Microwaves and Heat Transfer

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ENGR 23000

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11 December 2023

Abstract

This paper will serve as a brief overview of the different facets of the microwave oven and help readers understand how thermodynamic properties serve as the basic function of the technology. Microwave ovens have changed the way many households prepare food in modern times. The paper will also delve into the different technological advances that took place to help such technology exist.

At the end of this paper, readers should be able to grasp the basic concepts of how an microwave oven function, the fundamental parts that make up modern microwave oven and how heat transfer properties work within the oven in an more detailed form to better understand how such uses of radiation work to defeat health concerns misconstrued by the general public.

Introduction

What exactly differs a microwave oven from the much older and traditionally used convection oven? For starters, a microwave oven uses different methods of heat transfer to warm up content. A convection oven relies on the use of convection, hence the use of the word ‘convection’ in its name. This form of heat transfer relies on transferring heat from a region of higher thermal energy to another region of lower thermal energy. A microwave oven utilizes both convection and radiation. Such Propeties will be explored further in the ‘Thermodynamic Connection’ section of this paper.

Now to properly define a microwave oven, it's best to first understand the different parts of the microwave oven, starting off with the heating method. The microwave oven can create microwaves to carry out radiation as a heat transfer method. The microwaves are created in a

electron tube called the Magnetron (FDA) and such waves are bounced off the waveguide within the interior of the oven until it gets absorbed by the food. The other important components of the microwave oven include a cooling fan, turntable, and a transformer (Maytag). Not to the surprise of many, a microwave would require a high voltage input which cannot be provided by the electrical outlet in most people's homes. The transformer can multiply such input voltage to the necessary 3,000 to 4,000 voltages to cook food content.

Microwave ovens have been used as an alternative to convection ovens due to the more efficient processing of heat transfer. Microwaves produced by microwave ovens utilize electromagnetic radiation that causes motion in which then energy is converted to thermal energy (E.T. Thostenson). As discussed earlier, all of this is possible with the addition of the Magnetron. Magnetrons were first made by Britain as Radar technology for the war and their heating protentional was discovered by accident by Percy Spencer in 1945 (Bournemouth). With the connection between using microwaves to produce thermal energy, such application within cooking food was eventually picked up upon. Microwave ovens were first introduced for commercial use in 1946. However, such a device had yet to be seen as often as it is in every household as it is today until 1997, as the microwave oven continued to improve cost-wise and efficiency.

While best well known to be used for various home cooking needs, microwaves also serve a pivotal role in various other technological needs. Microwaves have applications to many technologies such as signal carriers in advanced technologies such as satellites, drones, airplanes, and ships (NASA). Microwaves have such a wide range of applications due to their inherent higher kinetic energy properties as well as their frequencies range. Beyond their fundamental role in culinary pursuits, these properties make microwaves exceptionally well-suited for an

array of diverse applications, showcasing their adaptability in both domestic and industrial settings. Whether it be its uses in communication within space exploration, aviation and maritime navigation, microwaves have continued to advance the technolgies dealt with in our modern times.

Despite the widespread use of the microwave oven, technology presents its own set of disadvantages to other heating methods. One problem many users may observe simply by using the microwave oven is its ununiformed heating patterns (M.E.C. Oliveira, et. al). As previously defined, microwaves can convert kinetic energy to thermal energy most effectively in high moisture items, as this will allow for more vibration within the molecules. Therefore, heating content with varying moisture content would lead to different temperature components of a food mixture.

Thermodynamic Connection

For the microwave to be made possible, the creation of microwaves must first be developed. Microwaves are small electromagnetic waves that were first created by Sir John Turton Randall to develop a radar to detect small waves. Microwave ovens use microwaves, a type of electromagnetic radiation, as heat transfer. Water within the item placed into the microwave oven will vibrate due to the waves being absorbed by the content, to which the mechanical energy will transfer to heat (J. Tang).

Radiation does not require a medium to transfer energy and is able to transfer energy at the speed of light, related through the equation $\lambda = \frac{c}{v}$, where v represents the frequency, c represents the speed of light, and λ represents the wavelength. In experimental relationships, Radiation is related to energy emitted through Stefan-Bolzman Law in which $q \, \alpha \, T^4$.

To relate the change from mechanical energy to thermal energy, the first law of thermodynamics must be obeyed. This will establish that no matter the conversion of energy, the total energy will remain the same. Without the presence of any work done to or by the system, the total heat energy would be the same. To look at the relationship that would determine amount of energy transfer due to heat, work and mass to change in kinetic, potential and internal energy, energy balance must be used. This equation is as follows: $E_{in} - E_{out} = \Delta E_{system}$. By employing the energy balance equation, it is now possible to calculate and analyze the changes in kinetic, potential, and internal energy. In application, one can now use the balance equation to help design anything that requires knowing energy in a system.

Microwave ovens also help heat content through conduction. While the radiation can help convert some of the energy to thermal energy, the inner portions of an item that may be considered larger will be heated through conduction. Such heat transfer method involves transferring energy by diffusion from the region of higher energy. With the outer portion heated through the microwaves, this will create a region of higher energy. Conduction differs from impact in that the transferred kinetic energy happens at a molecular level and does not cause an overall motion of the object. Conduction is most effective within a solid as the proximity of the molecular will reduce the losses of energy. Conduction as an experimental heat transfer mechanism utilizes Fourie's law in which $q \, \alpha \, \nabla T$, where heat is proportional to the gradient of Temperature.

Kinetic energy, a term frequently associated with potential and internal energy, is commonly regarded as a static form of energy in thermodynamics. These various forms of energy collectively contribute to the overall energy content contained within a given system. In contrast, dynamic forms of energy, including heat transfer, work, and mass transfer, are characterized by

their ability to traverse the boundaries of a system. Heat transfer, a prominent example of dynamic energy, occurs whether a system is closed or open, often also referred to as boundry phenomenon. Viewing the different forms of energy in terms of static and dynamic forms allows an understanding of how the different properties of the different types of energy interact within the world. Heat transfer being seen as moving energy across a boundary can help us understand that expended energy must. be added for such a process to happen.

Conclusion

The microwave oven is a powerful and innovative tool that took on many inventions to become what it is today. The creation of the Magnetron made it possible to create microwaves, an electromagnetic radiation, which has applications to various maritime and communications technologies. However, inherent to its method of heating food, microwaves can cause uneven heat distribution based on the food moisture content. More importantly, the thermodynamic processes that make such heating possible is the subject of heat transfer. Microwave ovens can utilize both radiation and convection to create a faster heat transfer in comparation to a convection oven.

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