On the Base Role of Entropy in the Unified Theories of Mechanics with Some of the New Independent Applications

Abstract: This article examines and studies the base role as well as some of the independent special applications of entropy in unified theories for direct use in problem analysis as well as application in equation integration of mechanics and thermodynamics. Today, entropy has become a concept beyond what is introduced in classical thermodynamics. In classical thermodynamics, entropy is considered as a governing law, and in fact, any process that establishes the first law is a feasible process if the second law is established. While in some special applications that are generally proposed in unified mechanical theories, entropy has been directly included in the analysis of problems and has become a direct basic concept to study relevant problem. What causes this special role for entropy in unified theories is related to the depth and wide range of applications of the second law of thermodynamics in physics as well as natural phenomena.

Keywords: Second Law of Thermodynamics; Entropy; Unified Theories; Mechanothermodynamics; Feasible Processes.

1. Introduction

The second law of thermodynamics is the most important physical law that has been introduced in all branches of science [1, 2]. Carnot can be considered the founder of the second law because he was the first to present irreversible thermodynamic cycles [3]. In classical thermodynamics, there are two main formulas for the second law: Kelvin-Planck and Clausius formulas [4-6]. These formulations are actually claims about feasible processes. Also, some formulations have been developed for the second law, which relies on claims about probabilistic processes [6]. For example, Caratheodory's formula is another formula in classical thermodynamics for the second law, which is presented for possible processes [7-10]. Clausius formulated the second law by introducing a physical quantity called entropy [11]. According to this Clausius relation, entropy must always increase. Therefore, the entropy sign produced can be known as a physical direction for physical processes, which is also called the arrow of time in some sources [12, 13]. In terms of classical thermodynamics, the physical concept of entropy is the loss of useful energy and its exchange with heat [6, 14-16]. The entropy formula in classical thermodynamics is used for equilibrium states, and no attempt is made to define it in non-equilibrium states [6]. Also, from the perspective of statistical physics, entropy is considered as a physical quantity that depends on the probability of the system's existence at a certain energy level and is calculated by examining the micro and macro states of the system [17, 18]. Therefore, the second law is equivalent to the fact that the probability of the existence of the system always increases [17].

The concept of entropy has been introduced in many branches of science and has become the basis of the analysis of phenomena as a basic law. A number of defined entropies along with their applications can be seen in relevant references [18-23]. The important point is that in most of these definitions, the energies involved in the process are directly the basis of the definition, and in other definitions, this energy is indirectly used to define entropy. Considering the position of entropy in today's sciences, it may not be wrong to consider it the most important law governing nature.

Entropy is basically introduced by the second law of thermodynamics. Various mathematical proofs have been presented for the second law, among which statistical mechanics methods can be mentioned. In statistical mechanics, individual particles are investigated in available energy levels and macroscopic
thermodynamic concepts are calculated. Boltzmann's entropy equation is of special importance in this, which basically examines the causes of irreversibility [15, 24-30].

The second law of thermodynamics can also be rewritten for separate systems [28]. Prominent views have also been raised regarding the second law, which can be followed up in the relevant references [29-31]. Although there are some challenges about the second law among scientists [32-35]. Unified theories use entropy concept as base of the unified equations. This matter is one of the most important challenges for researchers in the subject. This paper investigate and study some of the new important uses of entropy in unification of the mechanics and thermodynamics.

2. Entropy

Today, in many scientific branches, entropy has entered as an independent concept in the analysis of physical phenomena. In addition to the thermodynamic entropy that Clausius defined based on Carnot's assumption, other definitions have been provided for entropy, and each of them is used in the relevant cases. In this chapter, entropy is expressed along with examples of its new definitions, and also mechanothermodynamics is introduced as one of the branches of science that uses the concept of entropy in the analysis of relevant systems, and mechanothermodynamic entropy is expressed.

Like energy, the concept of entropy is one of the most important concepts raised in scientific theories. With the presentation of new scientific theories, this concept has not lost its place and value and in some cases its importance has also been increased. Historically, the concept of entropy was proposed after the concept of energy and the principle of energy conservation were introduced, and according to the way it is defined, it fulfills the requirements for the completeness of the set of equations governing physical problems and is one of the basic laws in the analysis of physical phenomena. Has become.

The principles and concepts related to entropy entered scientific fields in the 19th century, more specifically in thermodynamics and statistical physics, in order to explain equilibrium and investigate thermodynamic systems. The relevant theory has been developed in two different ways. Boltzmann's theory is one of the ways to expand the concepts related to entropy [36].

The older theory stems from a macroscopic view of entropy. In this case, entropy is explained based on a limited number of available values. Such as density, specific volume, temperature, pressure and any other characteristic that can explain the thermodynamic equilibrium state of a system from a macroscopic point of view [36].

Based on Carnot's idea, Clausius expressed the concept of entropy in the form of mathematical equations in 1867. He used the symbol $S$ for entropy and expressed it as follows:

$$ds = \frac{dQ}{T}$$  \hspace{1cm} (1)

Where $dQ$ is the exchanged heat, $T$ and is temperature.

People who helped develop this concept were more than physicists. People like Gibbs and Maxwell did a lot of work in developing this concept.

The other path is based on the perspective of microstructures or microscopic, and in fact examines the dynamics of substructures of matter. In fact, each general state is considered the sum of a large number of partial states, and the molecular motions will be the basis of the analysis. Maxwell and Boltzmann looked at the matter from this angle. Boltzmann believed that Clausius entropy is caused by molecular disorders, and on this basis, microscopic theories related to entropy were formed based on the dynamics of substructures. In this view, the equilibrium state can be obtained by optimizing the relevant functional [37].

Some researchers have interpreted the concept of entropy based on chemical energy or gravitational potential energy. In this view, energy will be the main concept for defining entropy, and based on it, entropy changes in different processes are investigated [38].

Investigating entropy from a physical point of view as well as from a mathematical point of view has been done by some researchers such as Mays and Christian [21]. From a physical point of view, entropy is considered as a concept for determining the direction of physical processes, and from a mathematical point of view, it means a governing clause for all governing equations, which, of course, must meet the relevant conditions.
3. Entropy and Feasibility

With the formulation of the laws of thermodynamics by Clausius, entropy has become a law governing the processes in such a way that the processes in which the energy conservation principle is true, occur only in conditions that are within the scope of the second law of thermodynamics. In other words, the entropy produced in the physical processes should be greater than or equal to zero. This law caused the scientific community's view of entropy to be interpreted as determining the direction of the processes, and in fact, only those processes are likely to increase the entropy of the system during their implementation.

In fact, the second law is not directly included in the analysis of physical phenomena and acts as an observer of the results of the first law. Any equation that wants to be used to determine the internal structure of physical systems, it is necessary that the predictions made by it are within the scope of the second law, otherwise this equation will not have scientific value [36].

4. Different Definition

In this part, some examples of entropies that are widely used in engineering problems are stated.

A: Thermodynamic Entropy

Based on Carnot's hypothesis, Clausius was able to formulate the entropy related to thermodynamic cycles. Thermodynamic entropy is defined based on the heat transferred between the system and the environment and depends on the heat transfer temperature (see equation (1)) [36]:

B: Tribo-Fatigue Entropy

This entropy is defined as follows [18]:

\[ s_{TF} = \frac{u_{\Sigma}^{eff} - u_0}{T} \]  \hspace{1cm} (2)

where \( u_{\Sigma}^{eff} \) is the sum of the effective energies, \( u_0 \) is the initial state energy and \( T \) is the temperature.

This entropy is defined in terms of the energy of the damage body. There is no need to perform calculations in the entire material and tribo-fatigue entropy is calculated only in an effective volume. Determining this effective volume can be different in different problems and according to our desire for the problem.

C: Total Entropy

Total entropy or mechanothermodynamic entropy is defined as follows [39]:

\[ s = \frac{1}{T} \sum_i \left( (1 - A_i)u_i \right) + s_{TF} \]  \hspace{1cm} (3)

\[ \frac{ds}{dt} = \frac{1}{T} \sum_i \left( (1 - A_i) \frac{du_i}{dt} \right) + \frac{ds_{TF}}{dt} \]  \hspace{1cm} (4)

Mechanothermodynamic entropy is used to investigate MTD systems.

D: Other Entropies

Many entropies have been defined in other branches of science. For example, we can mention the dynamic entropy that is mentioned in dynamic systems [37].

Another case is the specific entropy of gravity, which is created due to the distance or proximity of the particles in the system [11].

Other commonly used entropies can be called holographic entropy and supersymmetric entropy [19, 40, 41].

5. Principles of Mechanothermodynamics

Mechanothermodynamics has the following principles [22, 23, 41-43]. These principles are not mentioned in classical thermodynamics, and in fact, they introduce new concepts [44].
The First Principle:
"Mechanothermodynamic entropy production is caused by motion and displacement. This means that the entropy of existence is increasing."

This principle, in fact, qualitatively explains the nature of mechanothermodynamic entropy. As it is known, the entropy produced is actually caused by a series of additional and unnecessary displacements as well as deformations that may not occur in an ideal process. But natural processes are always such that some entropy is produced.

The Second Principle:
"The effective energy absorbed in the system when it has experienced its limit state is equal to the energy released (or wasted) from calculating the individual effective energies separately."

This principle expresses a special and prominent state of systems. In the mentioned state, the coupling between the energies is lost and these energies act independently and no other process is effective in converting the energies.

The Third Principle:
"Expansion and collapse in a system consists of processes that increase the possibility of vulnerability in the system."

This principle expresses a kind of chaos in nature. Based on this principle, in fact, the respective environments always lose some of their order and power of solidarity and move towards collapse. Deteriorations and disorders in their structure grow and develop. Vulnerability actually means the weakness of the environment against possible irritations, and more vulnerability means that in similar conditions, the possibility of crack progression is higher.

The Fourth Principle:
"During the movement and decay of an active system, each jump or sudden change in data represents a particular element for which alignment with other elements is possible."

"Data" means the collection of information that is available from a material system. This principle shows the behavior of a disturbance in its neighborhood. The special element means a material point where the disturbance can be considered as the starting point of the advance of the disturbance. Based on this principle, the relevant environments cannot experience high gradients and have a desire for uniformity in different values of physical quantities. In fact, it describes a kind of flow of physical quantities from points with higher intensity to points with lower intensity.

The mentioned set of principles provide the possibility of investigating a mechanothermodynamic state. As can be seen, there is a close relationship between energy and entropy in such a way that they are the basis of defining each other.

The set of principles that are built must have two sets of conditions. On the one hand, they should clearly and appropriately contain the prominent features of the desired phenomenon, and on the other hand, they should not be in conflict with comprehensive scientific laws and general principles. The set of principles are in fact the birth certificate of that branch of science and it is necessary to have the ability to introduce that branch of science completely. In mechnano-thermodynamics, it is necessary to determine the relationship between mechanical and thermodynamic behavior, determine the general trend of mechanical behavior and its direction, the mutual behavior of energies is known, and if there is a specific trend in all possible states, it is necessary to mention this as well.

As it can be seen, the principles formulated for mechanothermodynamics have these conditions and other researches are related to the use of these principles in related issues.

6. Direct Applications

The concept of entropy was originally proposed more as a rule governing scientific calculations, and in fact, there were processes that could increase the entropy of the system. In recent years, this concept found more applications and many concepts and interpretations about it entered the field of science in such a way that it is used as a law to analyze natural phenomena directly. For example, two cases are mentioned in this regard [45-48].
**Tribo-fatigue entropy:** This entropy is defined in damaged environments and is defined based on the energy of the effective volume around the damage. In fact, the damage will start to progress in conditions where the corresponding entropy exceeds a certain limit \[18\].

**Mechanothermodynamic entropy:** Mechnothermodynamic entropy is the main parameter in the evaluation of MTD systems. The condition for the activation of these systems is that the corresponding entropy exceeds the critical value \[23, 41-43\].

### 7. Conclusions

The status of the second law has progressed from being an observer to being the basis of problem analysis. This progress has been implemented by the concept of entropy, which, of course, besides thermodynamic entropy, nowadays other entropies are also defined based on the energy of the system, which directly include this concept in the analysis of problems.

The new role that entropy has found in various sciences and is expanding day by day, can be the message of a fundamental change in science. This means that with the expansion of unified theories, one can reach a deep and broad generality in scientific theories, which means that broad universal equations are presented and physical phenomena can be looked at with a general and deeper perspective from the perspective of entropy.

The scope of the expansion of unified theories is not limited to classical mechanics and thermodynamics, and is discussed in all scientific theories. Therefore, what is expected is to reach a space of analysis of physical phenomena where classical and modern perspectives are simultaneously considered.

### References


