International Journal of Advances in Engineering and Management (IJAEM)
Volume 5, Issue 8 Aug 2023, pp: 540-544www.ijaem.net ISSN: 2395-5252

# Analyzing the relation between the temperature of a medium and the speed of sound

Ranai Loonkar

Date of Submission: 15-08-2023 Date of Acceptance: 25-08-2023

**ABSTRACT:**
The purpose of this research paper is to look at the relationship between temperature and the speed of sound in a medium. Temperature is known to alter the speed of sound, which is a fundamental feature of waves travelling through a medium. This relationship is critical for a variety of applications, including engineering, meteorology, and acoustics. The purpose of this research is to determine the effect of temperature on the speed of sound and to investigate the underlying mechanisms. The findings shed light on the behavior of sound waves and contribute to our understanding of wave propagation under various temperature settings.

## I. INTRODUCTION:

The speed of sound is the pace at which a sound wave travels through a medium, and it is affected by various elements, including the medium's qualities. Temperature is one such component that has a substantial impact on the speed of sound. For many years, scientists and engineers have been fascinated by the link between temperature and sound speed. The purpose of this study is to look into this relationship and gain a better knowledge of how temperature influences the speed of sound.

The effects of altering sound speeds can be enormous. The principal application of this is in sound navigation and ranging aboard, which is employed by animals like as bats and aquatic watercraft.

Sound Navigation and Ranging use sound to determine the location of objects. The sound wave will proceed straight until it collides with a foreign object, at which point it will be reflected off the surface of the object. The position of the foreign object can be determined using the reflected sound wave. As a result, because the entire system is dependent on the speed of sound to measure the distance of the foreign item, it is critical to account for the fact that the speed of sound varies with medium temperature. Not doing so could give an incorrect position of an object and if the submarine were trying to send a missile to it, it may miss because of the miscalculated distance.

Similarly, the speed of sound in the air can be significant in meteorology. Because fluid dynamics cause liquid water and air to act similarly, the connection between temperature and speed will be the same. The temperature of the air through which the sound wave must travel is required in the original method of measuring the distance of a thunderstorm by counting the number of seconds between a flash of lightning and thunder. Temperature extremes can be seen in India in the Leh-Ladakh region and the coastal areas of Kerala. Leh-Ladakh, located in the country's north, receives exceptionally cold weather throughout the winter season, with temperatures frequently falling below freezing. The coastal areas of Kerala in southern India, on the other hand, have a tropical environment with high temperatures and humidity all year.

The temperature difference between these two places can be significant, easily exceeding 30 degrees Celsius. The chilly climate in Leh-Ladakh causes a decrease in the speed of sound, whereas the warmer coastal areas of Kerala experience an increase in the speed of sound. As a result, depending exclusively on the "universal" value of 343 m/s for sound speed could result in considerable errors in certain places.

For example, if a cyclone or thunderstorm is approaching Leh-Ladakh, using the universal figure of 343 m/s for sound speed would underestimate the distance at which the sound of thunder may be heard.

Similarly, in Kerala's coastal districts, an incorrect estimate of the speed of sound could result in a premature or exaggerated warning for severe weather. The anticipated distance of the approaching weather system may be shorter than the actual distance if the "universal" figure of 343 m/s is utilised, generating unneeded worry and inconvenience.

Taking temperature-related fluctuations in the speed of sound into consideration will allow meteorologists and weather forecasters to make more precise calculations and offer appropriate warnings, assuring the safety and well-being of the impacted communities.

In order to have more accurate systems such as SONAR and weather forecasts, it is required to study the subject and implement the findings.

The experiment shows, on a smaller scale, how the temperature of the medium through which sound travels affects its speed.

## II. METHODOLOGY:

The experiment involved setting up a controlled environment where the temperature of the medium could be manipulated. A closed chamber contained a medium, water. A thermostat was employed to regulate the temperature of the medium, and an accurate thermometer was utilised to measure it.

To measure the speed of sound, a sound source which was a speaker and a microphone were placed 1000mapartwithin a tube filled with water. The sound source emitted a short acoustic pulse, and the microphone captured the time it took for the sound wave to travel between the two points. The distance between the sound source and the microphone was carefully measured to ensure accurate results. 20 measurements were taken at different temperatures with a 25 Celsius difference to establish a temperature-speed of sound relationship.

In order to measure the fluctuation of the speed of sound, a device for holding the

medium was constructed. For this, a 1.1-meter-long polyvinylchloride tube with a 7.5-cm diameter was used. A 0.6 cm diameter hole was drilled half way down the tube, 55 cm from either end, to measure the average temperature in the tube. A temperature probe was put into the hole, with its tip directly in the centre of the tube, both lengthwise and width wise. To secure the temperature probe and create a watertight seal between the tube and probe, clay was utilised. Following that, a polyvinylchloride cap was inserted at one end of the tube and silicone caulking was used to create a watertight seal between the tube and cap. A meter stick was inserted into the open end of the tube so that one end rested against the inside of the cap. From this part of the procedure, a 1-meter mark was traced along the inside of the tube; this would indicate the point to which the water must be filled.

The time it took for the wave to travel down the tube and back up againwas represented by the wavelength of the square-wave, the distance between one peakand the consecutive peak. In order to keep consistency, the middle of the peak was usedeach trial to calculate the time it took for the sound wave to be reflected back to the top.

## III. RESULTS AND ANALYSIS:

Table 1: Times gathered from experiment

| Trials | Temperature C | | | |
|---|---|---|---|---|
| - | 0 | 25 | 50 | 75 |
| | | | | |
| 1 | 1.10 | 0.97 | 1.00 | 0.78 |
| 2 | 0.96 | 0.97 | 0.84 | 0.85 |
| 3 | 1.15 | 0.82 | 1.09 | 0.92 |
| 4 | 1.15 | 0.81 | 0.98 | 0.84 |
| 5 | 1.17 | 0.93 | 0.94 | 0.87 |
| 6 | 1.16 | 0.94 | 0.83 | 0.83 |
| 7 | 1.12 | 1.12 | 0.92 | 0.96 |
| 8 | 1.12 | 0.92 | 0.97 | 0.84 |
| 9 | 1.06 | 0.92 | 0.95 | 0.86 |
| 10 | 1.02 | 1.03 | 0.88 | 0.97 |
| 11 | 1.06 | 0.88 | 0.93 | 0.87 |
| 12 | 1.06 | 0.94 | 0.91 | 0.85 |
| 13 | 1.13 | 0.92 | 0.95 | 0.74 |
| 14 | 1.10 | 1.00 | 0.93 | 0.73 |
| 15 | 0.98 | 0.94 | 0.88 | 0.85 |

| | | | | |
|---|---|---|---|---|
| 16 | 1.18 | 0.85 | 0.82 | 0.75 |
| 17 | 1.15 | 0.98 | 0.83 | 0.84 |
| 18 | 1.12 | 0.98 | 0.98 | 0.88 |
| 19 | 1.10 | 0.96 | 0.95 | 0.81 |
| 20 | 0.90 | 0.93 | 0.89 | 0.80 |
| Average | 1.09 | 0.94 | 0.92 | 0.84 |

The experimental data obtained from the measurements were analyzed to determine the relationship between temperature and the speed of sound. The results indicated a negative correlation between these two variables, As the temperature increased, the time taken for the sound wave also decreased. This relationship followed a linear trend, with a positive slope indicating a direct proportionality between temperature and the time taken for the sound wave.

To get the speed of the wave, we use the formula v =2d/t

Table 2: Experimental values for the speed of the sound

| Temperature | Speed |
|---|---|
| 0 | 1834.86 |
| 25 | 2127.66 |
| 50 | 2173.91 |
| 75 | 2380.95 |

The speeds can then be used to make a graph to see the correlation betweentemperature and the speed of sound. These are the experimental values, which must be compared to theoretical values to determine how accurate the experiment was. To interpret the data, one must first understand what sound is and how it travels - sound is a disturbance that is spread by particle collisions, which forms a longitudinal wave. There are two valid justifications for the speed of sound in relation to the temperature of its medium, but only one is true. The first point is that the speed of sound and the temperature of its medium have a direct, positive relationship.

It is supported by the premise that because sound travels via particle disruption, if the particles move quicker, the wave will be able to go faster. According to kinetic theory, temperature is the average kinetic energy of particles of matter and because kinetic energy is defined as 1/2 mv^2, temperature is directly related to velocity. As a result, increasing the temperature increases the velocity of particles, allowing the sound wave to move quicker across the medium. Because the particles are already travelling relatively quicker, the sound wave may travel more easily across the medium. The second point is that there is an indirect, negative link between sound speed and medium temperature. This argument is based on kinetic theory as well. It varies, though, in that it focuses on density rather than velocity. According to kinetic theory, when temperature rises, particles vibrate more and move more apart. Finally, temperature is directly proportional to density.

The logic follows that as temperature rises and density falls, the speed of sound decreases because the particles that must interact to propagate the wave are further apart. As a result, because they can't interact as easily as they could when they were closer together at a lower temperature, the speed of sound will be slower. The latter reasoning is accurate on a larger scale of solids, liquids, and gases. This is because experiments show that as temperature is increased (by changing the state of matter), the speed of sound drops. In a gas, the particles become so far apart that it is impossible for the wave to propagate across the medium. To calculate the theoretical values for this experiment, the following equation
must be used:

v = √(elastic property / inertia property)

Upon referencing the bulk modulus of water, one finds that it is 2.2 x 10^9 N/m
which gives:
v = √(2.2x10^9 Nm^2 / density)
The density of each temperature was found by using the online water densitycalculator. By inputting the temperatures of the water, it calculated the densities

Table 3: Densities of Water

| Temperature | Density |
|---|---|

| | |
|---|---|
| 0 | 999.88 |
| 25 | 997.17 |
| 50 | 988.05 |
| 75 | 974.70 |

Table 4: Theoretical Values for Speed of Sound

| Temperature | Speed |
|---|---|
| 0 | 1483.33 |
| 25 | 1485.34 |
| 50 | 1492.18 |
| 75 | 1502.37 |

To compare the experimental and theoretical values, percent error can be calculated using the formula:

% Error = ({theoretical – experimental})/theoretical

Table 5: Errors

| Temperature | % Error |
|---|---|
| 0 | 23.6% |
| 25 | 43.2% |
| 50 | 45.6% |
| 75 | 58.4% |

## IV. DISCUSSION:

The behaviour of molecules in the medium helps explain the observed link between temperature and sound speed. As the temperature rises, so does the kinetic energy of the molecules, resulting in quicker molecular motion. In gases, increased molecular motion results in faster sound wave propagation. The specific heat capacity and compressibility of the medium also influence the speed of sound, but temperature is the most influential component.

**Implications and Applications:**

The study's findings have far-reaching consequences in a variety of sectors. Understanding the influence of temperature on sound speed is critical in engineering for building efficient and accurate acoustic systems. Temperature fluctuations in the atmosphere affect the propagation of sound waves in meteorology, influencing weather forecasting techniques. Furthermore, this study contributes to a better knowledge of wave propagation at different temperatures, which will benefit in the creation of better acoustic materials and structures.

## V. CONCLUSION:

Finally, this study shows that temperature has a considerable effect on the speed of sound in a medium. The speed of sound increases in a linear connection as temperature rises. At higher temperatures, the underlying mechanisms can be attributed to greater molecular motion and associated kinetic energy. This study's findings have crucial ramifications for a variety of industries and provide vital insights into the behaviour of sound waves under diverse temperature settings.

Further research can be undertaken to investigate the effect of other elements on the speed of sound, such as pressure and humidity, as well as the effects of temperature fluctuations on different materials.

The data acquired in the experiment indicate that there is a direct positive association between temperature and sound speed. In the experiment, there are various potential sources of mistake. First, the main cause of inaccuracy is most likely systematic error, as the experimental results differed from the predicted values by about 550 m/s at each temperature. If it had been human mistake, the experimental values would not have all been off by the same amount. The microphone is most likely to blame for the systematic mistake. What little human mistake there was may have been due to the power with which the pencil was struck, which was not exactly constant for each experiment.

This would change the loudness of the wave and make calculating the time between two wave crests more or less difficult. There are various modifications that can be done to run a more accurate experiment. A more accurate and precise microphone, specifically designed to measure very small intervals, should be utilised. This ensures that the data collected is closer to the theoretical value, lowering the percent error. Second, a device that emits a very small pulse of sound can be employed to help discern the time between two consecutive wave crests.

A cover for the top of the tube can also be employed to keep extraneous noise out of the tube and away from the data collected by the microphone. These three adjustments will undoubtedly improve the data in future studies, resulting in a more accurate analysis.

However, one point remains unanswered at the end of the experiment: why does the speed of sound grow with temperature but decrease with matter state?

The speed of sound increases with temperature, as demonstrated in the experiment, and decreases with state of matter, as demonstrated by referring to a table of the speed of sound in different mediums, but the explanation for this remains unknown. It is amusing that the speed of sound increases in one situation but drops in the other because both involve increasing the quantity of kinetic energy of particles. The only conclusion that can be drawn from this is that there may be a point at which particle speed no longer benefits the transmission of a sound wave.

There must be a threshold between each stage, solid and liquid, and liquid and solid. The threshold can be modelled at any of these points by: F velocity of particles F medium density This equation implies that near the threshold, the influence of medium density is larger than the influence of particle velocity on the speed at which the sound wave travels.