

# Energy Conservation Principle from the Perspective of the Energy Structure Theory

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**ABSTRACT----** *In this paper, the energy conservation principle is investigated from the perspective of the energy structure theory. Energy structure theory presents the basic equation as energy structure equation has been developed to study physical processes considering effects of the second law of thermodynamics directly. Energy components are used as basis of the energy structure equation. In this paper, to investigate the energy conservation principle using the energy structure equation, the variation of the energy structure equation is studied in different paths for the same amount energy applying to the system. In fact, a quasi-static path is used as a reference path, and other paths are studied using this reference when the same amount of energy is applied to the system in different conditions. Using this approach, in fact, energy conservation principle is applied to the energy structure equation, and therefore, the resultant relation has the first and second laws of thermodynamics as its basis together that has been developed in one relation. Therefore, the extracted relation will be a bidirectional relation that means all processes must satisfy this relation and vice versa.*

**Keywords:** Energy conservation principle; Energy structure equation; Energy applying; Quasi-static path; General paths

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## 1. INTRODUCTION

The connection between forces and motion of bodies is expressed by the principles of mechanics. From the perspective of the energy concept, these principles take a very important result on nature. In fact, it can be concluded from these principles that the sum of kinetic and potential energies of a physical body is always constant, and if work is done on the considered physical system from its surrounding, the sum of the changes in potential and kinetic energy is equal to the work had been done on the system[1]. This concept, in fact, is the energy conservation principle that is known as a unifying principle in physics [2].

Based on the energy conservation principle, it can be concluded that energy is a physical quantity that can change the state of the physical systems. When this principle is used to study a rigid body, it can be concluded which the work is done on the system is completely transformed into the kinetic energy of the body. In fact, based on the principle of energy conservation, to the extent that the work is done on the system by environmental bodies, its kinetic energy increases equally. But if this principle comes to a physical elastic body, it can be concluded that the sum of energy changes of elastic strain energy and kinetic energy of the system is equal to the work done by the surrounding. The energy conservation principle is known as one of the basic principles in thermodynamics [1]. The first and second laws of thermodynamic were developed by Clausius in 1865[3]. The first law of thermodynamics is a direct result of the principle of energy conservation that has been developed for thermal cycles, while the second law of thermodynamics examines the feasibility of performed physical processes.

The second law of classical thermodynamics is the most important physical law which has been accepted and established in all branches of science [4,5]. In fact, since Carnot has introduced irreversibility concepts by presenting Carnot's cycles, he can be known as the funder of the second law of thermodynamics [6]. From the point of view of classical thermodynamics, two main formulations have been extracted to the second law of thermodynamics: Kelvin-Plank and Clausius formulations of the second law [7-9]. From a point of view, these two classical formulations are all assertions about impossible physical processes, while some other formulations are extracted to the second law which relies on assertions about the possible physical processes [9].

Energy structure theory has been presented in 2020-2021 [10-16]. This theory has the first and second laws of thermodynamics as the basis of its equations [10]. In fact, energy structure theory introduces some new physical concepts including activated energy components, non-activated energy components, energy structure equation, reversible and irreversible energy components, irreversibility structure, irreversibility components, etc.

Energy structure equation is one of the most important equations of energy structure theory that has been extracted based on the energy components as well as independent and dependent energy components [11]. Therefore, this equation can be used to study a variety of scientific applications including irreversibility, viscoelasticity, probability in general physics, etc. [10-12,16].

In this paper, to investigate the energy conservation principle from the perspective of the energy structure theory, the variation of the energy structure equation is studied in different paths for the same amount of energy applying to the system. In fact, a quasi-static path is used as a reference path, and other paths are studied using this reference when the same amount of energy is applied to the system in different conditions.

## 2. ENERGY STRUCTURE EQUATION

When some energy is applied to the system, some of its energy components will be activated [12]. Activated energy components are independent or dependent on the energy applying condition. Independent components will be activated in all different conditions of energy applying including the quasi-static path.

Equation (1) is known as the energy structure equation [12]:

$$U_T = (u_1 + u_2 + \dots + u_m) + [g_1 + \dots + g_k] + [h_1 + \dots + h_n] + U_{T_0} \quad (1)$$

Where:

$$g_j = g_j(u_1, u_2, \dots, u_m) \quad (2)$$

$$h_p = h_p(\dot{u}_1, \dots, \dot{u}_m) \quad (3)$$

Where  $u_i$  is the energy component of the system. Also,  $g_j$  and  $h_p$  are dependent energy components have been activated in the performed processes. The term  $U_{T_0}$  is sum of the all energy components which does not act in the performed process.

## 3. THE SAME AMOUNT OF ENERGY APPLYING

It is supposed that the same amount of energy is applied to the system in different conditions. Also, a quasi-static path is used as a reference path. Due to equation (1), in the reference path, independent components will be activated only.

Therefore, equation (4) must be satisfied whenever the same amount of energy is applied to the system in different conditions:

$$\sum_{i=1}^m (\delta u_i) + \sum_{q=1}^k \sum_{i=1}^m \left( \frac{\partial g_q}{\partial u_i} \delta u_i \right) + \sum_{p=1}^n \sum_{i=1}^m \left( \frac{\partial h_p}{\partial \dot{u}_i} \delta \dot{u}_i \right) = \sum_{i=1}^m \delta u'_i + \sum_{q=1}^k \sum_{i=1}^m \left( \frac{\partial g_q}{\partial u_i} \delta u'_i \right) \quad (4)$$

Since equation (4) also must be satisfied for all independent components, therefore:

$$\delta u_j + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \delta u_j \right) + \sum_{p=1}^n \left( \frac{\partial h_p}{\partial \dot{u}_j} \delta \dot{u}_j \right) = \delta u'_j + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \delta u'_j \right) \quad (5)$$

That  $\delta u_j$  is the energy variation of the independent component  $u_j$  when  $\dot{u}_j \neq 0$  as the value of energy  $\delta U_T$  is applied to the system. And also,  $\delta u'_j$  is the energy variation of the independent component  $u_j$  when  $\dot{u}_j \cong 0$  as the value of energy  $\delta U_T$  is applied to the system.

Equation (5) can be rewritten as follows:

$$\left( 1 + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \right) \right) (\delta u_j - \delta u'_j) = - \left( \sum_{p=1}^n \left( \frac{\partial h_p}{\partial \dot{u}_j} \right) \right) \delta \dot{u}_j \quad (6)$$

Equation (6) is a direct result of the energy conservation principle. In fact, the principle of energy conservation is applied to the equation (1). Equation (6) relates the variation of the energy structure in different paths to each other.

Therefore, using bellow calculations:

$$-\left[ \frac{\left( \sum_{p=1}^n \left( \frac{\partial h_p}{\partial u_j} \right) \right)}{\left( 1 + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \right) \right)} \right] = \frac{(\delta u_j - \delta u'_j)}{\delta \dot{u}_j} \tag{7}$$

$$-\left[ \frac{\left( \sum_{p=1}^n \left( \frac{\partial h_p}{\partial u_j} \right) \right)}{\left( 1 + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \right) \right)} \right] \left( \frac{\delta u_j - \delta u'_j}{\dot{u}_j} \right) = \frac{(\delta u_j - \delta u'_j)}{\delta \dot{u}_j} \left( \frac{\delta u_j - \delta u'_j}{\dot{u}_j} \right) \tag{8}$$

$$\left[ \frac{\left( \sum_{p=1}^n \left( \frac{\partial h_p}{\partial u_j} \right) \right)}{\left( 1 + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \right) \right)} \right] \left( \frac{\delta u_j - \delta u'_j}{\dot{u}_j} \right) = - \frac{(\delta u_j - \delta u'_j)^2}{\dot{u}_j \delta \dot{u}_j} \tag{9}$$

Since the quasi-static path is used as a reference path, therefore:

$$\left[ \frac{\left( \sum_{p=1}^n \left( \frac{\partial h_p}{\partial u_j} \right) \right)}{\left( 1 + \sum_{i=1}^k \left( \frac{\partial g_i}{\partial u_j} \right) \right)} \right] \left( \frac{\delta u_j - \delta u'_j}{\dot{u}_j} \right) \leq 0 \tag{10}$$

Relation (10) is a direct result of applying the energy conservation principle on the energy structure equation. This relation must be satisfied in all performed processes. Therefore, each path that satisfied relation (10) is a feasible path, and also all feasible paths satisfied this relation. This is a direct result from that energy structure theory has the first and second laws of thermodynamics as its basis. In fact, relation (10) has the first and second laws of thermodynamics as its basis together has been developed in one relation.

Therefore:

According to the principle of energy conservation, the feasible paths for a physical system are that relation (10) to be satisfied and vice versa.

Where extracts a new statement to the energy conservation principle.

#### 4. CONCLUSIONS

The energy structure equation has the second law of thermodynamics as its basis has been developed for energy applying to the system in different conditions. Since this equation is extracted based on the energy components of the system, by studying it in different paths, the relevant physical quantities in the energy could be investigated.

To investigate the energy conservation principle from the perspective of the energy structure theory, the variation of the energy structure equation can be studied in different paths for the same amount of energy applying. By this, in fact, energy conservation principle is applied to the energy structure equation, and the result relation has the first and second laws of thermodynamics as its basis in one relation.

Relation (10) uses a quasi-static path as a reference path. In fact, for the same amount of energy applying to the system, general paths are investigated using the variation of this path. In a quasi-static path, independent components of energy are not active, therefore, this path is a reversible path as a reference path [12].

Relation (10) must be satisfied by all performed processes. Also, each physical process that satisfied this relation, is a feasible process. In fact, relation (10) is a bidirectional relation. This is a direct result from that this relation has the first and second laws of thermodynamics as its basis together in one equation.

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