A STUDY OF INFLUENCE OF VERTICAL VIBRATION ON HEAT TRANSFER COEFFICIENT FROM HORIZONTAL CYLINDERS

Assist. Prof. Dr. Majid. H. M. Al-Shorafa'a
Al-Najaf Technical College
Foundation Of Technical Education

ABSTRACT

Electrically heated horizontal cylinders of diameters 2.15cm,3cm, and 3.8cm were vibrated vertically in stagnant air at a frequency (10,15,20Hz) and amplitude range from (0.0005m) to (.0076m). The effect of different parameters on the heat transfer ratio (h_v/h_o) was investigated from its outer surface. It is concluded that, heat transfer ratio increases at high frequency and small diameter. Vibration Reynolds number has good effects on heat transfer ratio. (Gr.Pr) has bad indication on heat transfer ratio at high temperature difference (high heat flow). The vibration intensity also has good influence on heat transfer.

الخلاصة

اسطوانات أفقية مسخنة كهربائيا باقطار 2.15 و3.0 و 3.8 سم تهتز اهتزازا عموديا في هواء ساكن بتردد (10و15و20)هرتز و بسعة تتراوح بين (0.0005م) إلى (0.0076م). تم دراسة تأثير العوامل المختلفة على نسبة انتقال الحرارة (h_v/h_o) من سطحها الخارجي. وقد استنتج بان نسبة انتقال الحرارة تزداد مع التردد العالي والقطر الصغير. وعددرينولد الاهتزازي له تأثير جيد على نسبة انتقال الحرارة في حين إن عدد (Gr.Pr) لهم تأثير ضعيف على نسبة انتقال الحرارة من الاسطوانات المهتزة عند فرق درجات الحرارة الواطئ (انتقال حرارة منخفض). كذلك وجد بان كثافة الاهتزاز لها ـاثير جيد على انتقال الحرارة.

KEY WORDS
Influence of Vertical Vibration, Heat Transfer From Horizontal Cylinders, Heat Transfer Coefficient

INTRODUCTION

Heat transfer by free convection from engineering machineries can be increased by several methods. One of these methods is to create a relative motion between the heat surface and the surrounding fluid medium. This can be done by mechanical vibration, sound and fluid fluctuating methods.

One of the earliest investigations of the vibration effect on heat transfer was done by **(Martinelli and Boelter 1938)** . They studied the effect of vibrations upon the heat transfer from a horizontal tube immersed in the water**. (Penny and Jefferson 1966)**. Studied the heat transfer from an oscillating wire. The influence of vertical mechanical vibrations on a free convection heat transfer from a large horizontal cylinder has been studied by **(Fand and Keye 1971). (Armarly and Madson 1973)** studied heat transfer from oscillating horizontal wire. **(Dawood and Mathotra 1980)** studied heat transfer from horizontal cylinders vibrated in air and they found that heat transfer is increased up to two and half times. Heat transfer from finned horizontal cylinders, that vibrated vertically was studied by **(Yacoab and Sabieh 1997).** In this study the increase in vibration heat transfer coefficient to free heat transfer coefficient recorded to be about (1.16). **(Makki Al-Uboydi 2001)** in his thesis studied a wide range of vibration effects on the heat transfer from horizontal cylinders.

In this study the effects of vibration parameters on the heat transfer coefficient are investigated.

EXPERIMENTAL APPARATUS

The experimental apparatus consists of the following:-

1- Testing cylinder: which is used as a heated vibrated horizontal cylinder made of aluminum with outside diameters of (0.0215m, 0.03m, and 0.038m), with a heating length of 0.38m. This cylinder is heated by an electric heater passing through its core. The electric heater consists of resistance coil with voltage variance and current ammeter. Five thermocouples nodes are fixed on the cylinder outer surface to measure the temperatures at different places on the cylinder.

2- Rigid frame: The cylinder is fixed on a heavy rigid frame . this frame is fixed on a table with plastic fixtures to absorb the vibration from the frame.

3- Vibration instruments: The vibration instruments that used in the vibration generation and measurements are
   a) Piezoelectric accelerometer
   b) Vibration exciter
   c) Power amplifier
   d) Vibration meter with filter
   e) Functional generator
   f) Oscilloscope

The process of measuring is done as follows:

1- Heating the cylinder and measuring this value of heat flow by $Q = IV$. This quantity of heat generation due to electric current passage is equal to the heat transfer from the outer surface of the cylinder

2- When the study state was reached temperature is measured with no vibration.

3- The vibration exciter is operated with some frequency and amplitude values, to vibrate the cylinder.

4- When the steady state is reached the measurements are done and recorded from the instruments .

5- These previous four steps are repeated with different values of heat transfer, amplitudes, frequency and with different cylinder of different diameters.

THEORY

The heat generated electrically in the cylinder is transferred to the ambient by radiation and convection due to the temperature difference between the cylinder surface and the ambient.

$$Q = Q_r + Q_c \tag{1}$$

where Q=heat generated in the coil [W]

Q_r=heat transfer by radiation [W]

Q_c=heat transfer by convection [W]

The heat transfer by radiation can be calculated from the following equation

$$Q_r = A\varepsilon\sigma(T_s^4 - T_a^4) \tag{2}$$

Where A=surface area [m^2]

ε= the emissivity (taken as 0.9)

σ=Stefan Boltizmann constant= $5.67 \times 10^{-8} [W/m^2K^4]$

T_s= surface temperature [K]

T_a= ambient area temperature [K]

Then;

$$Q_c = Q - Q_r \tag{3}$$

The value of heat transfer by convection can be calculated from eq.(3). The heat transfer by convection can be represented as:

$$Q_c = Ah(T_s - T_a) \tag{4}$$

hence

$$h = \frac{Q_c}{A(T_s - T_a)} \tag{5}$$

where h=coefficient of heat transfer by convection [W/m^2.K]

The dimensionless number Nu (Nussult Number) if function of coefficient of heat transfer by convection and is represented by:

$$Nu = \frac{hd}{k} \tag{6}$$

where d is the diameter of the cylinder in meter and k is the thermal conductivity of the fluid(air).

For free convection (with no vibration or any other effects on the heat flow) from the horizontal cylinder Nu is a function of (Gr.Pr).

$$Nu = f(Gr.\Pr) \tag{7}$$

Where Gr= Grashof number and Pr=Prandtl number, and h in free convection can be denoted as h_o. For force convection under the effect of vibration only the heat transfer coefficient is a function of many parameters as illustrated in following equation.

$$h_v = f(d, f, a, \mu, Cp, \rho, l, T_s, T_a, k) \tag{8}$$

Where f=frequency, a=amplitude, μ= viscosity, ρ=density, Cp=specific heat, and l= length.

From eq(8) the relation can be rewritten by dimension less form that:

$$Nu_v = f(\mathrm{Re}_v, \mathrm{Pr}, \frac{al}{d^2}) \tag{9}$$

Where $\mathrm{Re}_v = \dfrac{2\pi afd\rho}{\mu}$

and the relation between the vibration heat transfer coefficient and the free heat transfer coefficient can be written as

$$\frac{h_v}{h_o} = \frac{Nu_v}{Nu} = \frac{f(Gr.\mathrm{Pr})}{f(\mathrm{Re}_v, \mathrm{Pr}, \frac{al}{d^2})} = f((Gr.\mathrm{Pr}), \mathrm{Re}_v, \mathrm{Pr}, \frac{al}{d^2}) \tag{10}$$

RESULT AND DISCUSSION

The different parameters were taken in consideration to study its effect on heat transfer by convection from a horizontal vibrated cylinder in air.

a- Effect of vibration intensity

The vibration intensity is defined as the product of vibration amplitude by a frequency (a.f) with a unit of [m/sec].

Fig(1) to Fig(3) show the effect of the vibration intensity on the ratio of heat convection with vibration to the free convection (convection ratio=(h_v / h_o))with different values of heat transfer (Q). The trend of the behavior of the increase in convection ratio is same, but its values affected by the frequency. The convection ratio increases with the increases of frequency. These figures show that as the heat transfer value is increased the convection ratio will decreases. This means that as the temperature difference is raises the free convection is increases and so the convection ratio decreases.

b- Effect of vibration Reynolds number

The effects of Re_v on the convection ratio for different heat transfer values (Q) and for different diameter and frequency values are illustrated in Figs (4(a,c,e)-6(a,c,e)). It is shown that with increase of Re_v , the convection ratio also increased. The frequency has the positive effect on the convection ratio. This effect increase with low heat transfer(low temperature difference), because at this case the effect of temperature difference is decreases so the increase in heat transfer is due to frequency.

c- Effects of (Gr.Pr)

To study the effect of the free convection terms (Gr.Pr) on the convection ratio, the relation between (Gr.Pr) and (h_v/h_o) was also drown on Figs(5(b,d,f)-7(b,d,f)). It was shown from these figs that as heat transfer increase the term (Gr.Pr) is also increased and the convection ratio decreased and becomes about unity at high heat transfer. As the temperature difference is increased the buoyancy is increased and so the free convection term (Gr. Pr) effect is also increased.

The trend of the behavior is same for all values of (Q) with change in frequency and diameter.

d- Effect of the diameter of the shaft

It is shown from Fig(6(a,c,e)) that the effect of the diameter has indication on the convection ratio at high frequency, because at high frequency the free boundary layer may damaged and the heat transfer becomes in the region of turbulent force convection. These effects are inversely influence by the heat transfer by free convection as indicated with the (Gr.Pr) effects on the convection ratio, Figs(7(b,d,f)). It is shown at low frequency and large diameter, the convection ratio becomes high, Fig(7,a).

e- Effects of frequency

The effect of frequency on convection ratio is indicated in fig(8). The convection ratio is increases with increase of (Re_v), Fig(8,a,c,e). the convection ratio decreased with increasing of (Gr.Pr) and frequency, fig(8,b,d,f). The term (Re_v) indicates the inertia force effect, and this will increase the convection ratio. The term (Gr. Pr) indicates the buoyancy force effect, and this will decrease the convection ratio.

CONCLUSIONS

It is concluded that heat transfer has been affected by the vibration. The heat transfer increases greatly at high frequency and small diameter. The convection ratio is decreased with the increasing of the temperature difference(high heat transfer).

The vibration Reynolds number has good effects on the heat transfer from the cylinder. The free convection term (Gr.Pr) has bad effect on the vibration heat transfer.

This study can be expanded to include other shapes to study the vibration effects on the heat transfer from it.

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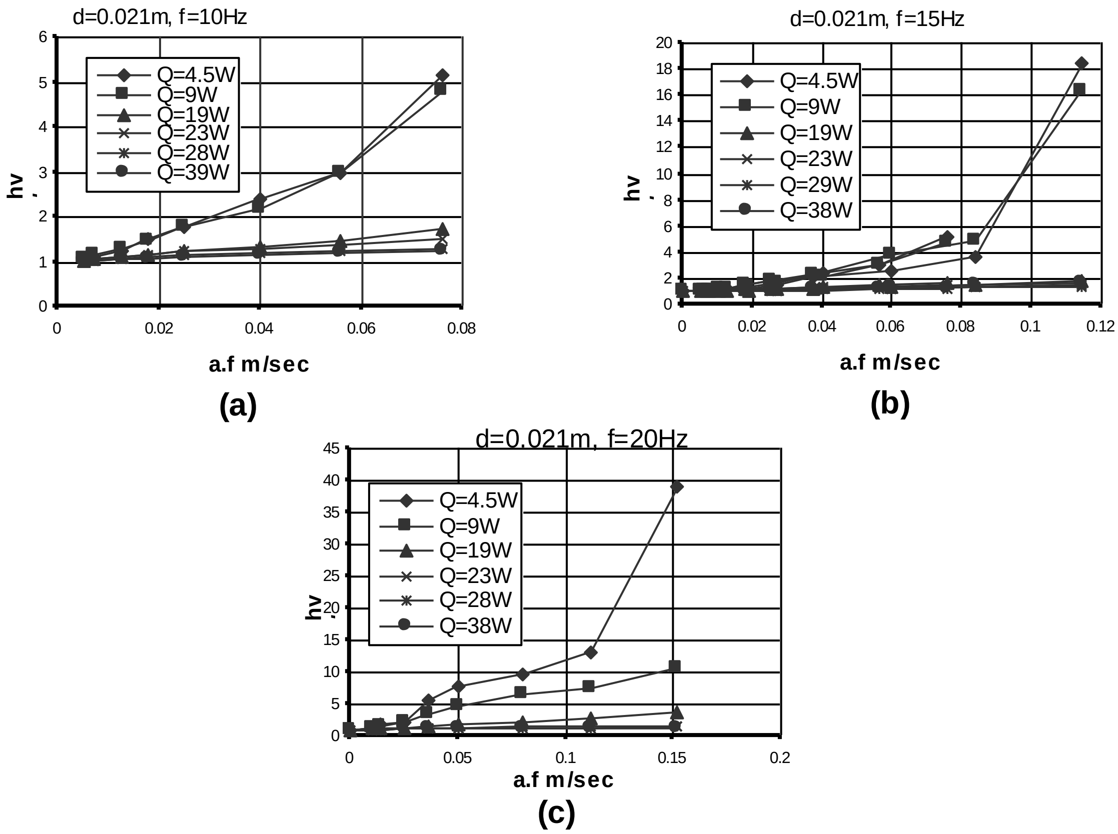
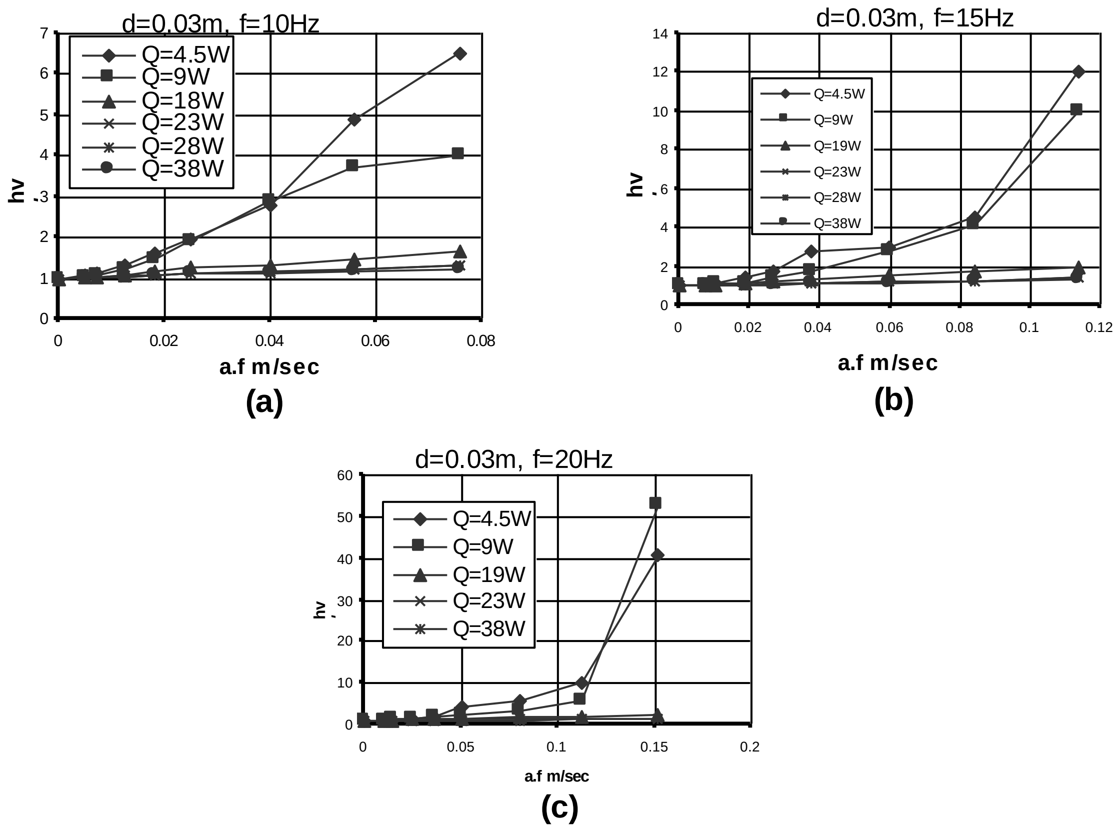
LIST OF SYMBOLS:

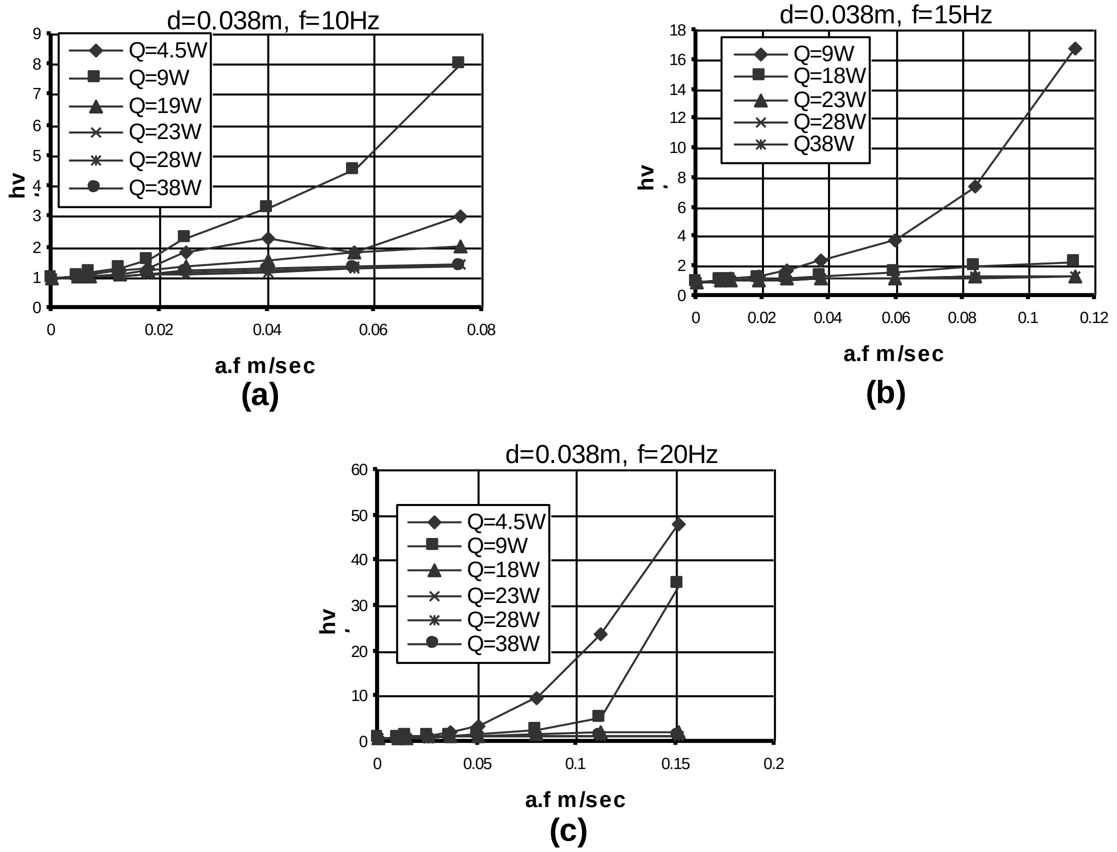
A	Area m^2	Nu_v	Vibration Nusslt number
a	Amplitude m	Pr	Prandtl number
Cp	Specific heat kJ/kgK	Q	Heat transfer W
d	Diameter of cylinder m	Q_c	Convection heat transfer W
f	Frequency Hz	Q_r	Radiation heat transfer W
Gr	Grashof number	Re	Reynolds number
h	Heat transfer coefficient $W/m^2.K$	Re_v	Vibration Reynolds number
h_o	Free heat transfer coefficient $W/m^2.K$	V	Voltage V
h_v	Vibration heat transfer coefficient $W/m^2.K$	ε	Emmisivity
I	Current am	ρ	Density m^3/sec
k	Thermal conductivity W/m.K	σ	Stefan-Boltzmann constant
l	Length of cylinder	μ	Viscosity kg(m.s)
Nu	Nussult number		



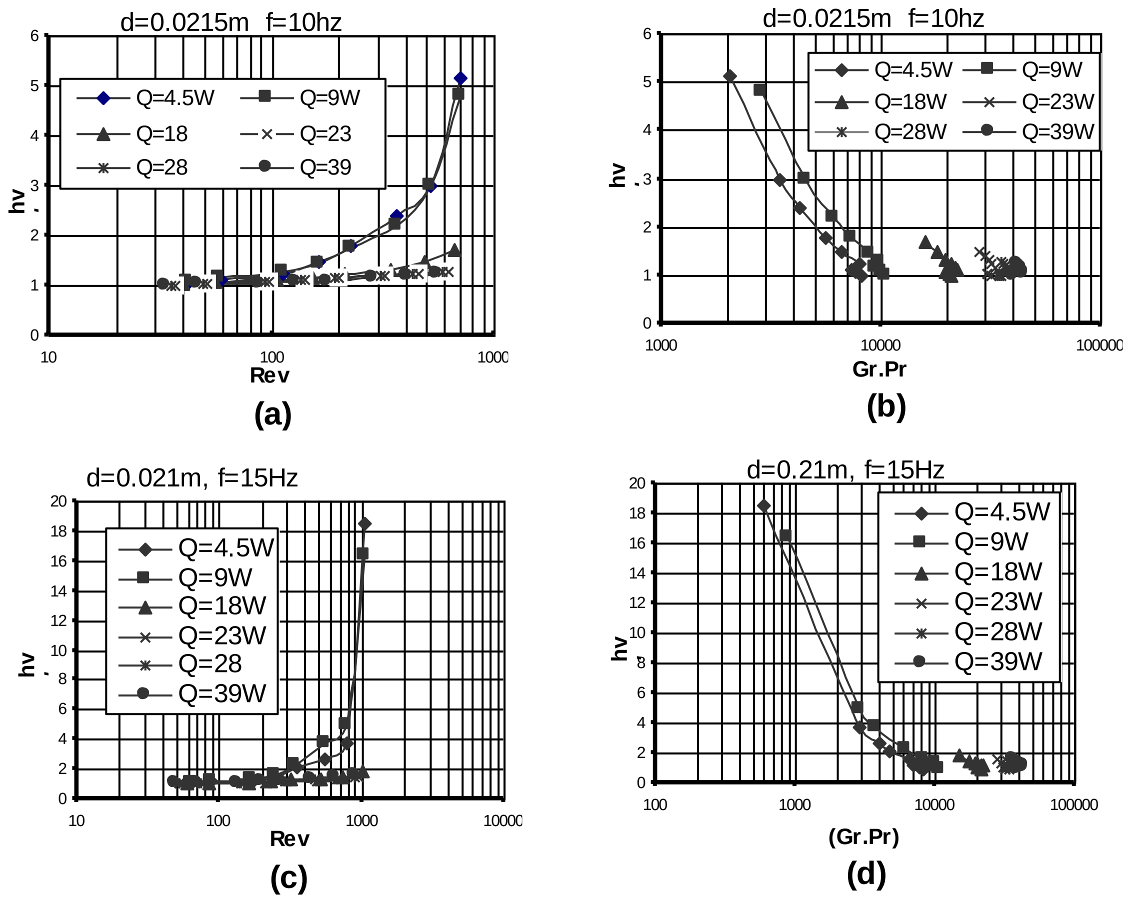
Fig(1) The Effect of Vibration density on Heat Transfer Coefficient for Different frequency and Heat Flux At d=0.021m

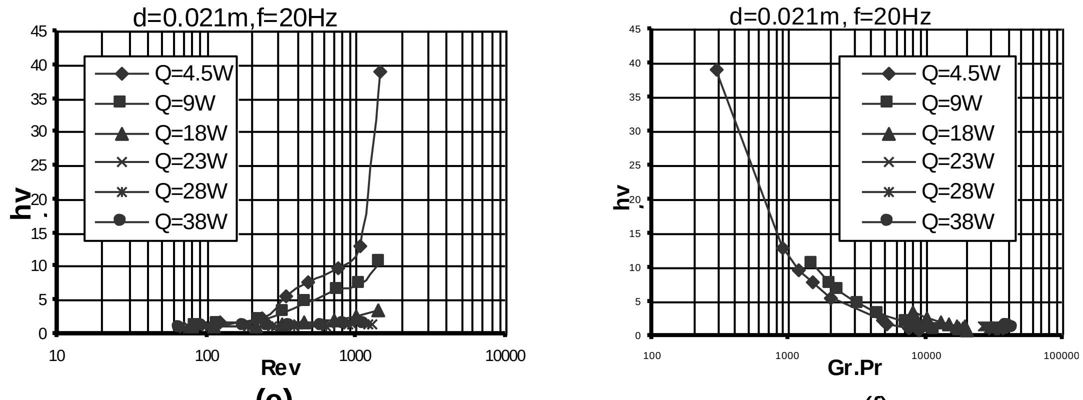


Fig(2) The Effect Of Vibration Density on heat Transfer Coefficient for Different Frequancy And Heat Flux at d=0.03m



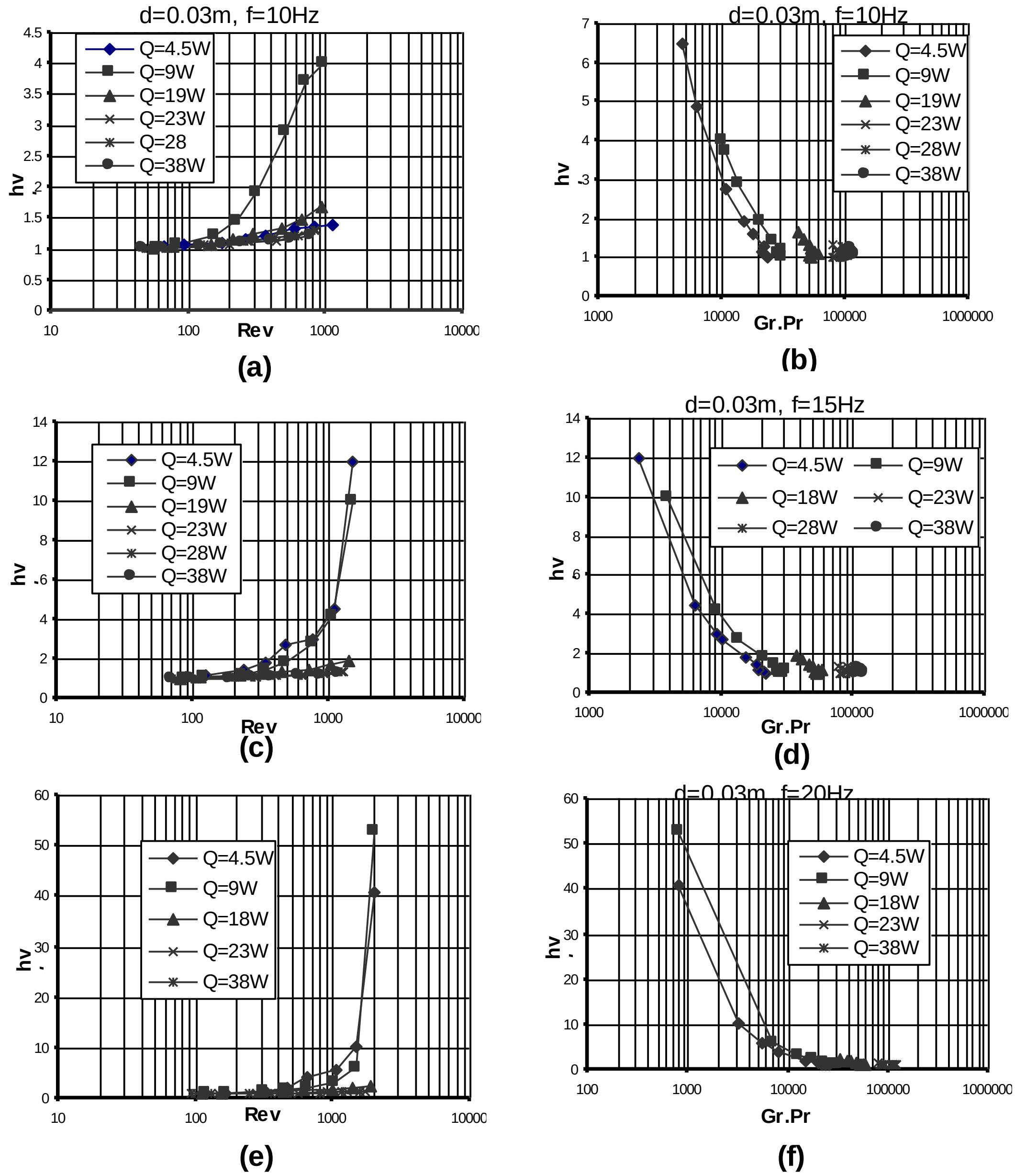
Fig(3)The effect Of Vibration Density on Heat Transfer Coefficient for Different Frequency and Heat Flux at d=0.038m



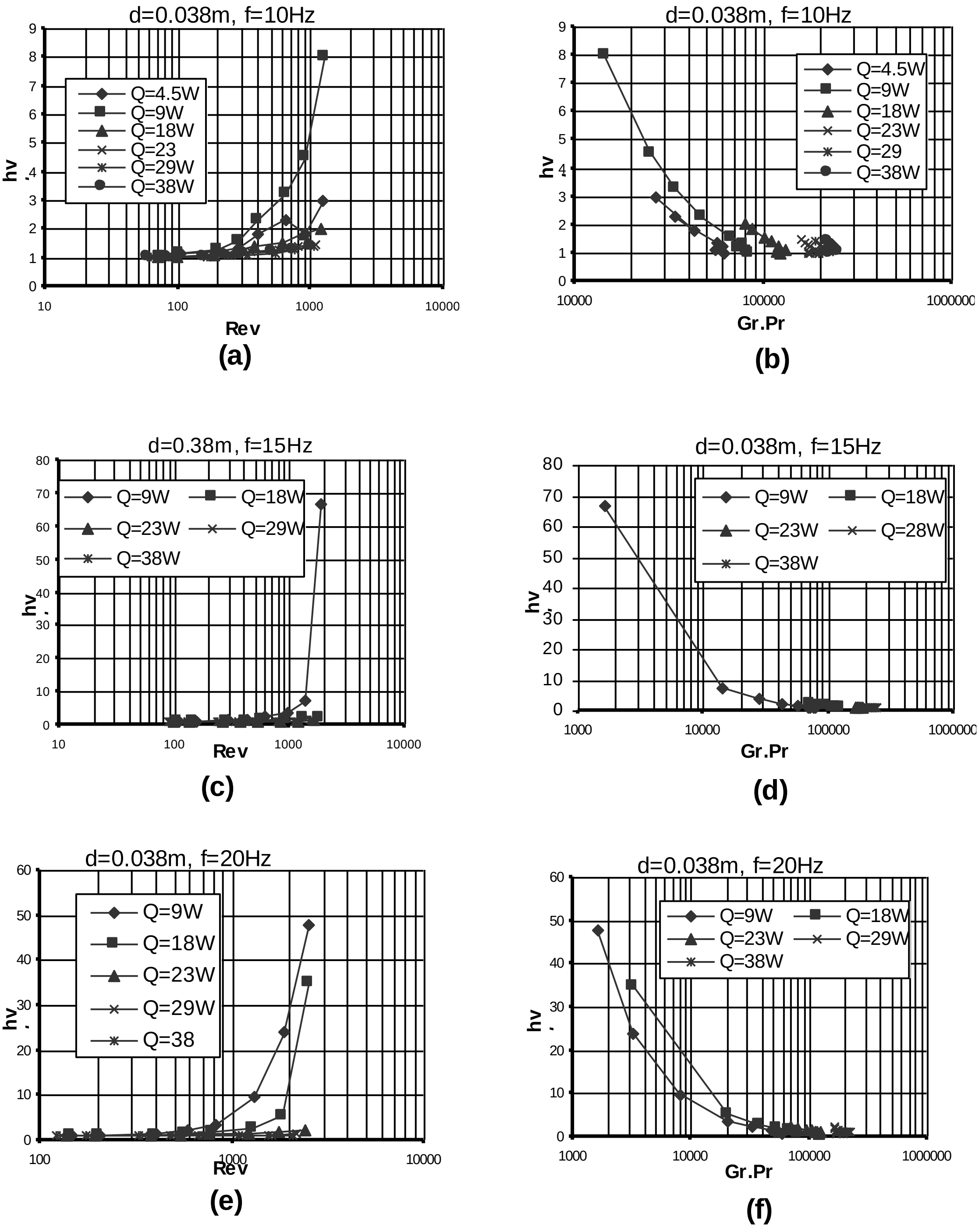


(e) (f)

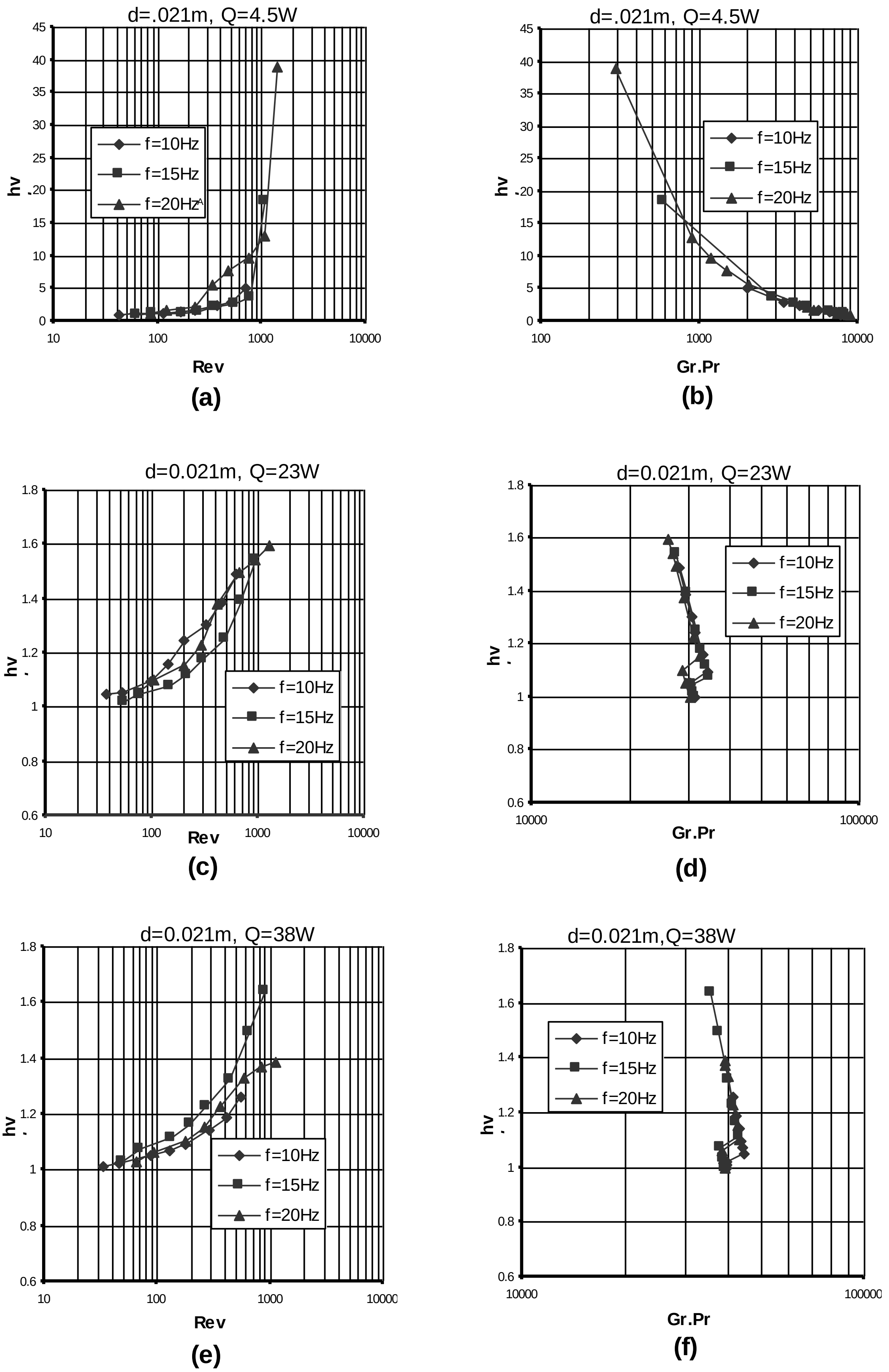
Fig(4) The Effect Of Re_v, and (Gr, Pr) on Vibration heat Transfer Coefficient at d=0.021m for Different Frequency



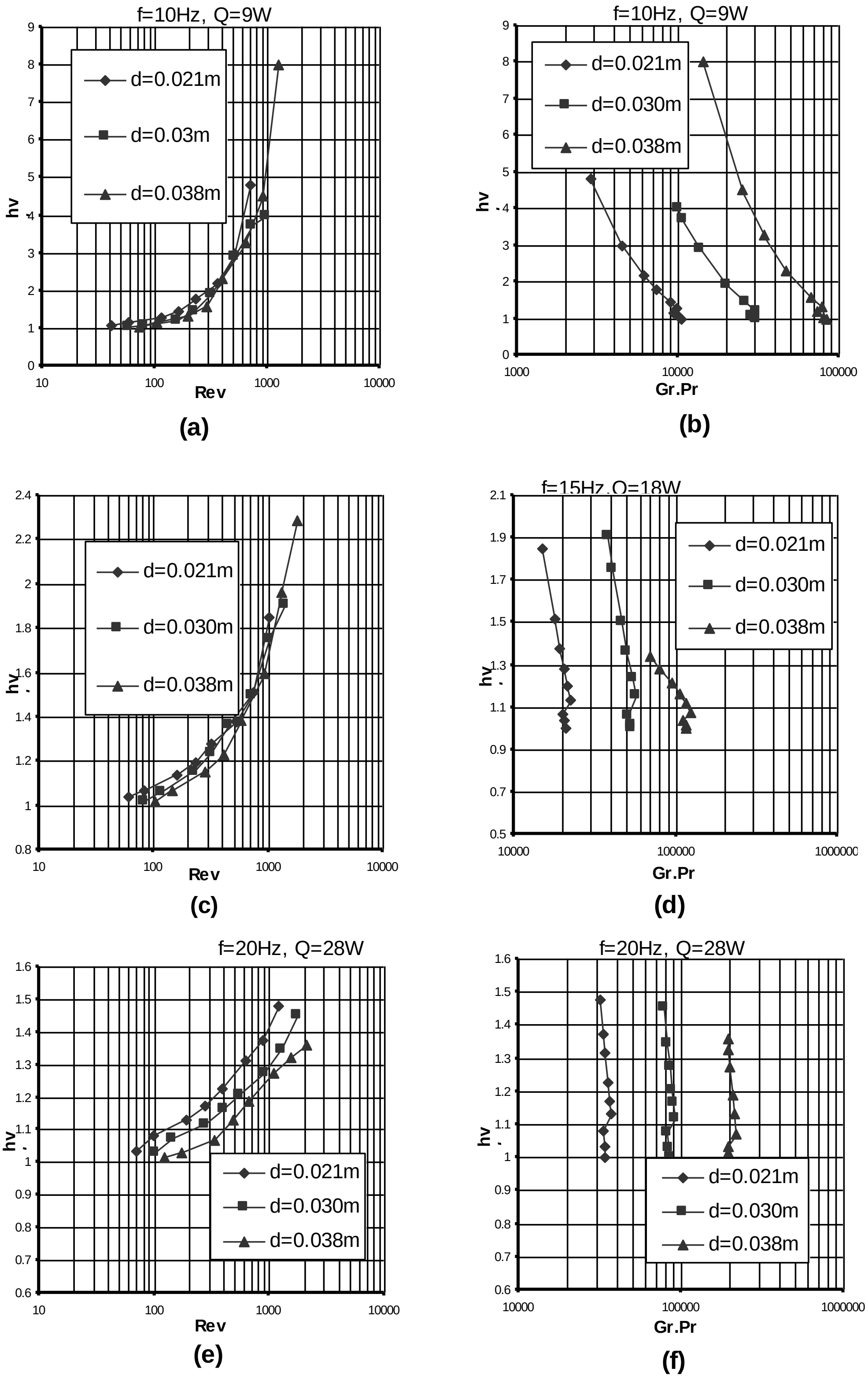
Fig(5) The Effect Of Re_v, and (Gr, Pr) on Vibration heat Transfer Coefficient at d=0.030m for Different Frequency



Fig(6) The Effect Of Re_v, and (Gr, Pr) on Vibration heat Transfer Coefficient at d=0.038m for Different Frequency



Fig(7) The Relation Between (Re_v), (Gr, Pr) and The (h_v/h_o) for Different Frequency at d=0.021m for different Heat Transfer



Fig(8) The Relation Between (Re_v), (Gr, Pr) and The (h_v/h_o) for Different Diameters at Different Frequency and Heat Transfer