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Research Paper

Kelvin-Voigt and Elastic Load-deflection Models under Special Relativity

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ABSTRACT

The classical Kelvin-Voigt and elastic load-deflection models in describing the mechanical response of materials under applied forces in this fundamental research are described. When materials experience high-velocity deformations under supersonic motion, classical mechanics fails to account for essential relativistic effects such as time dilation and length contraction. This study extends these models by incorporating special relativity to improve the accuracy of stress-strain predictions in supersonic conditions. By relativistic behavior of motion, a theoretical framework for analyzing hypervelocity mechanism, structural-mechanical behavior of materials in aerospace applications, and the dynamic stability of supersonic velocities are provided. Our approach is particularly relevant for the development of smart materials, adaptive structural systems, and defensive shielding technologies used in space exploration and supersonic velocities. Furthermore, we explore the oscillatory behavior and energy dissipation mechanisms in relativistic regimes, offering insights into the stability and damping characteristics of high-velocity mechanical systems. The findings bridge the gap between classical continuum mechanics and relativistic physics, presenting a novel methodology for studying the deformation and load-bearing behavior of materials under extreme accelerations. These results have significant implications for advanced engineering applications, including spacecraft shielding, high-speed transportation, and next-generation aerospace structures.

Keywords: Hypervelocity; Load-deflection; Special relativity; Boltzmann principle.

1 INTRODUCTION

THE behaviors of a system can be described based on the fundamental principles of structural mechanics. In mechanical science taking into account relativistic theory, a moving structural system with high velocity with a specific rest mass has the relativistic mass, velocity, and relativistic energy which changes within the time rate [1].

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Hence, we consider a system as a mechanical system and explain the state behaviors using concepts of structural mechanics [1, 2]. This idea helps us to understand the relativistic mechanism of hypervelocity impacts on defensive shields, electromagnetic weapons that require precise modeling of materials under high accelerations, study of smart materials used in advanced industries such as aerospace and defense, or help us to analyze the behavior of aerospace structural materials under re-entry conditions or high-speed travel, design of thermal and mechanical shields, and analyze material behavior in interplanetary or interstellar travel, which may approach relativistic speed. In structural mechanics, parameters such as deformation, deflection, elastic load-deflection, strain, stress, compressive strength, and tensile strength are very important in describing a system [2, 3]. These parameters are compared to a reference position of the system and can describe the behavior of a system under an external force that depends on a third parameter, time t. As we know, in physics deformation is the change in the dimension (size or shape) of a system that can occur because of forces or changes in temperature, etc.; on the other hand, in structural mechanics, deformation of a system can take place because of applied loads and using the load-deflection function concerning a third parameter, time t, which refers to the applied load and the resulting deformation. Ludwig Boltzmann formalized this through the Boltzmann Superposition Principle (BSP) [3,4], which posits a linear relationship between an external load, $F(t)$, and the elastic load-deflection, $\xi(t)$, mediated by time t. Elastic load-deflection refers to temporary deformations that fully recover upon removal of the external force.

$$F(t) \approx \xi(t) \tag{1}$$

Provided the system stays within its elastic limits. For a structural system of mass m, the elastic load-deflection $\xi(t)$, is proportional to the applied force, $F(t)$, with a time-dependent proportionality constant, $\beta(t)$ [4]. The load-deflection function quantifies the relationship between externally applied forces and resulting deformations under specific conditions, offering a framework to characterize structural behavior. This study extends the application of BSP from structural mechanics to special relativity (SR), modeling a system behavior by integrating BSP with relativistic velocities to derive properties for structural systems. This theoretical study also assesses the validity of BSP in the relativistic limit under Lorentz transformations [4]. The primary objective is to illustrate how integrating structural mechanics principles with relativistic physics provides novel insights into material behavior and characteristics. Hence, we can effectively describe the properties and behavior of a structure changes in response to an external load. The concept of load-deflection function according to physical properties concepts of a system generally refers to the relationship between an externally applied force and the resulting deformation of the structure under specific conditions. Therefore, we aim to discuss the representation of a particle using the BSP method based on structural mechanics theories connecting them to RS. In this theoretical research, our goal is to find a new aspect to define the characteristics of a system in the context of relativistic velocities and structural mechanics [5,6]. Finally, in the summary and conclusion section, we express the main purpose of the current study. The goal of this theoretical research is to show the importance of relativity in structural mechanics under the Kelvin-Voigt model in the relativistic limit under the Lowrance transformation when a system is subjected to an external force.

2 SOLID RHEOLOGICAL MODEL

The rheology of solid matter or solid rheology is the study of the deformation of materials under applied forces. In this context, some of the characteristics of matter such as stress, strain, and creep can be described based on the forces acting on matter, and their definitions are related to the resulting deformations in stress conditions. Solid rheology holds great importance in modern sciences, including the research on the ability of matter to recall specific properties after the conditions that caused the original state and to return to the original state. When a force is applied to a solid object, it causes the object to deform, so deformation represents and describes the change in position or shape of the solid matter due to the applied force [2, 7,8]. In the solid rheology, the relationship between the applied force and the resulting deformation is named "load-deflection" $\xi(t)$; and for some specific types of matter, the load-deflection relationship is linear but this linear relationship depends on time t and it has complexity influenced by the force acting at time t, which can be described by $\xi(t) = const.F(t)$. Function $\xi(t)$- is the elongation produced by a time-varying force. On the other words, the load-deflection $\xi(t)$ represents the displacement (elongation) produced by the time-varying force $F(t)$, and then $\xi(t)=\frac{d\xi(t)}{dt}$, would represent the velocity of the matter (object) at time t, which is the rate of change of elongation concerning t. The load-deflection $\xi(t)$ is a physical quantity that shows how much a system will deform by acting an external force $F(t)$ in the time duration $dt=t_2-t_1$ i.e., $\xi(t)=\beta(t)F(t)$ and the proportionality constant is supposed to be a function of time. On the other words, the load-deflection $\xi(t)$ is the elongation produced by the time dt varying force $F(t)$. So, the velocity of the deflection (the elastic load-deflection) in the inertial one-dimensional coordinate system along the $x-axis$ is defined by relation $\xi(t)=\frac{d\xi(t)}{dt}$. Variation of the elastic load-deflection by the time dt is $\dot{\xi}(t)=\beta(t)\dot{F}(t)$, the characteristic function of the system is $\beta(t)$, and it is supposed to be a constant function of time [8]. Hence, following the rheological model, the elastic load-deflection its rate of change, and also its effects on the structural system can help us to describe a system's behavior under relativistic conditions. Any model in structural mechanics for describing the elastic load-deflection effects and behavior is associated with elastic elements (springs - oscillatory systems) and viscous elements (dashpots - provide damping or resistance to motion). In this research, the spring can indeed be considered as an oscillatory system. An oscillatory system exhibits a characteristic behavior of the constituent particle under external force when they undergo oscillatory motion from their equilibrium position at high velocities. This back-and-forth motion (oscillatory motion) can be presented as the individual oscillation of the constituent particles or the collective oscillation of the structural system. We consider a system as a linear spring-dashpot system in Fig.1, based on structural mechanics and obeys Hook's law and Newton's law precisely. As we know, oscillatory motion can be described by Hooke's Law $F_k(t)=k\xi(t)$ and dashpot effect can be described by Newton's law $F_\eta(t)=\eta\dot{\xi}(t)$.

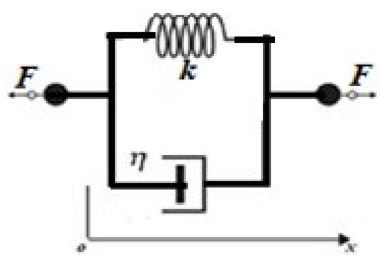

Fig. 1
The Kelvin-Voigt model of parallel spring-dashpot combination as an interacting particle in the external field.

In the solid rheological model, the system is presented as a spring and characterized by the spring constant parameter *k*; also, the viscous properties are presented as a dashpot and characterized by the dashpot constant parameter η. Here we declare that the theoretical formulation of the spring-dashpot system that we choose to describe a state property under the BSP method is formed of a parallel configuration of a linear spring and a dashpot Fig. 1, which is named after the Kelvin-Voigt model [1, 4, 6]. The parallel configuration of the spring and dashpot (the Kelvin-Voigt model) describes the total deformation of the spring force and the damping force, under the dynamic stability of interaction. Hence, the elongation of the spring and dashpot is the same for the spring and dashpot $\Delta\xi_k(t)=\Delta\xi_\eta(t)$, so, the dynamics of the system and its variation over time are explained by equations

$$F(t)=F_k(t)+F_\eta(t)=k\xi(t)+\eta\dot{\xi}(t) \tag{2}$$

and

$$F(t)=\dot{P}_k(t)+\dot{P}_\eta(t) \tag{3}$$

Therefore, the behavior of the spring-dashpot system gives us the characteristic that is analogous to a harmonic oscillator and makes it a useful model for studying a particle state mechanism, i.e., $F_k(t)$ describes deflection and $F_\eta(t)$ diminishes the deflection; and $\dot{P}_k(t)$ describe the rate of fluctuation and variation of momentum concerning time; if $\dot{P}(t) \prec 0$, it indicates that the force is increasing over time, if $\dot{P}(t) \prec 0$, it signifies a decrease in force, and if $\dot{P}(t) = 0$ it suggests that the force is not changing concerning time [9-11]. We can present a useful function for the Kelvin-Voigt model that describes the connection between the elongation of spring and the elastic load-deflection of dashpot as follows:

$$\beta(t) = \frac{a}{k}\left(1 - e^{-\frac{kt}{\eta}}\right) \tag{4}$$

where a= constant and presents the best linear form of sudden or impulsive external force $F(t)$, that occur at a specific time instant ($dt \to 0$), and then persist indefinitely which is described by the Heaviside step function:

$$F(t) = aH(t) = a\begin{Bmatrix} 1, & x \geq 0 \\ 0, & x \prec 0 \end{Bmatrix}$$

where $H(x)$ is the Heaviside step function.

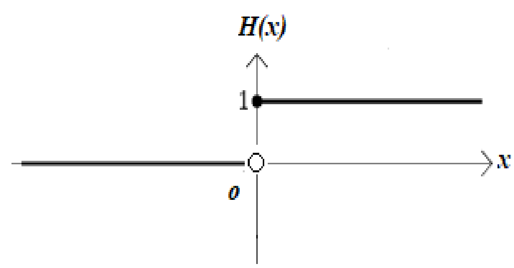

Fig. 2
The Heaviside step function.

If $F(t) \geq 0$, then as presented in Fig. 2, $H(t) = 1$ and we consider $a = 1$ The term $e^{-\frac{kt}{\eta}}$ describes the exponential decay form of the response with time. When $t \to \infty$, the term $e^{-\frac{kt}{\eta}} \to 0$, the response of matter reaches a steady state. Hence, $\beta(t)$ describes the relation between the relationship between stress and strain in the matter).

3 SPOECIAL RELATIVITY WITHIN THE KELVIN-VOIGT FRAMEWORK

This section aims to derive the relativistic momentum over time and elucidate the relativistic dynamics [4,5,8] of an object with rest mass m|, based on a solid rheological model [8]. Consider an object of mass m in an inertial rest frame K , moving with velocity u along the x-direction, where $F = m_0 \frac{du}{dt}$ holds in this frame. We then introduce a coordinate system K', moving at a relative velocity v concerning K, to examine the motion of the mass in K and capture the relativistic effects on mass and velocity. To characterize the relativistic properties of a moving mass and link them to the Kelvin-Voigt model, we define the relativistic momentum as $p = mv = m_0\gamma v$, and the relativistic force as $F = \dot{p} = \frac{d}{dt}\left(m_0 \gamma v\right)$, based on the spring-dashpot dynamics of the Kelvin-Voigt model [1, 8, 9]. This requires applying the Lorentz transformation within quantum field theory. In natural units where c is the speed of light (c = 1), the Lorentz transformation Fig. 3, along the *x*-direction is expressed as follows:

$$\begin{cases} x' = \gamma\left(x(t) + v(t)\right) \\ t' = \gamma\left(t + v(t)x(t)\right) \end{cases}$$

where $\gamma = \left(1 - v^2(t)\right)^{-\frac{1}{2}}$ is the Lorentz factor.

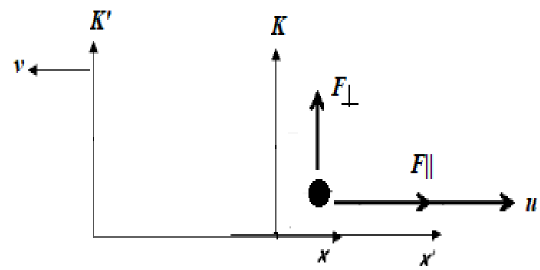

Fig. 3
The Minkowski spacetime of a moving object.

We consider an object of mass *m* accelerating under an external force *F* in the inertial frame *K*, where it has a relativistic velocity *v*. This force causes the velocity *v* to change in the inertial frame K', with components perpendicular $dv_{\perp}$ and parallel $dv_{\parallel}$ to v, as follows:

$$dv_{\perp} = \frac{du_{\perp}}{1 + vdu}\sqrt{1 - v^2} \tag{5}$$

$$dv_{\parallel} = \frac{du_{\parallel} + v}{1 + vdu} - v \tag{6}$$

As we know in the rest coordinate the velocity of object u= 0 , hence Eqs. (**Error! Reference source not found.**) and (**Error! Reference source not found.**) represent in the form of

$$dv_{\perp} = \frac{1}{\gamma} du_{\perp} \tag{7}$$

$$dv_{\parallel} = \frac{1}{\gamma^2} du_{\parallel} \tag{8}$$

Using the relativistic transformation between frames K and K', with $dt' = \lambda dt$, under $F(t) = \dot{p}(t)$ an external force along the x direction, we define the relativistic dynamics of a system with velocity *v*, rest mass m_0 , and relativistic mass $m(t) = \gamma m_0$. The external force in K' can be expressed separately as $F_{\parallel}$ and $F_{\perp}$ based on the equations of motion in the rest frame K , relating the velocity components $dv_{\parallel}$ and $dv_{\perp}$ in a relativistic framework from K to K'.

$$F_{\parallel} = \frac{m_0 du_{\parallel}}{dt} = m_0 \gamma^3 \frac{dv_{\parallel}}{dt'} = \frac{d}{dt'}(m_0 \gamma v)\left(\frac{\vec{v}}{v}\right) \tag{9a}$$

$$F_{\perp} = \frac{m_0 du_{\perp}}{dt} = m_0 \gamma^2 \frac{dv_{\perp}}{dt'} = \gamma p' \frac{d}{dt'}\left(\frac{\vec{v}}{v}\right) \tag{9b}$$

$$F(t) = F_{\parallel} + F_{\perp} \tag{10}$$

and then by putting $dv_{\parallel} = dv, \frac{d}{dt}\left(\frac{\vec{v}}{v}\right) \perp \left(\frac{\vec{v}}{v}\right)$, we can define

$$F(t) = \frac{d}{dt}(\gamma m_0 v)\left(\frac{\vec{v}}{v}\right)\gamma + p\frac{d}{dt}\left(\frac{\vec{v}}{v}\right) = \frac{dp'}{dt}\left(\frac{\vec{v}}{v}\right) + \gamma p' \frac{d}{dt}\left(\frac{\vec{v}}{v}\right) \tag{11}$$

where p is the momentum in the stationary frame K and p' is the momentum of matter in the frame K', and

$$\frac{d}{dt}\left(\frac{\vec{v}}{v}\right) = \left(v\frac{d\vec{v}}{dt} - v\frac{dv}{dt}\vec{v}\right)\frac{1}{v^2} = \left(v\frac{d\vec{v}}{dt} + v\frac{d\vec{v}_{\parallel}}{dt} - \frac{dv}{dt}\vec{v}\right)\frac{1}{v^2} = \left\{v\frac{1}{v^2} + \left(v\frac{dv}{dt} - \frac{dv}{dt}v\right)\left(\frac{\vec{v}}{v}\right)\right\}\frac{1}{v^2} = \frac{1}{v}\frac{d\vec{v}_{\perp}}{dt}$$

Now using $F(t) = \dot{p}(t)$, and linear momentum $p(t) = m(t)v(t)$, one can represent Eq. (**Error! Reference source not found.**) as follows:

$$F(t) = \dot{p}_{\perp} + \dot{p}_{\parallel} = \dot{m}(t)v(t) + m(t)\dot{v}(t) \tag{12}$$

Now, we take into consideration the moving matter properties under the relativistic conditions according to the solid rheological model and then present the relativistic bound state of two particles within this context and framework. As we presented above, the solid rheological model of the bound states at high energy should be explained in the context of relativistic interaction and relativistic theories. Therefore, as in the earlier segment, the characteristic function of the relativistic system reads

$$v(t) = \beta_r(t)F(t) = \beta_r(t)H(t) = \beta_r(t) \tag{13}$$

According to (**Error! Reference source not found.**), a spring-dashpot system can present and describe the motion of a relativistic bound state within an external strong field with relativistic velocities. As we know, at the relativistic limit, the mass $m(t) = \gamma m_0$ of moving object, increases with velocity. Consequently, an object with relativistic mass $m(t)$ accelerates and its velocity will increase but the maximum limit of the velocity of a moving object $v(t)$ cannot exceed the speed of light *c*. Therefore, we can consider that in relativistic conditions of interactions within the external field, we should consider two different types of forces: the first one is the force $F_v(t) = F_{\parallel}$, that acts on the object and accelerates it, and finally, as a result, increases the rest mass of an object and is the equivalent of the spring force $F_k(t)$. The second one is the force $F_{\dot{v}}(t) = F_{\perp}$, that prevents the velocity of the moving mass (object) in the relativistic condition i.e., $v \prec c$, and is the equivalent of dashpot force $F_\eta(t)$. So, the total acting force can be expressed in the following form

$$F(t) = F_v(t) + F_{\dot{v}}(t) = F_{\parallel} + F_{\perp} \tag{14}$$

Now, we consider the spatial changes of the object in the relativistic condition as a spring-dashpot system due to the Eqs. (**Error! Reference source not found.**), based on the mathematical presentation of the BSP and behavior of the spring-dashpot system for a moving mass [5, 11]. We consider that the velocity of the mass and its derivation is proportional to the applied force $F(t) \sim v^n(t) \sim \dot{v}^m(t)$, but the constants of proportionality are a function of time. So, equation reads

$$F(t) = [m_0\dot{\gamma}]v(t) + [m_0\gamma]\dot{v}(t) \tag{15}$$

One can represent using the Kelvin-Voigt model by the linear spring constant k and the damping coefficient of dashpot η

$$F(t) = k\xi(t) + \eta\dot{\xi}(t) \tag{16}$$

i.e., $F_v(t) = [m_0\dot{\gamma}]v(t)$ produces acceleration and increases the rest mass of an object $m = m_0\gamma$ as a deformation force $F_k(t)$ (spring), while $F_{\dot{v}}(t) = [m_0\gamma]\dot{v}(t)$ reduces the velocity of the moving matter, based on the relativistic principles it keeps the velocity below c , as a deflection force $F_\eta(t)$ (dashpot) and its damping effect which reduces the deformation in the Kelvin-Voigt model [10, 11]. In this context, the derivation function of the Lorentz factor to time given by

$$\dot{\gamma} = v(t)\dot{v}(t)\gamma^3 \tag{17}$$

Hence the total force of increasing mass of matter and reduced velocity of matter below the speed of light from reads

$$F(t) = \left[m_0\gamma\dot{v}(t)\frac{v(t)}{1-v^2(t)}\right]v(t) + [m_0\gamma]\dot{v}(t) = m\dot{v}(t)\frac{v^2}{1-v^2(t)} + m\dot{v}(t) = m(t)\dot{v}(t)\left(1+\frac{v^2(t)}{1-v^2(t)}\right) = m\gamma^2\dot{v}(t) \tag{18}$$

and then from the relation $F(t) = \dot{m}(t)v(t) + m(t)\dot{v}(t)$ and using (**Error! Reference source not found.**) and (**Error! Reference source not found.**), the relativistic characteristic function of the system $\beta_r(t)$ using BSP supposes to be as follows:

$$v(t) = \frac{1}{\dot{m}(t)}\left(1 - e^{-\frac{\dot{m}(t)}{m(t)}t}\right) \tag{19}$$

From **Error! Reference source not found.**19) under the asymptotic conditions of the special relativistic theory at t=0 and $t = \infty$, we determine important characteristics of the relativistic object in the Kelvin-Voigt model as follows:

$$t \to 0 \Rightarrow \eta = [m_0\gamma] = m_0 \tag{20}$$

and

$$t \to \infty(v \cong c \to 1) \Rightarrow \mu = [m_0\dot{\gamma}] = 1 \tag{21}$$

and the result of the characteristic function of the relativistic system $\beta_r(t) = v(t)$ under the Kelvin-Voigt model for a moving object with the rest mass m_0, the moving mass and relativistic velocity $v(t)$ at time t in the natural unit system (c=1) can be presented in the form

$$v(t) = 1 - e^{-\frac{1}{m(t)}t} \tag{22}$$

4 APPLIED PERSPECTIVE OF THIS RESEARCH

Understanding how materials deform under applied forces is a fundamental part of modern material science and structural mechanics. When a material is subjected to external forces, key properties like stress, strain, and creep determine how it reacts whether it stretches, compresses, or eventually recovers its shape. These properties define the material's ability to withstand and adapt to forces, which is crucial in engineering, aerospace, and physics applications. When a force acts on a solid object, it causes deformation, which is simply a change in shape or position. The core concept that describes this relationship between the applied force and the material's response, reflects how much the material elongates or deforms over time when a force is applied. For many materials especially in the linear viscoelastic regime, this relationship is directly proportional but may depend on time, and represents by a time-dependent force. Therefore, the importance of relativity in structural mechanics under the Kelvin-Voigt model is particularly presented above in the context of relativistic mechanics, it shows us how a system responds when it is subjected to extreme speeds or forces approaching the limits imposed by relativity. In this scenario, we are not merely dealing with classical deformations but must also consider relativistic corrections to how energy, force, and deformation propagate within materials. Hence, the applied perspective of this research focuses on bridging classical structural mechanics and relativistic physics to address modern engineering and scientific challenges. The Kelvin-Voigt model, as a foundational viscoelastic model, has been extensively used to analyze materials that exhibit both elastic and damping behaviors. However, when materials and systems are subjected to extremely high velocities, strong fields, or rapid dynamic loads, classical interpretations of stress-strain relationships become insufficient. This is where special relativity becomes crucial, and our research explores this intersection. From an applied standpoint, incorporating relativistic effects into the Kelvin-Voigt framework allows for accurate modeling of material behavior under extreme conditions, such as aerospace and spacecraft engineering: re-entry vehicles and hypersonic aircraft experience intense dynamic loads and thermal stresses. Understanding the viscoelastic and relativistic deformation of structural components ensures their integrity and safety. Spacecraft shielding against micrometeoroid and debris impacts requires precise modeling of high-speed collisions, where relativistic corrections become relevant for predictive simulations; Advanced defense and protective structures: high-velocity projectiles, including electromagnetic railgun munitions or laser-induced impacts, impose loading rates that necessitate a relativistic-mechanical analysis of material response for armor and protective layers. Hypervelocity impacts on defensive shields, relevant to both military and space applications, require understanding the coupled elastic-viscous-relativistic response; astrophysics and space exploration materials: materials used in interstellar or relativistic-speed probes encounter forces and environments where traditional material models fail. Integrating relativistic corrections to viscoelastic models helps predict long-term durability and dynamic response in unknown extreme conditions; Nuclear and particle physics engineering: in facilities like particle accelerators or fusion reactors, materials are exposed to high-energy particle flows, demanding a relativistic interpretation of stress-strain relations for component longevity and performance. Understanding oscillatory and dissipative behaviors of structural materials within high-energy physics environments enhances both safety and design; Smart materials and nanotechnology: advanced smart materials, including nanocomposites and meta-materials, may undergo ultra-fast dynamic processes (e.g., femtosecond-scale deformations), where relativistic time-dependent effects could influence their real-time mechanical responses.

5 RESULTS AND DISCUSSION

In this article we can define five important and useful points with their relevance to modern high technology and future mechanical science:

1. Integration of relativity with structural mechanics: significance to describe high-velocity impacts or supersonic technology, high-speed aerospace engineering, space travel, and electromagnetic weapons where relativistic subjected to ultra-high motion.
2. Hypervelocity impact and defensive shields: understanding how materials respond to hypervelocity impacts is crucial for protective structures, especially in aerospace and defense industries. This point is useful for developing advanced shielding materials for spacecraft, satellites, and military defense systems to withstand high-speed projectiles.
3. Smart materials and adaptive structural behavior: smart materials, which can dynamically adapt to external forces and environmental changes. This is important for aerospace and automotive industries, enabling materials that self-heal, adjust stiffness, or respond to external stimuli such as temperature or electromagnetic fields.
4. Elastic load-deflection in advanced engineering: the Kelvin-Voigt model in the relativistic limits allows for a better understanding of material behavior under extreme conditions. It can be useful for designing thermal and mechanical shields for spacecraft, high-speed trains, and supersonic structures where load-deflection properties are critical.
5. Oscillatory behavior and energy in high-velocity systems: we described how oscillatory motion (spring-dashpot system) is essential for analyzing dynamic stability in structural mechanics under ultra-high motion. It plays a key role in vibration control in buildings, earthquake-resistant structures, high-speed transportation systems, and nano-scale mechanical systems where damping and stability are critical. Hence, we can see these insights bridge the gap between usual structural mechanics and relativistic based of structural mechanics using theoretical general relativistic physics. This research provides a foundation for future developments in mechanical engineering, material science, and space exploration.

6 CONCLUSIONS

The term "history-dependent behavior of matter" typically refers to the idea that the current state of a matter is influenced by its past interactions. It implies that matter such as a structural system retains information about its previous states, which can impact its response to external force. This concept is relevant in structural mechanics and is explained based on the Kelvin-Voigt model, which is a mathematical representation used to describe the behavior of elasticity and viscosity of matters. In the Kelvin-Voigt model, the matter is represented by a spring-dashpot connected in parallel. The spring represents the elastic component and returns matter to its original state after removing the load-force. The dashpot represents the viscosity behavior of matter, which resists the deformation. This consideration of the spring-dashpot and the moving relativistic system led us to present the relativistic effect of external forces, which can act as loading effects on the deformation behaviors of springs and dashpots. This explanation describes how the movement of an object is mathematically connected to the intrinsic history of the loading force (external force) on the spring and dashpot. Using the RS theory, we calculated the relativistic characteristic function of the system that presents the relativistic velocity of the moving system. This correction of mass is defined based on the equations $F(t) = k\xi(t) + \eta\xi(t)$, and $F(t) = [m_0\dot{\gamma}]v(t) + [m_0\gamma]\dot{v}(t)$ at the relativistic velocity helped establish a connection between SR theory and the history-dependent behavior of a system. The results presented the different relations using the relativistic corrections to the moving equation. We defined good approximation and proximity to be equivalent to the relativistic parameters such as the velocity of the moving system at time t, equivalently of the constant parameters k to the derivation of mass and the η constant parameters k to the constituent mass of moving system at relativistic velocities. These behaviors are explained based on the characteristics of the spring-dashpot model of the moving object. In summary, this research presents a novel extension of the Kelvin-Voigt viscoelastic model, adapted for relativistic environments, offering practical insights for cutting-edge technologies in aerospace, defense, astrophysics, and advanced material science. By developing a deeper understanding of elastic load-deflection behaviors under relativistic constraints, this work paves the way for designing materials and structures capable of withstanding extreme mechanical and dynamic loads with enhanced reliability and functionality.

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DECLARATIONS

The authors declare that they have no competing interest regarding the publication of the article.

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