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# End Correction of a Resonant Standing Wave in Open Pipes of Different Diameters

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**Abstract**

The end correction and diameter of pipe is related according to equation C= xD, C is end correction and D is diameter. Before in the research the value of X= 0.33 for λ/D ratio from 11 to 45.( Taylor 2011)

Now the value of x is calculated for λ/D ratio 15 to 99.It was found that the value of x= 0.486 for λ/D ratio from 15 to 99.In order to find the value of x=C/D empirical approach is used. All the major issues in the previous research are solved here by using PASCO System interface workshop 750.

**Keywords:** End Correction, Diameter, Wavelength, Open Pipes from both ends, Waves

## 1. Introduction

In waves a quantity changes periodically, In water waves is the height of water , in electromagnetic waves electric and magnetic field ,in Sound waves pressure.(Beiser 2008) .The sound waves are longitudinal waves ,it travel in the form of compression and rarefaction .According to Issac Asimove Sound waves consist of periodic compressions and rarefactions. The individual molecules of air move in one direction when compressed, then in reverse direction when rarefied, the volumes of compression and rarefaction move outward and are propagated in a direction parallel to the back and forth portion of the molecules. Such a waves in which the particles move parallel to the propagation of sound waves are called longitudinal waves.(Issac Asimove 1996) In the open pipe both ends are open, when sound waves travel through open pipe and reach the open end the cross-sectional area of pipe changes as sound enters in the open air so a part of wave will be reflected back from the open end and interfere with the coming sound wave from the speaker .A stationary wave is generated when two waves of identical properties moves in opposite direction in the same medium at the same time. Sound wave travel in the form of compression and rarefaction. (Harris 1996).In the stationary waves at nodes destructive interference and at antinodes constructive interference happen. So at nodes amplitude of vibration is zero and at antinodes amplitude of vibration is maximum. In open pipes air molecules are free to vibrate at both ends so antinodes are produced at both ends of open pipes (Poh Liong Yong 98).As the air is open at both the ends of pipe so antinodes are in the air at a small distance from the end of pipe. This small distance from the open end is called end correction ( Nelkon & parker 1995).

## 2. Method

The following equation is used to calculate the end correction for open pipe from both sides.

$L + 2c = \lambda/2$

$C = (V/2f - L)/2$

For the calculation of end correction C the above equation is used.

C=End correction(small distance of antinodes from the open ends)

V= Speed of Sound

f= Frequency of sound waves at resonance

L= Length of PVC pipe

The instrument details is given below to find the relation between End Correction (C) and diameter (D) For a resonant standing wave in open pipe for first harmonic.

1-PASCO 750 interface

2-Power Amplifier

3-Open Speaker

4-Resonance Tube (PVC pipes of different diameters)

5-Sound Sensor

6-Vernier Calliper to measure the diameter of pipes

7-Tape measure

## 2.1 Procedure

1- Place the speaker in front of open pipe at angle of $90^0$
2- In the PASCO system the data studio has a signal generator window that controls the output of power amplifier.
3- Amplitude selected to 3 volt and frequency of sound start from 10 hertz at signal generator window to find the resonance frequency for a particular diameter of pipe, and signal output of power amplifier is connected to the speaker.
4- Sound sensor is connected to interface Pasco 750 and on the scope, Sound waves are seen which are generated from the speaker, the frequency is noted when sound become loudest and amplitude becomes maximum. For Ist harmonic. In this experiment sound sensor is used instead of human ear to detect the resonance frequency.

## 2.2 Data Collected

During the experiment temperature was constant as it is done in controlled temperature

$T^0C = 18^0C$( Centrally air conditioned)

Speed of sound=v= 331.5m/s + 0.6x $T^0C$
= 342.3 m/s

Length of pipe= 80 cm = 0.8m
Diameter range= 16.2mm to 107 mm
Number of pipes=6
From the data it is also clear as the diameter increases, the value of End Correction also increases and data also shows that for the pipes of same material and same length, Resonant frequency for Ist harmonic changes as the diameter change, As the diameter of pipe increases the fundamental frequency decreases.

## 3. Discussion

When open speaker is placed at one side of pipe, open speaker vibrate and applied a periodic force on the air molecules inside the pipe. When the frequency of the open speaker and fundamental frequency of pipe matches the resonance produced and a loud sound is heared. When the natural frequency of vibrating object and applied force frequency matches, amplitude of vibration increased. (Nelkon& Parker 1995).

For stationary waves, two waves are involved, incident and reflected.These waves may be represented by the equation as stated by Poh Liong Yong(1994)
$Y_1=a \sin(\omega t - 2\pi x/ \lambda)$ where a is the amplitude and $\omega$ is the angular frequency
$Y_2= a \sin(\omega t +2\pi x/ \lambda)$
According to principal of superposition, the resultant wave can be represented as
$Y=Y_1 + Y_2$
So the resultant wave can be represented in terms of equation as
$Y= a \sin (\omega t - 2\pi x/ \lambda) + a \sin(\omega t +2\pi x/ \lambda)$
$=2a \sin \omega t \cos 2\pi x/ \lambda$
$= (2a \cos 2\pi x/ \lambda)\sin \omega t$ when this equation is compared with sin equation $Y= A \sin \omega t$
The amplitude of resultant wave can be written as.
Amplitude $=A=2a \cos 2\pi x/ \lambda$
Where A is the amplitude of the resultant stationary wave for a point at a distance x from reference point .At nodes amplitude is zero.

$A=2a \cos 2\pi x/\lambda=0$ when $2\pi x/\lambda=\pi/2, 3\pi/2$

So $x=\lambda/4, 3\lambda/4$

Hence the distance between two successive nodes= $3\lambda/4-\lambda/4=\lambda/2$

In the same way distance between two antinodes=$\lambda/2$

The above mathematical process shows that the distance between two successive nodes or antinodes is $\lambda/2$.In open pipes at both ends antinodes are formed because air particles are free to vibrate.(Poh liong 1994).

## 4. Result

The value of X here found is 0.486.for C = xD

The result is for open pipes (PVC) from both sides for **λ/D** ratio from 15 to 99. Previously in the work of Taylor Boelkes and Ingrid Hoffmann it was shown that value of x= 0.33 for **λ/D** ratio 11 to 45.

The major issue in the research of Taylor Boelkes and Ingrid Hoffmann was use of human ear to detect the resonance of sound, there may lot of mistakes by considering human ear to calculate the resonance frequency, here sound sensor is used. In the previous research it was issue and here in data studio a scope window is used when sound become loudest. It is accurate method to find the resonance frequency. There is need of research to conduct pipes of different materials and each material of different diameter and for open and closed pipes of same length and same diameter but different material, to find the end correction, research should be conducted to find the difference of end correction under these conditions.(Taylor& Ingrid 2011).

## 5. Conclusion

The end Correction C=X D, according to this research the value of X for **λ/D** ratio from 15 to 99 is 0.486.This research is not in agreement with the work of Taylor Boelkes and Ingrid Hoffmann.The major issue in the research of Taylor Boelkes has solved by using sound sensor instead of human ear.

The graph between Diameter along X- axis and End Correction along Y- axis is show in the below graph.

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Table 1.

| Sr. No | Diameter D（ meter） | Frequency （hertz） | End Correction (C) | **λ/D** |
|---|---|---|---|---|
| 1 | 0.0162 | 210 | 0.0076 | 99 |
| 2 | 0.0223 | 208 | 0.0114 | 72 |
| 3 | 0.0347 | 204 | 0.0190 | 46 |
| 4 | 0.051 | 199 | 0.0310 | 31 |
| 5 | 0.0793 | 192 | 0.0450 | 20 |
| 6 | 0.107 | 188 | 0.051 | 15 |

The graph between Diameter (along x-axis) and End Correction (y- axis) is show in the below graph