Annals of
Biotechnology and Biomedical Science

Research Article

Elastomechanics Fundamentals for Bones and Fractures

Emin Taner Elmas[1]*, İsmail Kunduracioğlu[2]

[1]Department of Automotive Technology, Iğdır University, Turkey

[2]Major Science Department of Mechatronics Engineering, Iğdır University, Turkey

Submission: April 05, 2025; Published: April 16, 2025

***Corresponding Author:** Emin Taner Elmas, Assistant Professor Dr., Vocational School of Higher Education for Technical Sciences, Division of Motor Vehicles and Transportation Technologies, Department of Automotive Technology, Iğdır University, Turkey & Graduate School of Natural and Applied Sciences - Major Science Department of Bioengineering and Bio-Sciences, Iğdır University, Turkey.

ABSTRACT

This article gives general information about the "Elastomechanics Fundamentals for Bones and Fractures". The study has been realized within the scope of a Ph.D. lesson which is lectured by Asst. Prof. Dr. Emin Taner ELMAS. The name of this Ph.D. lesson is "Medical Engineering and Advanced Biomechanics" and taught at the Major Science Department of Bioengineering and Bio-Sciences at Iğdır University, Turkey. İsmail KUNDURACIOĞLU is a Ph.D. student and he is one of the students taking this course. This article has been prepared within the scope of this Ph.D. lecture, as a part of one of his (İsmail KUNDURACIOĞLU) homework assignment tasks which was prepared using the summary translation of Reference [1]: Book Chapter 3. [1-55].

KEYWORDS

Elastomechanics, Bone, Fracture, Elastic Deformation, Plastic Deformation, Structure of Bones, Body Mechanics, Human Body Mechanics, Medical Body Mechanics, Macroscopic Level, Microscopic Level, Thermodynamics, Energy Transfer, Fluid Mechanics, Heat Transfer, Mathematics, Medical Technique, Medical Engineering, Medicine, Biomechanics, Biomechanical Analysis, Bioengineering, Health Science

INTRODUCTION

Elastomechanical Fundamentals: Bones and Fractures

The human body is made up of various biomaterials with different mechanical properties. Tissues such as bones, skin, blood vessels, lungs, bladder, and heart differ in their elastic and plastic behavior. In this article, before moving on to the mechanical properties of these materials, we will examine the basic elastic and plastic properties [1].

A rigid body can be deformed by a pair of forces (F ⃗_1 and 〖-F ⃗〗_2) acting in opposite directions to each other. In this case, the sum of the forces is in equilibrium, and the object does not move:

$$\vec{F}_1+\vec{F}_2=0.$$

When the magnitude of the force F is proportioned to the surface area A, the pressure is defined as p=F/A or the tension is defined as σ=F/A. If the stress is applied in only one direction, this is called a uniaxial stress. Depending on the direction of the force, uniaxial tension can be in the form of pulling or compression. When an equal magnitude of stress is applied to all surfaces, this is defined as hydrostatic pressure (Figure 1) [1].

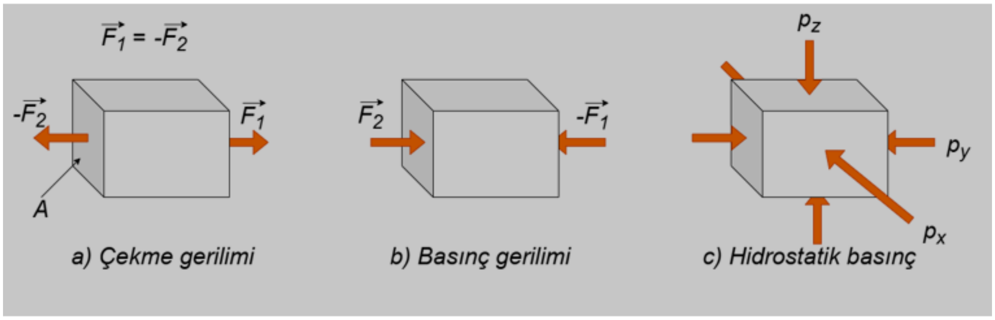


Figure 1: Tensile and compressive stress are caused by pairs of forces acting on surfaces, while hydrostatic pressure is caused by forces acting equally in all directions [1].

Bones are subjected to both internal (body weight and muscle forces) and external (impacts and load-bearing) forces. The tasks of providing support to the body, enabling movement and protecting internal organs are directly related to the material properties of bones. Bones have a hierarchical structure from the nanoscale to the macro scale, and thanks to these properties, they exhibit viscoelastic responses, fracture behaviors, and self-repair abilities [1-55].

METHOD, FINDINGS and DISCUSSION

Elastic Deformation:

When a rigid body is subjected to uniaxial stress, it reacts to the stress by changing shape. This shape change is measured by the relative change in length: ε=Δl/l. Tensile stress causes the material to elongate, and compressive stress causes it to shrink. The relationship between stress σ for small deformations and ε of shape change is linear and is known as Hooke's Law (Figure 2):

$$\sigma=E\varepsilon$$

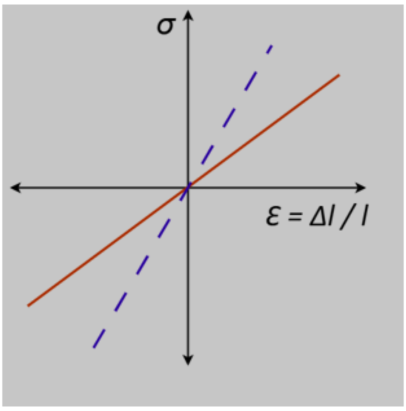


Figure 2: Graphing of Hooke's Law on stress-shape change for soft and hard materials. [1]

Here, E is called the elastic modulus or Young's modulus. This module determines how rigid or flexible the material is. For example, rubber has a low EE value, while steel has a very high E value. The unit of voltage is [σ]=Nm2=Pascal, and the elastic modulus E has the same unit. The elastic modulus of various materials is given in Table 1 [1].

Material	E (GPa)
Alumina	70
Steel	200
Wooden	13
Bone	15
Rubber	0.5

Table 1: Elastic Modulus of Some Materials [1].

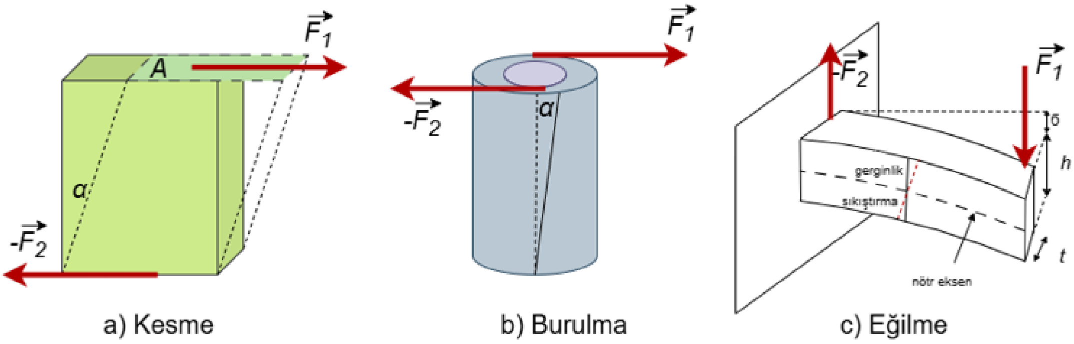
A rigid body varies not only with the change of length but also with the transverse direction. For example, tensile stress stretches the object in the direction of tension, while causing contraction in the perpendicular direction. This effect is defined by the Poisson ratio:

$$\mu=(\Delta t/t)/(\Delta l/l)$$

Usually the Poisson ratio varies between $0.2 \leq \mu \leq 0.4$. In addition, materials can also be deformed under shear forces. Shear forces lead to an angular change within the material. The shear stress τ is defined similarly to Hooke's Law:

$$\tau=G.\alpha$$

Here, G is the shear modulus and α is the cutting angle. Shear forces are especially important in understanding the mechanism of bone fractures. Elastic deformation occurs by tangential forces exerted from the opposite direction of the object; These forces create a change in the angle of the object, not its volume. The tangential force is defined as the force component reflected on the surface area A, and these pairs of forces do not impart angular momentum to the object. Thus, a distinction is made between shear, torsional and bending deformations. These three types of deformation are presented in Figure 3 [1].



(a) Shear

(b) Torsion

(c) Benture. In bending, the tension along the neutral axis is zero [1].

Figure 3: Types of elastic deformation caused by tangential forces.

It is possible to measure the hardness of the material by bending a beam. Hardness k is defined as the ratio between the applied force F and the observed deviation δ:

$$k=F/\delta$$

A high k-value indicates that the material is harder [1].

Plastic Deformation:

As long as a material remains below a certain critical stress level, it can return to its original shape when the applied force is removed. This constitutes the scope of validity of Hooke's Law. However, ductile materials that exceed this critical level, called "yield stress", exhibit an irreversible plastic flow by undergoing permanent deformation (Figure 4) [1].

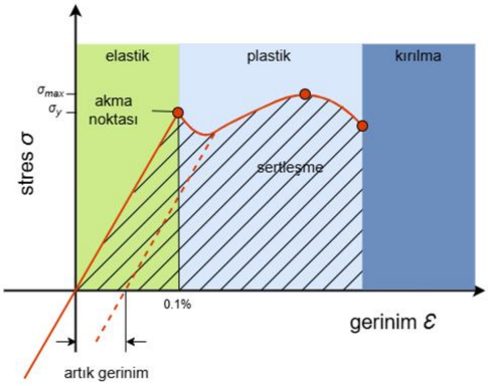


Figure 4: Stress-strain curve showing the transition process to plastic deformation. The yield point refers to the maximum stress before the start of plastic deformation. The dashed line indicates the irreversibility of the stress released beyond the yield point, while the shaded area represents the toughness of the material [1].

Even after stress is removed, permanent shape changes occur in the material. Especially for metal sheets, this plastic deformation process is of great importance in terms of part production in industry. During plastic deformation, dislocation movements and grain boundary changes occur in crystal structures. Continued deformation causes work hardening of the material, which makes it more durable[1].

The level of ductility of materials determines how much they can change shape under tensile or compressive force. Metals generally have ductile structure, while materials containing ionic and covalent bonds show brittle properties. For example, a metal mug may warp and change shape, while a porcelain mug may break suddenly. Bones, on the other hand, are observed to exhibit more complex mechanical behaviors due to their compound and heterogeneous structures.

The toughness of a material is defined by the energy density it can store up to its breaking point:

$$E/V=\int_0^{\varepsilon_{frac}}\sigma d\varepsilon$$

This integral represents the interlaced area in Figure 4. As the area grows, the toughness of the material also increases. Ductile materials generally have high toughness, while brittle materials show high strength but low toughness properties[1].

Elastic Properties of Beams

Bones consist of a hard shell on the outer surface and a porous structure on the inside. This combination allows a lightweight structure to be maintained without sacrificing rigidity. The same principle applies to engineering structures; In the design of bridges and aircraft, for example, it functions similarly to the use of lightweight but strong materials. It consists of bone tissue, collagen and minerals, and the balance of these components directly affects mechanical strength. Bones with too much mineral show a hard but brittle structure, while mineral deficiency causes the bones to soften [1].

Long bones exhibit a form structurally similar to hollow cylinders, optimizing their load-bearing capacity. The torque (T) required to bend a beam is expressed as:

$$T=L\times F$$

Here, L is the length of the beam, and F is the applied force (Figure 3(c)). Alternatively, torque in terms of moment of resistance (W) can be expressed as:

$$T=W\times\tau$$

Here τ is the cut-off stress. The moment of resistance, on the other hand, depends on the geometry of the beam and is defined by the following integral:

$$W = 1/L \int L2\ dA$$

For example, for a beam with a rectangular cross section (Figure 5 (a)):

$$T= 〚th〛 \text{^}2/6$$

where t is the thickness of the beam; h is its height. This formula is considered as an important parameter in the strength analysis of beams used in engineering structures [1].

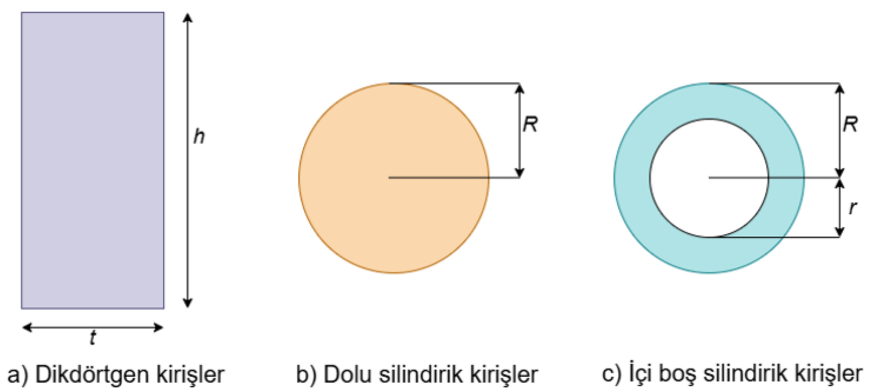


Figure 5: Moments of resistance for different beam geometries:

(a) rectangular beams

(b) solid cylindrical beams

(c) hollow cylindrical beams. [1]

If a cylindrical beam with the same cross-sectional area is considered, the moment of resistance is even higher. The advantage of hollow cylindrical beams, which are lighter but show similar properties in terms of strength, can be explained by the following equation (Figure 5(b) & 5(c)):

$$W=\pi/4\ (R^4-r^4)/R\approx\pi/4\ R^2\ \Delta R$$

This result shows that the hollow structure of long bones is mechanically advantageous and provides lightness without sacrificing rigidity. In addition, the spongy trabecular structure of the bones increases mechanical stability, reducing the risk of fragility [1].

Structure of Bones

While the human skeleton has about 270 bones at birth, these combine over time to become 206 bones in adulthood. Bones have different shapes and sizes:

Long bones: It is located in the extremities, such as the legs and arms.
Short bones: Located on the wrists and ankles.
Irregular bones: The spine and some facial bones fall into this category.
Flat bones: These are structures such as the skull, ribs and sternum.

Each bone has a hard cortical shell on the outside and a spongy trabecular structure on the inside. Especially long bones contain the medullary cavity, which is peculiar only to them. The main functions of bones include functions such as protecting vital organs, providing movement through joint and muscle connections, production of blood cells, and mineral storage [1].

When examined at the microscopic level, it is seen that bone tissue has a hierarchical structure with seven levels. The main organic component of bones is collagen, which has a fiber-like protein structure. Collagen increases durability by forming triple helix structures and optimizes the mechanical properties of bones by combining with hydroxyapatite (HA) nanocrystals. Bones contain cells such as osteoblasts, osteoclasts, and osteocytes. Osteoclasts provide restructuring by breaking down old bone tissue, while osteoblasts are responsible for the synthesis of new bone tissue. Osteocytes, on the other hand, maintain cellular communication by sensing mechanical impulses in the bone. This dynamic balance allows bones to change shape and adapt over time [1].

Elastic and Plastic Properties of Bones

When bones are examined from an elastomechanical point of view, they can be defined as biocomposite materials consisting of mineralized collagen fibrils. These fibrils form the basic building blocks of bone tissue and can be found in structurally different patterns. They exhibit a dense and parallel organization in the cortical region, while in the trabecular region they form a more random network structure. Due to these properties, bones are heterogeneous materials with variable density and elasticity [1].

Macroscopic Level: Macroscopic stress-elongation tests are applied to determine the general mechanical properties of the bones. Although these tests allow the bones to be examined in a way that is similar to the actual loading conditions in the body, they do not fully explain the mechanism of tensile strength or the fracture processes. Bones are anisotropic in nature and show variable reactions to loads applied on different axes. For example, compression and tensile forces are evaluated in tests along the long axis of long bones, while bending force is measured in tests performed at right angles [1].

As a result of these tests, it was observed that the resistance to bending force was lower than the compression force. This situation reveals that bone fractures usually occur as a result of bending loads. In addition, it exhibits the most sensitive condition to fractures because it has torsional loading, the lowest yield stress and elastic modulus. Macroscopic fracture models resulting from different types of loading are shown in Figure 6 as representatives [1].

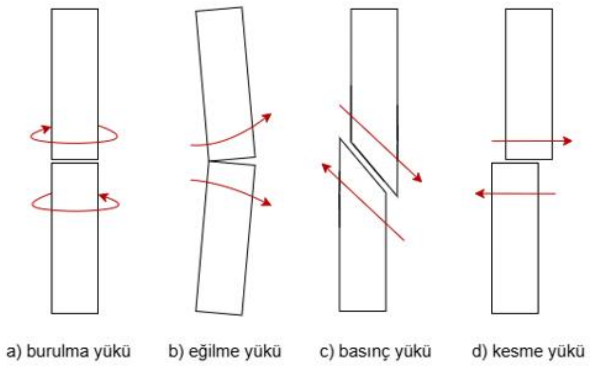


Figure 6: Fractures of long bones due to different types of loads:

(a) Torsional load
(b) bending load
(c) compressive load
(d) Shear load. [1]

The elastic and viscoelastic properties of bones are closely related to the mechanical responses of their constituents, collagen and minerals. Depending on the stress rate, an increase in elastic modulus and yield stress was observed. This phenomenon has been tried to be explained by mechanical models, revealing the viscoelastic characteristic of bones. Although mechanistic approaches such as the Kelvin-Voigt and Maxwell models are used, it is argued that they do not fully represent the complex mechanical response of bones. The fatigue properties of the bones are marked with a dashed line in Figure 7. Fatigue is the decrease in the strength of a material as a result of repeated loads applied on it. However, in bones, this condition usually occurs in just a few cycles, without the need for thousands or millions of cycles. Microcracks that occur at this early stage severely reduce the durability of the bones; Without adequate recovery time, these cracks accumulate, leading to eventual structural failure [1].

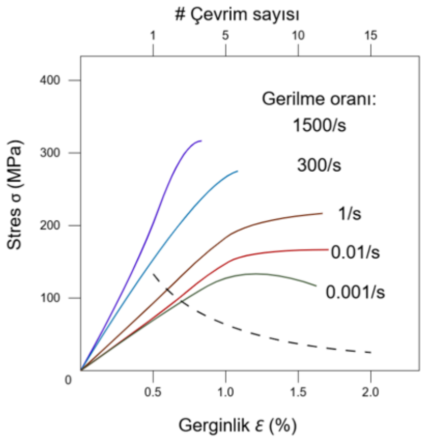


Figure 7: The viscoelastic behaviour of the bones varies depending on the rate of increase of the applied stress. The dashed line below reveals the yield stress corresponding to a specific number of load cycles[1].

Citation: Emin TE, İsmail K (2025) Elastomechanics Fundamentals for Bones and Fractures. Ann Biotech & Biomed Sci 1(1): 1-12.

Elastic properties differ in cortical and trabecular bones. Cortical bone has a high density and low porosity (0.05-0.1), while trabecular bone has a lower density (0.43 g/cm³) and high porosity (0.75-0.95). These differences directly affect the mechanical behavior of both bone types. Cortical bone has higher strength, while trabecular bone exhibits greater toughness. This is also demonstrated by the stress-strain relationship (Figure 8) [1].

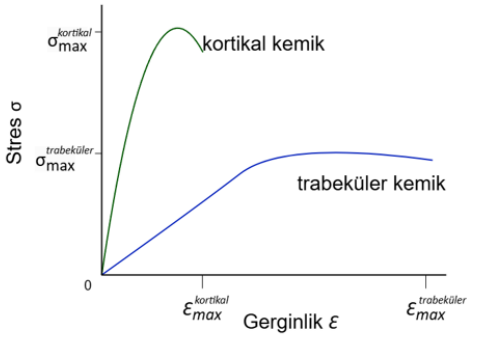


Figure 8: Stress-strain behavior of cortical and trabecular bones shows different slope and toughness characteristics. It is important to consider these structural differences [1].

Microscopic Level: Various hypotheses have been put forward to explain the mechanical strength of bones. One of them is that the molecular slip mechanism allows the weak bonds to break and the composite to deform without damage. Another hypothesis is that bone mineral crystallites contribute to strength because they are resistant to fracture. Advanced imaging techniques such as x-ray scattering and nanoscopic stress-strain tests have been used to study this issue [1].

As a result of these studies, it has been revealed that bone tissue is exposed to different levels of strain. The ratio between the strain values of fibrils and mineral particles shows how the strain is distributed under mechanical loading. In particular, the interfibrillary matrix is thought to reduce the brittleness of the mineral structure by absorbing the shear forces of crosslinked fibrils. Thanks to this mechanism, bones are able to maintain their strength even under high stress [1].

In analyses using scanning electron microscopy (SEM) and atomic force microscopy (AFM), it has been observed that microcracks in bones are held together by a certain organic structure. This binding structure plays a critical role in the transmission of interfibrillar shear stresses. This organic compound, which acts as an adhesive, is thought to increase the strength of bones and contribute to absorbing more energy before they break. In addition, ligaments can reform when the load is lifted, making the bones more resistant to repetitive loads.

Finally, it is important to compare the elastic properties of bones with other biological structures of the body. Structures such as lung tissue, blood vessels, bladder and eyeball also exhibit elastic properties [1-55].

CONCLUSION

This comprehensive review reveals how the elastic and plastic properties of bones are shaped at the macroscopic and microscopic level, explaining the basic principles underlying their mechanical strength. The mechanical behavior of bones and fracture mechanisms are discussed in detail along with their elastic and plastic deformation properties. In the introductory part, an overview of the structural and biomaterial properties of bones is presented, while in the elastic deformation part, the reversible behavior of the material under load is examined within the framework of Hooke's Law. In the plastic deformation section, permanent shape changes that occur when the yield stress is exceeded and its effects on material durability are discussed [1].

While the elastic properties of the beams reveal how the structures that optimize the load-bearing capacity of the bones work, the structural hierarchy of the bones and the different components (collagen, minerals and osteons) they contain are examined in detail. Finally, macro and microscopic analyses of the elastic and plastic properties of bones have revealed both holistic durability and micro-scale deformation mechanisms [1].

This study highlights the importance of multiscale approaches to understanding the complex mechanical properties of bones and provides a solid foundation for future studies. In both clinical practice and from a materials science perspective, a better understanding of bone behavior is critical to the development of treatment modalities and the improvement of biomaterial designs [1-55].

REFERENCES

1. Hartmut Zabel (2017) Medical Physics, Physical Aspects of Organs and Imaging, Walter de Gruyter GmbH, Berlin/Boston Volume 1.
2. Elmas, Emin Taner (2020) ELMAS's Theory of Thermodynamics": A Scientific Approach for 5th Law of Thermodynamics -A Theoretical Application Example for Medical Thermodynamics. Op Acc J Bio Sci & Res 2(1).
3. Emin Taner Elmas (2024) Medical Treatment Method of Alzheimer's Disease & Parkinson's Disease by the Help of the Natural Musical Sound of Nây-ı Şerîf, Instrument of Ney (Ney: Turkish Reed Flute, Nay). IJCMCR 42(3).
4. Elmas, Emin Taner (2020) Medical Treatment Method of "Bio-robotic Resonance and Thermodynamical Interaction" with Analogy of "Frequency – Resonance Setting Formation" on the Application of "Algorithm for Smart Drugs Controlled by a Bio-robotic System" developed for the "Treatment of Covid-19, Coronavirus and Virus Infections". Open Access Journal of Biogeneric Science and Research (BGSR). Op Acc J Bio Sci & Res Volume 1.
5. Elmas Emin Taner (2020) Scope of Applications for Medical Technique at Science and Engineering, Open Access Journal of Biogeneric Science and Research (BGSR). Op Acc J Bio Sci & Res Volume 1.
6. Emin Taner ELMAS (2024) System Design and Development of a Novel Unique Neuro-Physical Medical Treatment Method for SMA-SPINAL MUSCULAR ATROPHIA-Disease and for Similar Neurological Muscle Diseases. Herculean Res 4(1): 90-97
7. Fevzi Daş, Emin Taner Elmas, İhsan Ömür Bucak (2024) Book Chapter: Innovative Use of Machine Learning-Aided Virtual Reality and Natural Language Processing Technologies in Dyslexia Diagnosis and Treatment Phases; From the Edited Volume Digital Frontiers - Healthcare, Education, and Society in the Metaverse Era IntechOpen Limited.
8. Emin Taner ELMAS (2024) Design of Bionic Eye and Artificial Vision System; a Unique Project "Mobile Bio-Eye-Tronic System". Herculean Res 4(1): 97-100.
9. Emin Taner ELMAS (2024) Project for "Amphibious Mobile Snow Track Ambulance" for Healthcare System. Am J Biomed Sci & Res 22(4).
10. Emin Taner ELMAS (2024) The first "Olive Seedlings" and "Artichoke Seedlings" Planted in Iğdır Province, Turkey. Am J Biomed Sci & Res 22(5).
11. Emin T Elmas, İhsan Ö Bucak (2023) Modeling and Simulation of Smart-Drug Algorithms Through Frequency Modulation for the Treatment of Covid-19 and Similar Viruses. Global Journal of Research in Medical Sciences 3(5): 1-6.
12. Emin T E, İhsan Ömür B (2024) FM Modulated Smart Drug Algorithm for the treatment of Cancer Cells. In Global Journal of Research in Medical Sciences 4: 1-6.
13. Emin Taner ELMAS (2023) Prototype Desıgn, Productıon and Functıonıng of a Portable (Movable), Home-Type (Domestıcal) Hemodıalysıs Machıne (Unıt). In Global Journal of Research in Medical Sciences 3(6): 11-12.
14. Elmas Emin Taner (2019) Thermodynamical Balance Associated with Energy Transfer Analysis of the Universe Space as a Pressure Vessel Analogy. Journal of Applied Sciences, Redelve International Publications 2019(1): RDAPS- 10002.
15. Elmas Emin Taner (2017) Productivity and Organizational Management (The Book) (Chapter 7): Prospective Characteristics of Contemporary Engineer (By the Approach of Mechanical Engineering) Contribution and Role of the Mechanical Engineer to the Organization Management and Productivity.
16. Elmas, Emin Taner (2017) Prospective Characteristics of Contemporary Engineer (By the Approach of MechanicalEngineering) Contribution and Role of the Mechanical Engineer to the Organization Management and Productivity).

17. ELMAS Emin Taner, ALMA MH (2025) Iğdır University ISO 50001 Energy Management System Certification Studies. In Global Journal of Research in Engineering & Computer Sciences 5(2): 6-24.

18. Hartmut Zabel (2017) Medical Physics, Volume2: Radiology, Lasers, Nanoparticles and Prosthetics, Walter de Gruyter GmbH, Berlin/Boston.

19. Steven Vogel (2013) Comparative Biomechanics – Life's Physical World, Published by Princeton University Press, USA.

20. Roland Ennos (2012) Solid Biomechanics, Published by Princeton University Press, ISBN:978-0-691-13550-2, USA.

21. Mark Strikman, Kevork Spartalian, Milton W Cole (2015) Applications of Modern Physics in Medicine, Princeton University Press, USA,

22. Emin Taner Elmas (2024) Design of Bio-Artificial Liver Organ. J Biomed Sci Biotech Res. 2(3): 1-4.

23. ELMAS ET (2024) Design of Bionic Ear-Cochlear Implant and Artificial Hearing System; a Unique Project "Mobile Bio-Ear-Tronic System".

24. Emin Taner Elmas (2024) A Review for Combined Cycle Power Plants. Bi¬omed J Sci & Tech Res 58(1).

25. ELMAS Emin Taner (2024) Dimensional Unit Analysis Applications for Heat Pipe Design. In Global Journal of Research in Engineering & Computer Sciences 4(5): 12-26.

26. ELMAS, Emin Taner. (2024). Calculation of the Filling Amount of Working Fluid to be Placed in a Heat Pipe. In Global Journal of Research in Engineering & Computer Sciences 4(5): 100-108).

27. ELMAS, Emin Taner. (2024). Providing Fully Developed Flow for Waste Exhaust Gas at the Inlet Region of a Heat Pipe Air Recuperator. In Global Journal of Research in Engineering & Computer Sciences 4(5): 118-124.

28. Emin Taner Elmas (2024) ONLINE BOOKLET - E -Print - A Review for Combined Cycle Power Plants.

29. Emin Taner ELMAS, Doktora Tezi (2011) "Yüksek Sıcaklıklı, Isı Borulu, Isı Geri Kazanım Ünitelerinin Tasarım Parametrelerinin Termodinamiksel ve Deneysel Analizi", Tez Danışmanı:Prof. Dr. Ali Güngör, Ege Üniversitesi Fen Bilimleri Enstitüsü Makina Mühendisliği Anabilim Dalı, Termodinamik Bilim Dalı, İzmir,

30. Elmas Emin Taner, Yüksek Lisans Tezi, (1999) "Evaporation Plant For Recyling of Caustic Soda", Thesis Advisor: Prof. Dr. Fehmi Akdoğan, Dokuz Eylül Üniversitesi Fen Bilimleri Enstitüsü Makina Mühendisliği Anabilim Dalı, Enerji Bilim Dalı, İzmir.

31. Emin Taner E (2023) Thermodynamical and Experimental Analysis of Design Parameters of a Heat Pipe Air Recuperator. Global Journal of Research in Engineering & Computer Sciences 3(6): 6-33.

32. Emin T E (2023) Design, Production, Installation, Commissioning, Energy Management and Project Management of an Energy Park Plant Consisting of Renewable Energy Systems Established at Igdir University. In Global Journal of Research in Engineering & Computer Sciences 3(6): 67-82.

33. Hasan TAMSÖZ, Emin Taner ELMAS (2021) ÇELİK ÜRETİMİNDE ELEKTRİK ARK OCAKLARINDA ENERJİ MALİYETLERİNİN VE ENERJİ VERİMLİLİK FAKTÖRLERİNİN ARAŞTIRILMASI INVESTIGATION ON ENERGY COSTS AND ENERGY EFFICIENCY FACTORS OF ELECTRIC ARC FURNACE FOR STEEEL PRODUCTION, Fenerbahçe Üniversitesi Tasarım, Mimarlık ve Mühendislik Dergisi - Journal of Design, Architecture & Engineering. 1(3): 163-180.

34. Adem KAYA, Emin Taner ELMAS (2022) SİNTER TESİSLERİNDE ENERJİ KULLANIM NOKTALARI VE ENERJİYİ VERİMLİ KULLANACAK YÖNTEMLERİN BELİRLENMESİ DETERMINATION OF ENERGY UTILIZATION POINTS AND THE METHODS USING THE EFFICIENT ENERGY FOR SINTERING PLANTS, Fenerbahçe Üniversitesi Tasarım, Mimarlık ve Mühendislik Dergisi - Journal of Design, Architecture & Engineering 2 (2): 170-181

35. Emin Taner ELMAS (2024) The Electrical Energy Production Possibility Research Study by using the Geothermal Hot Water Resources, which is a a kind of Renewable Energy Resource, located at the Region of Mollakara Village which is a part of Diyadin Town and City of Ağrı, Turkey. In Global Journal of Research in Engineering & Computer Sciences (41): 90-101.

36. ELMAS Emin Taner (2024) Energy Analysis, Energy Survey, Energy Efficiency and Energy Management Research carried out at Iğdır University. In Global Journal of Research in Engineering & Computer Sciences 4(2): 12-30.

37. ELMAS Emin Taner (2024) A Research Study of Salt Dome (Salt Cave) Usage Possibility for CAES – Compressed Air Energy Storage Systems. In Global Journal of Research in Engineering & Computer Sciences 4(2): 128-131.

38. ELMAS Emin Taner (2024) Wankel Rotary Piston Engine Design Project. In Global Journal of Research in Engineering & Computer Sciences 4 (3): 1-4.

39. ELMAS Emin Taner (2024) An innovative solar dish type collector – concentrator system having an original - unique geometrical mathematical model called as DODECAGON which has 12 equal segments. In Global Journal of Research in Engineering & Computer Sciences 4(3): 31-38.

40. Emin Taner ELMAS (2024) Waste Heat Recovery Boilers (WHRBs) and Heat Recovery Steam Generators (HRSGs) used for Co-generation and Combined Cycle Power Plants. Op Acc J Bio Sci & Res 12(1).

41. ELMAS Emin Taner (2024) Presentation and Curriculum of Division of Motor Vehicles and Transportation Technologies & Department of Automotive Technology at Vocational School of Higher Education for Technical Sciences at Iğdır University, Turkey. In Global Journal of Research in Engineering & Computer Sciences 4(3): 60-67.

42. Emin Taner ELMAS (2023) Design and Production of a Unique Hand-Made Energy-Efficient 4 x 4 – Four Wheel Drive (4wd – 4 Matic) Traction System Electric Automobile. In Global Journal of Research in Engineering & Computer Sciences 3(6): 48-51.

43. ELMAS Emin Taner (2024) Three – Pass Fire Tube Boilers for production of Steam, Hot Water and Superheated Water. In Global Journal of Research in Engineering & Computer Sciences 4(4): 29-38.

44. Elmas Emin Taner (2017) Evaporation Plant for Recycling of Caustic Soda, INTERNATIONAL JOURNAL of ENGINEERING TECHNOLOGIES-IJET 3(3).

45. Elmas Emin Taner (2014) Çağımızın Mühendisinden Beklenenler, Gece Kitaplığı.

46. Emin Taner ELMAS, Levent Ogul (2025) The Effects of Medicine and Music Therapy Practices on Human Health. IJCMCR.; 50(2): 003.

47. Emin Taner E, Servet K (2025) Biomechanical Analysis of Transtibial Prosthesis Designed for Runners. Biomedical and Clinical Research Journal 1(2).

48. ET Elmas, MA Cinibulak (2025) Fundamental Scientific and Technical Issues related with the "Hip Replacement Design and Biomechanical Analysis". Journal of Material Science and Nanotechnology, Matsci Nano J.

49. Kunduracioğlu İ (2018) Examining the Interface of Lego Mindstorms Ev3 Robot Programming. Journal of Educational Technology & Online Learning 1(1): 28-46.

50. Kunduracioglu I (2024) CNN Models Approaches for Robust Classification of Apple Diseases. Computer and Decision Making: An International Journal 1: 235-251.

51. Kunduracioglu I (2024) Utilizing ResNet Architectures for Identification of Tomato Diseases. Journal of Intelligent Decision Making and Information Science 1: 104-119.

52. ELMAS Emin Taner, KUNDURACIOĞLU I (2025) A Model for Second Law of Thermodynamics, Relationship between Health, Disease, Aging, Death Processes and Consciousness, Nervous System and Time. In Global Journal of Research in Medical Sciences 5(2): 1-6.

53. ELMAS Emin Taner, KUNDURACIOĞLU I (2025) Metabolic Heat Production with Energy Transfer and Laws of Human Thermodynamics: The Energy Balance of the Human Body. In Global Journal of Research inMedical Sciences 5(2): 7-14.

54. Elmas ET, Kunduracıoğlu I (2025) Artificial Heart Design and Biomechanical Analysis. Open Access Journal of Medicine and Healthcare, Research Article 1(1): 01-06.

55. ELMAS Emin Taner, KUNDURACIOĞLU I (2025) Fundamentals of Human Vision System. In Global Journal of Research in Medical Sciences 5(2): 103-117.