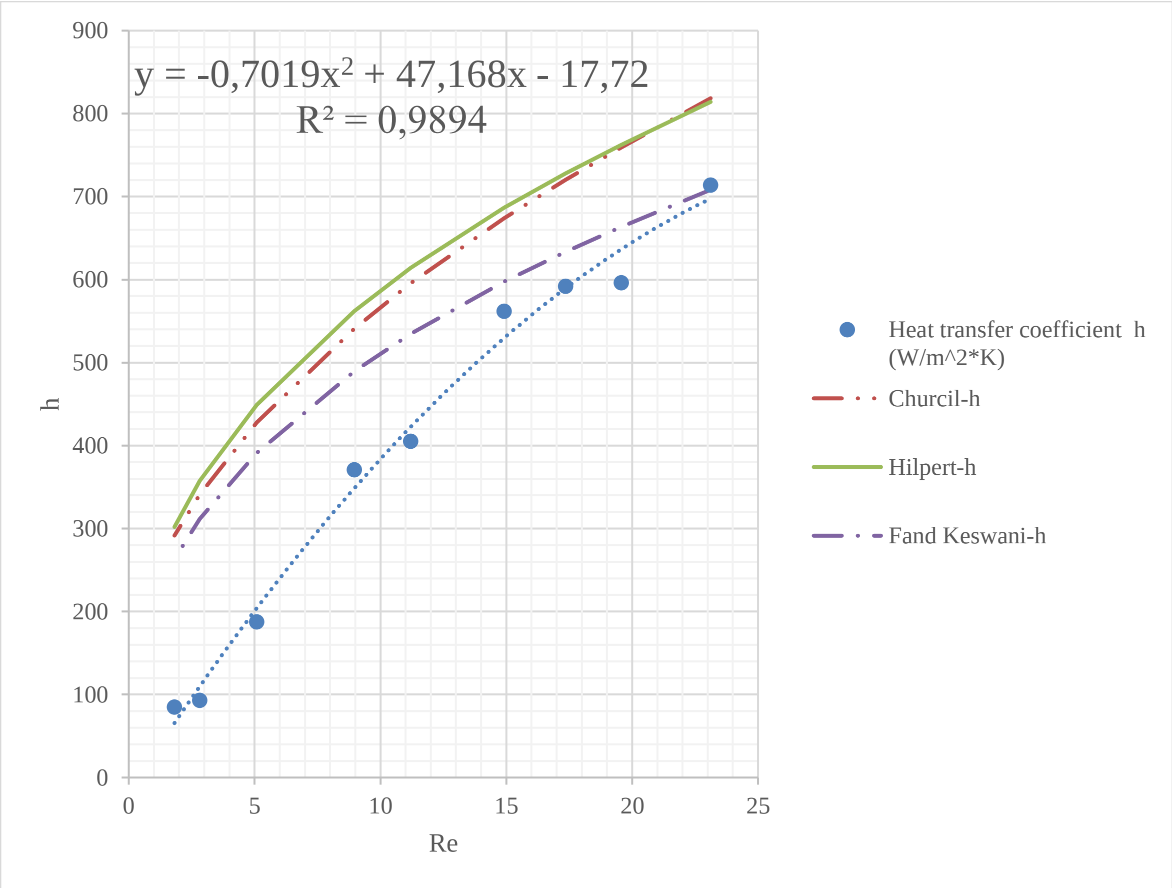
Other formulas in the literature have been searched. The following values are available for comparison with the literature.

Table 10 (Churcil-Nu,h ; Hilpert-Nu,h ; Fand Keswani-Nu,h values.)

Churcil-Nu	Churcil-h	Hilpert-Nu	Hilpert-h	Fand Keswani-Nu	Fand Keswani-h
2,732550327	818,5354504	2,717905585	814,1486179	2,364390383	708,2531391
2,534692492	759,2671361	2,545218588	762,420228	2,214534004	663,3636609
2,404754336	720,3441613	2,430752993	728,1320591	2,115193014	633,6060672
2,249998847	673,9871545	2,291856008	686,5254672	1,99462997	597,4914074
1,988131689	595,5448473	2,050755867	614,3039201	1,785308559	534,7891788
1,805772361	540,9191106	1,87636556	562,0653034	1,633856052	489,4215803
1,427629322	427,6463633	1,498963885	449,0146317	1,305971538	391,2037742
1,138784434	341,1228771	1,193576058	357,5357081	1,040516757	311,6867945
0,973478103	291,6053657	1,008083358	301,9713698	0,879196507	263,3633137

The heat transfer coefficient-Reynolds numbers values found are shown in a single graphic.

Figure 3 (The heat transfer coefficient-Reynolds numbers)



$Nu = 0,079Re^{1,1138}$

5.4.Parallel Flow 0,1 mm

0.1mm Ni-Cr is placed carefully into the wind turbine.Parallel flow type use for this experiment. Air flow rate is controlled by frequency. Voltage is measured with the multimeter. The current is measured from the power supply. Resistance is found by voltage / current. The values measured are shown in Table 11.

Table 11 (Diameter, frequency, speed, voltage, current, resistance, power values.)

Diameter (mm)	Frequency	Speed (m/s)	Voltage	Current	Resistance	Power (W)
0,1	7,2	5	16,13	0,45	35,84444444	7,2585
0,1	6,4	4,5	16,14	0,45	35,86666667	7,263
0,1	5,8	4	16,16	0,445	36,31460674	7,1912
0,1	5,1	3,5	16,16	0,44	36,72727273	7,1104
0,1	4,3	3	16,17	0,44	36,75	7,1148
0,1	3,7	2,5	16,2	0,44	36,81818182	7,128
0,1	3	2	16,2	0,44	36,81818182	7,128
0,1	2,2	1,5	16,26	0,44	36,95454545	7,1544
0,1	1,6	1	16,28	0,44	37	7,1632

The effect of radiation is measured. By measuring the temperatures, the values Nusselt and heat transfer coefficient are found.

Table 12 (Nusselt, heat transfer coefficient, radiation, Reynolds number, T surfaces and Tf values.)

Nu	Heat transfer coefficient h (W/m^2*K)	Radiation (W)	Re	T surface (K)	T surface (C)	Tf (C)
2,450597189	734,0763879	0,082855196	23,1171	423,00	150,00	86,5
1,902376653	590,0529374	0,117641929	15,5172	453,33	180,33	101,666
0,609018721	233,2932693	0,626141386	9,04245	661,61	388,61	205,806
0,275905248	124,2184746	1,780252461	5,83576	853,49	580,49	301,745
0,264204222	119,9269198	1,871325015	4,81444	864,05	591,05	307,025
0,231170454	107,4979596	2,1655782	3,91135	895,76	622,76	322,88
0,231170454	107,4979596	2,1655782	3,12908	895,76	622,76	322,88
0,172877415	84,22721648	2,855176699	2,1535	959,17	686,17	354,5825
0,155293823	76,80915564	3,117663511	1,38903	980,30	707,30	365,1505

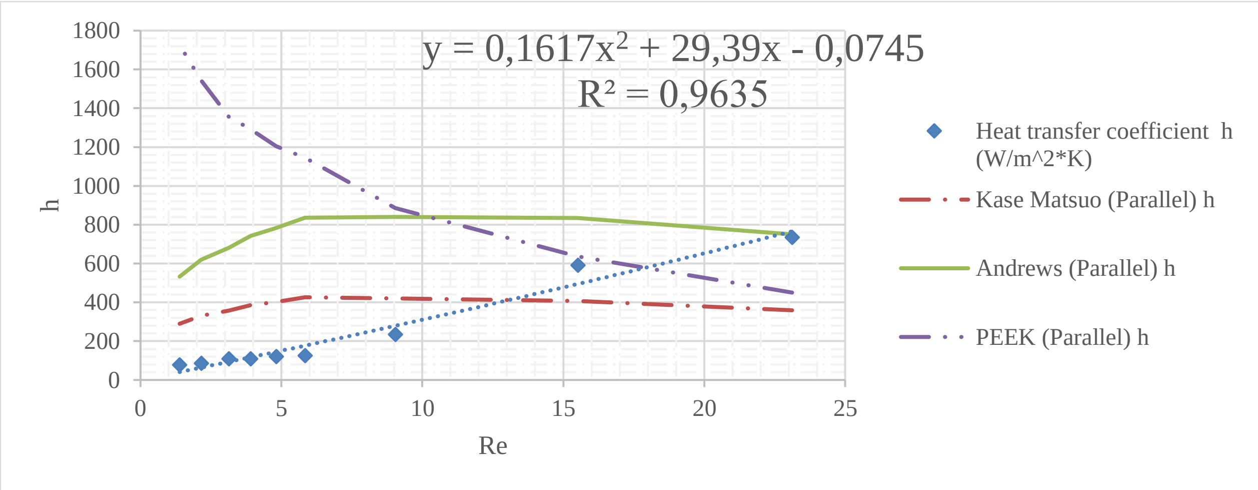
Other formulas in the literature have been searched. The following values are available for comparison with the literature.

Table 13 (Kase Matsuo-Nu,h ; Andrews-Nu,h ; PEEK-Nu,h values.)

Kase Matsuo (Parallel) Nu	Kase Matsuo (Parallel) h	Andrews (Parallel) Nu	Andrews (Parallel) h	PEEK (Parallel) Nu	PEEK (Parallel) h
1,1989556	359,1471501	2,506734548	750,8923338	1,503335353	450,3241051
1,049497332	406,8982491	2,154383967	835,2713604	1,641126511	636,2774671
0,876292006	419,5951201	1,754697722	840,2023491	1,848154659	884,9523576
0,757052419	426,0515946	1,485698728	836,1168875	2,035071824	1145,291361
0,709936787	402,8159145	1,38096001	783,552394	2,123054375	1204,614418
0,662348438	385,0032763	1,276138647	741,7811112	2,222333892	1291,776021
0,61477836	357,3522171	1,172389867	681,475058	2,334154035	1356,773716
0,542649974	330,4790909	1,017205658	619,4881001	2,534132457	1543,311215
0,46872201	289,7905172	0,86108185	532,3696124	2,790772603	1725,413825

The heat transfer coefficient-Reynolds numbers values found are shown in a single graphic.

Figure 4 (The heat transfer coefficient-Reynolds numbers)



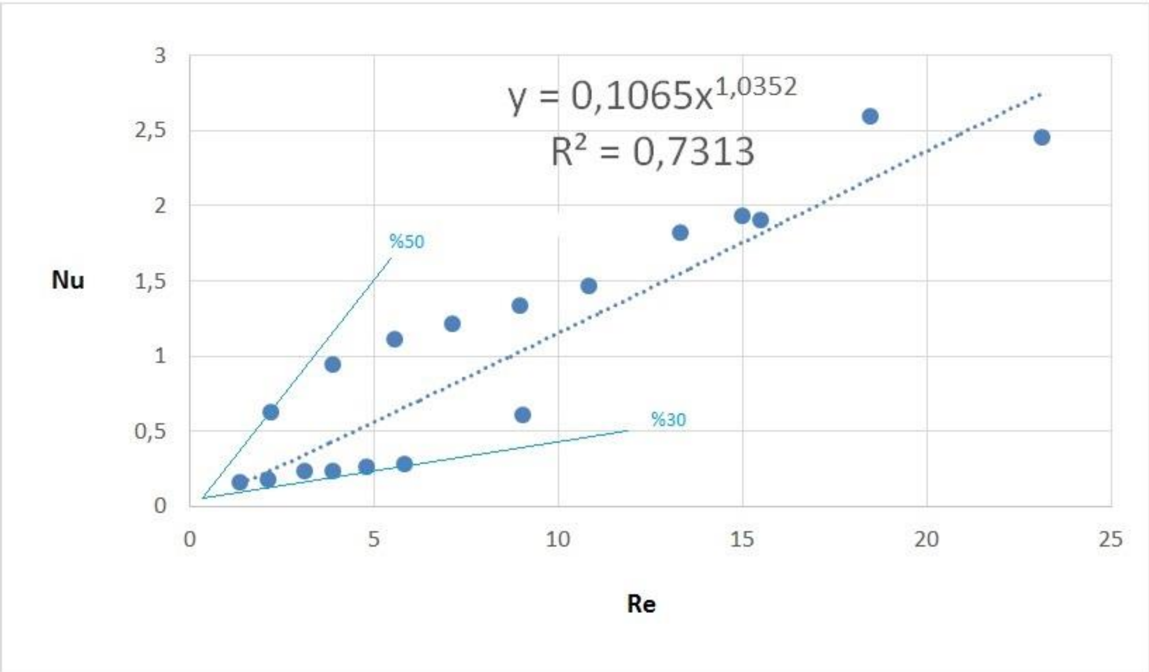
$Nu = 0{,}0682Re^{1{,}0682}$

5.5.Nu-Re Parallel Flow for 0.08 mm and 0.1 mm

Table 14 (Nusselt numbers and Reynolds numbers)

Re	Nu
23,11711129	2,4506
18,49368903	2,59624
15,51724138	1,90238
14,99531396	1,92714
13,32511618	1,81642
10,82904039	1,46454
9,04244978	0,60902
8,975989229	1,32883
7,155635063	1,21242
5,835764902	0,27591
5,574912892	1,11152
4,81444333	0,2642
3,912949908	0,94537
3,911353093	0,23117
3,129082475	0,23117
2,153501594	0,17288
2,212367355	0,62476
1,38903358	0,15529

Figure 5 (Nusselt numbers-Reynolds numbers)



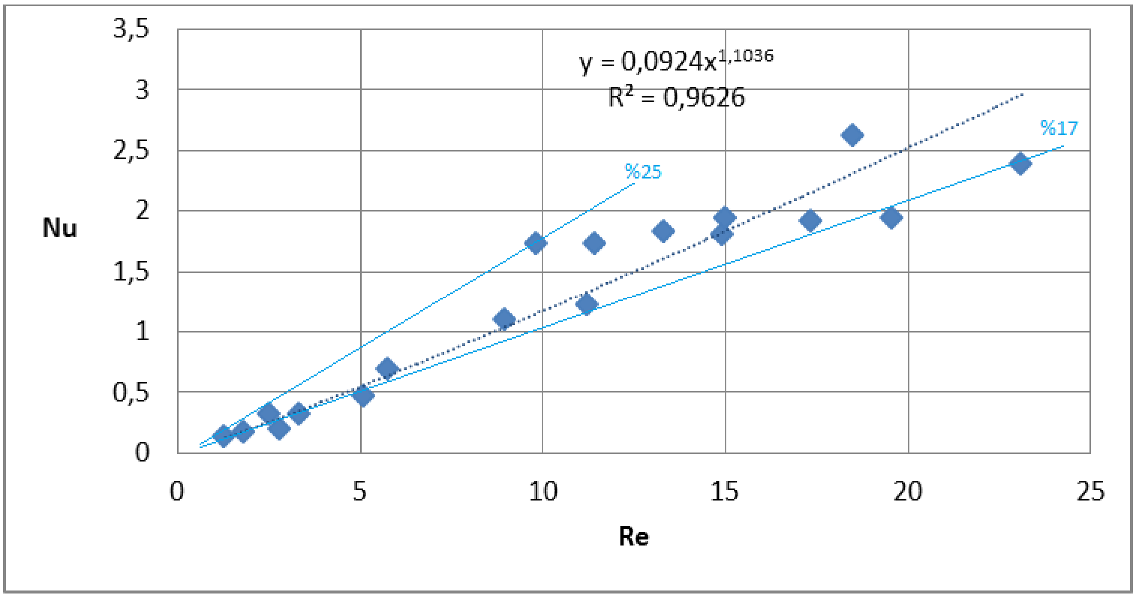
$Nu= 0,1065Re^{1,0352}$

5.6.Nu-Re Cross Flow for 0.08 mm and 0.1 mm

Re	Nu
23,11711129	2,383079484
19,56521739	1,934514941
17,36111111	1,917484589
14,91901108	1,804817774
11,2054025	1,218284569
8,962179602	1,093395814
5,084039167	0,463585506
2,816901408	0,195652119
1,816530427	0,175259511
18,49368903	2,622540582
14,99531396	1,943022943
13,32511618	1,829746085
11,44234895	1,72733641
9,807727672	1,72733641
5,775339301	0,692258717
3,343782654	0,313714265
2,507836991	0,313714265
1,279385895	0,132278766

Table 15 (Nusselt numbers and Reynolds numbers)

Figure 6 (Nusselt numbers-Reynolds numbers)



$Nu = 0{,}0924Re^{1{,}1036}$

6. CONCLUSIONS

We have studied the cross-and-parallel flow of known diameter wires. We obtained experimental values with wind tunnel and various instruments in laboratory.We did a literature search and compared all the results. The differences are due to the shape and internal structure of the materials they use. We found our own correlations with the results. The results are as follows.

In general, when the fluid is cross-flow, if the number of reynolds is less than 10, then churcill is greater than Fand-Keswani corellations. These results are easily observed from the graphs. In the case of parallel flow, when the number of reynolds reaches 20, the correlations of Adrews are closer to our results. At lower reynold numbers, our correlated bowl is closer to Matsou. As a result, the correlations we have obtained from the experiments are given below in order to use Nusselt in thin wires in low reynold numbers.

Table 16 (Conclusion correlations)

0,08 mm (Cross Flow)	$Nu= 0,0982Re^{1,1433}$
0,08 mm (Parallel Flow)	$Nu= 0,3848Re^{0,6032}$
0,1 mm (Cross Flow)	$Nu= 0,079Re^{1,1138}$
0,1 mm (Parallel Flow)	$Nu= 0,0682Re^{1,0682}$
Parallel Flow for 0.08mm and 0.1 mm	$Nu= 0,1065Re^{1,0352}$
Cross Flow for 0.08mm and 0.1 mm	$Nu = 0,0924Re^{1,1036}$

7. REFERENCES

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