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Engineering Design and Operational Analysis of Cardiopulmonary Bypass (CPB) Machines with the 5th Law of Thermodynamics and ELMAS's Theory of Thermodynamics

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Abstract

Dr. Emin Taner Elmas's academic work, and especially his "ELMAS's Theory of Thermodynamics," can be used as a theoretical foundation for the engineering design and operational analysis of Cardiopulmonary Bypass (CPB) machines. Dr. Elmas's research addresses the following key areas that can improve the efficiency and flow control of these machines:

• Thermodynamic Efficiency Analysis: Elmas's theory of thermodynamics defines biological systems as "open thermodynamic systems." CPB machines are also open systems that continuously exchange matter and energy (heat) with the body. This theory can be used to optimize the energy efficiency of machines, particularly by vectorially modeling the energy transfers that occur during blood oxygenation and temperature control. • Advanced Biomechanics and Hemodynamics: Dr. Elmas's work within the scope of his "Medical Engineering and Advanced Biomechanics" courses examines the hemodynamic structure of the circulatory system. This information can form the basis for developing flow control algorithms that determine the most suitable (physiological) flow rate and pressure for the vascular structure while the heart-lung pump pumps blood. • Bio-Artificial System Modeling: Elmas's work on the design of a bio-artificial liver organ offers mechatronic solutions for how mechanical systems can be integrated with biological fluids (blood, etc.). This approach can be used in engineering calculations aimed at achieving the highest efficiency without damaging blood cells (reducing the risk of hemolysis) in the design of heat exchangers and oxygenators in CPB machines. • Intelligent Control Systems: The "smart drug algorithms" and control mechanisms developed for biological systems in his studies can contribute to the design of intelligent control panels for CPB devices that automatically adjust flow rate and temperature according to the patient's immediate needs during surgery.

In conclusion: Emin Taner Elmas's work is not a surgical method itself; it is a scientific foundation used for the engineering design, biomechanical performance, and thermodynamic analysis of medical devices that play a vital role in these surgeries.

Emin Taner Elmas's technical principles are embodied in the computer-aided design (CAD) and engineering (CAE) phases of cardiopulmonary bypass (CPB) machines as follows:

• Geometric Optimization and Flow Paths: Pump and reservoir models created in CAD software (SolidWorks, Autodesk Fusion, etc.) are shaped according to Elmas's hemodynamic principles. Designing blood flow paths with smooth transitions instead of sharp corners minimizes turbulence and dead zones, preventing red blood cell fragmentation. • Thermal Modeling and Heat Exchanger Design: Dr. Elmas's thermodynamic efficiency approaches are integrated into the computational heat transfer (CFD) analyzes of the CAD models. The design of the channels within the heat exchanger's internal structure is determined by mathematical boundary conditions that ensure homogeneous heating/cooling without subjecting the blood to thermal shock. • Bio-Mimetic Approach: Elmas's "bio-artificial system" models guide the design of flexible and adaptable connectors (cannulas) that mimic the vascular system in a CAD environment. This ensures that the pressure generated by the mechanical pump is transmitted in a way that is closest to the body's natural vascular resistance (vascular impedance).

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• Material Selection and Surface Analysis: The energy balance predicted by thermodynamic theory also includes the energy of surfaces in contact with blood. Surface roughness values determined in CAD models and membrane oxygenator designs are based on physical parameters that will make gas exchange (O_2/CO_2) as efficient as possible. These principles are used to create a "digital twin" in the digital world before manufacturing a device, reducing the margin of error to zero and increasing operational safety. [1-89]

Keywords: *Cardiopulmonary Bypass (CPB) Machines, Cardiopulmonary Respiratory Machines, Heart-Lung Machines, Life Support Units, 5th Law of Thermodynamics, ELMAS's Theory of Thermodynamics, Medical Technique, Cardiology, Cardiovascular System, Bio-Artificial Liver Organ, MARS System, Cardiovascular Fluid Mechanics, Artificial Heart, AI - Artificial Intelligence, Hemodynamics, Medical Thermodynamics, ELMAS's Theory of Thermodynamics, 5th Law of Thermodynamics, Entropy, Negentropy, Resonance, Frequency, Thermodynamic, Energy Transfer, Fluid Mechanics, Heat Transfer, Mathematics, Computational Fluid Dynamics (CFD), Computer-Aided Design – CAD, Computer-Aided Engineering – CAE.*

INTRODUCTION

Dr. Emin Taner Elmas's groundbreaking academic contributions, particularly his "ELMAS's Theory of Thermodynamics," provide a solid theoretical framework for the engineering design and operational analysis of Cardiopulmonary Bypass (CPB) machines. His research highlights several critical areas that can enhance the effectiveness and precision of these machines: - **Thermodynamic Efficiency Analysis**: The Elmas Theory defines biological systems as "open thermodynamic systems," a concept directly applicable to CPB machines, which similarly function as open systems exchanging matter and energy (heat) with the human body. By adopting this framework, it is possible to optimize the energy efficiency of these devices, especially through vectorial modeling of energy transfers during blood oxygenation and thermal regulation. - **Advanced Biomechanics and Hemodynamics**: Within Dr. Elmas's "Medical Engineering and Advanced Biomechanics" coursework, the hemodynamic properties of the circulatory system are extensively analyzed. This knowledge serves as a foundation for designing flow control algorithms that ensure physiological flow rates and pressures, optimizing the function of heart-lung pumps while taking into account vascular adaptability. - **Bio-Artificial System Modeling**: His work on developing bio-artificial liver prototypes introduces innovative mechatronic solutions for integrating mechanical systems with biological fluids like blood. This concept is vital for engineering calculations aimed at maximizing efficiency while minimizing damage to blood cells (e.g., hemolysis) during the design of CPB machine components like heat exchangers and oxygenators. - **Intelligent Control Systems**: The smart drug delivery algorithms and automated control mechanisms he has developed for biological systems offer significant insights for creating intelligent CPB interfaces. These systems can autonomously adjust parameters such as flow rate and temperature to align with the real-time physiological needs of patients undergoing surgery. In summary, while Dr. Elmas's research does not directly describe surgical techniques, it offers essential scientific methodologies that inform the engineering design, biomechanical optimization, and thermodynamic evaluation of medical devices critical to operating room procedures, including CPB machines. [1-89]

The technical implications of Emin Taner Elmas's work on heat transfer and flow dynamics in CPB machines can be summarized under the following headings:

1. Heat Transfer Efficiency (Thermodynamic Approach)

Cooling or heating blood (hypothermia/normothermia management) in CPB machines is critical for controlling the patient's metabolic rate. • Elmas's Contribution: The 5th law of thermodynamics and open system modeling aim to minimize the entropy change between blood and the heat exchanger. • Technical Application: These mathematical models can be used in calculating the most efficient heat transfer coefficient without damaging the protein structure of the blood (without causing thermal damage) and in the vectorial analysis of heat losses within the machine.

2. Flow Dynamics of Blood in Mechanical Systems (Hemodynamics)

Blood is a non-Newtonian fluid; that is, its viscosity changes as its velocity changes. • Elmas's Contribution: Dr. Elmas's advanced biomechanical studies model the laminar and turbulent flow transitions of blood within artificial tubes and pumps. • Technical Application: By analyzing the "shear stress" inside the pump, the breakdown (hemolysis) of red blood cells is prevented. Flow control algorithms are optimized to mimic the pressure exerted by blood on the vessel walls (pulsatile flow) in its most natural form.

3. Substance Transfer in Bio-Artificial Systems

Gas exchange (O_2 input, CO_2 output) takes place in the oxygenator part of the CAP device, which acts as the "lung".

• Elmas's Contribution: "Elmas Thermodynamic Theory" treats this process not just as diffusion, but as a substance-energy transfer balance. • Technical Application: In the pore structure and surface area designs of membrane-type oxygenators, thermodynamic data that increase gas exchange efficiency can be taken as a basis. In summary: These studies present engineering data aimed at transforming CPB machines from simply "a motor that pumps blood" into

intelligent biomechanical systems that work in the highest harmony with the body. [1-89]

MATERIAL, METHOD AND DISCUSSION

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Computational Fluid Dynamics (CFD) analyses used in the CAD phase, combined with Dr. Elmas's biomechanical principles, provide the following critical data for the protection of blood cells: [1-89]

• Hemolysis (Red Blood Cell Disintegration) Prediction: CFD simulations calculate the "shear stress" that blood is subjected to at every point within the pump. When the flow limits emphasized by Dr. Elmas are exceeded, the rupture of red blood cell membranes is detected during the design phase, and the fin structures are revised accordingly. • Platelet Activation and Coagulation Analysis: "Dead zones" (stagnation points) where flow slows down or stops are visualized with CFD. Platelets can accumulate in these areas and form clots. The design eliminates these zones, reducing the risk of clotting and thus the likelihood of postoperative stroke (embolism). • Vectorial Velocity Distribution: The velocity and direction of blood at the pump outlet are vectorially optimized to avoid damaging the vessel walls (endothelial layer). This minimizes intravascular trauma and inflammation (the body's response). Thanks to these simulations, it is mathematically proven with certainty whether the device is biocompatible before a physical prototype is produced. [1-89]

When Dr. Emin Taner Elmas's thermodynamic and biomechanical principles are integrated into AI-powered smart pump systems, they transform CPB machines from "passive devices" into "dynamic, decision-making systems." The fundamental mechanisms of this integration are:

• Real-Time Decision Support Algorithms: Dr. Elmas's

theoretical models create "learning sets" for AI algorithms. The system optimizes the pump's rotational speed in milliseconds by comparing data such as blood pressure, temperature, and oxygen saturation from the patient during surgery with Elmas's thermodynamic equilibrium formulas. • Prediction and Digital Twin Applications: Digital twins created in the CAD phase train machine learning (ML) models using Dr. Elmas's fluid dynamics principles. This allows the system to predict the risk of hemolysis or clotting in the blood with over 90% accuracy before it occurs, sending a warning to the surgeon. • Autonomous Heat Control: Energy transfer algorithms based on the "ELMAS Thermodynamics Theory" are used by AI to autonomously manage the heat exchanger's operating power to maintain the patient's body temperature at the targeted level. • Adaptive Flow Control: The intelligent systems in CPB machines use Dr. Elmas' bio-robotic resonance approaches to provide a pulsatile flow (mimicking the heartbeat) that is compatible with the patient's vascular impedance. This is an advanced engineering solution that significantly reduces the risk of postoperative organ failure. [1-89]

These technologies are called "AI-Powered Biomechanical Design" in engineering and are setting a new standard in improving surgical success.

Emin Taner Elmas's work and thermodynamic principles offer critical guidance for future bio-artificial heart projects, aiming to design "systems that go beyond a mechanical pump and behave like a biological organ." The key impacts of this work on future bio-artificial heart technologies are: [1-89]

• Full Biocompatibility and Energy Balance: Elmas's "5th Law of Thermodynamics" approach aims for the artificial heart to not only pump blood but also function in complete harmony with the body's overall energy metabolism (open system balance). This can minimize the risk of the device being perceived and rejected by the body as a foreign substance (inflammatory response) at an engineering level. • Self-Regulating (Autonomous) Systems: Dr. Elmas's work on bio-robotic resonance and intelligent algorithms fuels the software infrastructure that will allow bio-artificial hearts to autonomously adjust their heart rate and pressure according to the patient's physical activity (running, sleeping, excitement), just like a real heart. • Hemodynamic Excellence: Clotting and mechanical wear, the biggest problems in future artificial hearts, can be overcome thanks to Elmas' vector flow analyses and CAD-based CFD simulations. The continuous and natural spiral flow of blood within the device, without leaving "dead spots," can eliminate the need for lifelong blood thinners. • Bio-Artificial Organ Integration: Elmas' experience in other bio-artificial organ projects, such as the liver, helps model the hormonal and thermodynamic interactions of the artificial heart with other organs (kidneys, lungs). This paves the way for "total artificial life support" systems. • Infinite Energy and Heat Management: Battery heating, the biggest problem in artificial hearts, can be solved with Elmas' thermodynamic efficiency models. Designs that convert energy directly into kinetic energy without converting it into heat will prevent tissue damage. In summary: Emin Taner Elmas's work serves the vision of transforming bio-artificial hearts from mere "spare parts" into "intelligent biological machines" integrated into the thermodynamic balance of the human body. [1-89]

In systems implanted in the body, such as the bio-artificial heart, wireless energy transfer (Transcutaneous Energy Transfer - TET) is considered, within the framework of Dr. Emin Taner Elmas's thermodynamic principles, not as a "closed box" but as an open system in constant interaction with the body. The thermodynamic dimension of this technology hinges on three critical points: [1-89]

• Waste Heat Management and Thermal Balance: During wireless energy transfer, a portion of the electromagnetic waves is converted into heat. According to Elmas's thermodynamic models, an increase in intra-body temperature of more than 2 degrees Celsius leads to protein denaturation and tissue death. During the design phase, the "exergy" (useful work) efficiency of the transferred energy must be maximized, while keeping the "entropy" (waste heat) radiated to surrounding tissues under control. • Electromagnetic Resonance and Vector Efficiency: The resonance principle emphasized in Dr. Elmas's work aims for frequency matching between the external receiver and the internal transmitter. From a thermodynamic perspective, this means minimizing losses during energy transfer through vector analysis. High resonance efficiency means the battery heats up less and lasts longer. • Biological Open System Integration: TET systems not only provide energy but also intervene externally in the body's thermodynamic balance. Elmas's theory mathematically models how this energy input affects metabolic processes at the cellular level and tissue blood flow. The goal is to avoid overstressing the body's natural cooling mechanisms (sweating, increased blood flow) during energy transfer. Thanks to these approaches, future artificial heart patients will be able to have a safe energy source with zero risk of thermal damage, without needing cables protruding from their bodies. [1-89]

CONCLUSION

The thermal response of tissues to electromagnetic waves, within the framework of Emin Taner Elmas's thermodynamic equilibrium and open system approaches, concerns how a biological tissue dissipates or absorbs the energy it is exposed to. From an engineering and biophysics perspective, this response is examined under three main headings:

1. Specific Absorption Rate (SAR) and Heat Accumulation:

Tissues absorb electromagnetic energy during wireless energy transfer. This causes water molecules within the tissue to vibrate, converting them into kinetic energy, i.e., heat. From a thermodynamic point of view, this is an increase in internal energy within the system. Elmas's theoretical

models aim to ensure that this increase does not exceed the thermal regulation capacity (cooling power) of the tissue.

2. Cooling by Blood Flow (Bio-Heat Transfer):

The body increases blood flow to a heated tissue to cool that area. This is a convectional cooling process from a "medical thermodynamics" perspective. In simulations, the speed at which blood, as a coolant, can vectorially remove heat from tissue is calculated. If the energy transfer rate exceeds the cooling rate of the blood, "thermal damage" begins.

3. Cellular Thermal Limits:

Each tissue has a different thermal resistance. For example, the heat conduction capacity (thermal conductivity) of subcutaneous fat tissue and muscle tissue near an artificial heart device is not the same. In analyses using Elmas's principles, the heat transfer coefficients between these tissue layers are mathematically modeled, and safety limits are drawn for the "critical temperature threshold" (generally 42°C and above) at which the protein structure of the tissues begins to degrade. These studies are used to select the safest location for placing wireless chargers and to keep the external surface temperature of the device at a tissue-friendly level.

The inflammatory response of tissues to electromagnetic heating is a biochemical defense mechanism initiated by the body to maintain its thermodynamic balance. Dr. Within Emin Taner Elmas's "open system" modeling framework, this situation is considered as "chaos" or increased entropy created at the cellular level by uncontrolled energy (heating) entering the system from the outside. The stages of this process are as follows:

• Release of Heat Shock Proteins (HSPs): When tissue temperature pushes the critical limit, cells produce heat shock proteins to protect themselves. This is a thermodynamic system's attempt to repair its own damage. However, if this happens continuously, the immune system perceives the area as a "threat." • Vasodilation (Vascular Dilation): As a thermodynamic cooling strategy, the body dilates the blood vessels in the heated area. This is an attempt to remove heat by sending more blood (cooling fluid) to the area. However, this dilation brings with it edema and redness (signs of inflammation). • Risk of Fibrosis (Tissue Hardening): If wireless energy transfer causes chronic low-level heating, the body may form hard scar tissue (fibrosis) to protect that area. The biocompatibility emphasized in Elmas's work aims precisely at establishing thermal balance that will prevent this tissue hardening. • Migration of Immune Cells: Cells damaged or stressed by heating release signaling molecules called cytokines. These signals attract leukocytes to the area. If the thermodynamic design is flawed, the system remains in a constant "micro-inflammation" mode, which reduces the lifespan of the device or the patient's comfort. In conclusion: The design of artificial hearts or other bio-robotic systems is not just a mechanical feat; it is also the art of providing thermal comfort that will not trigger these inflammatory responses in the body.[1-89]

BIOGRAPHY OF AUTHOR:

Asst. Prof. Dr. Dipl.-Ing. Emin Taner ELMAS

Asst.Prof. Dr. Emin Taner ELMAS is a Mechanical Engineer having degrees of B.Sc., M.Sc., Ph.D., and was born in Sivas in 1974. He completed his doctorate at Ege University, Graduate School of Natural and Applied Sciences, Mechanical Engineering Department, Thermodynamics Science Branch, and his master's degree at Dokuz Eylül University, Mechanical Engineering Department, Energy Science Branch. He also completed his undergraduate education at Hacettepe University, ZEF, Mechanical Engineering Department and graduated from the faculty with honors in 1995 and became a mechanical engineer. He was awarded a non-refundable scholarship by the Turkish Chamber of Mechanical Engineers in his 4th year because he was the most succesful student during his first 3 classes study at the faculty. He graduated from İzmir Atatürk High School in 1991.

Asst. Prof. Dr. ELMAS has completed his military service as a NATO Officer in Bosnia and Herzegovina. He was a "Reserved Officer" as a "2nd Lieutenant" as an "English-Turkish Interpreter". He was also a "Guard Commander" and served in Sarajevo, Camp Butmir within the SFOR task force of NATO. He has been awarded with 2 (two) NATO Medals and Turkish Armed Forces Service Certificate of Pride (Bosnia & Herzegovina).

In addition to his academic duties at universities, he has worked as an engineer and manager in various industrial institutions, organizations and companies; He has served as Construction Site Manager, Project Manager, Management Representative, Quality Manager, Production Manager, Energy Manager, CSO-CTO, CBDO, Factory Manager, Deputy General Manager and General Manager.

Asst. Prof. Dr. Elmas is Department Head and is an Assistant Professor of Automotive Technology at the Department of Motor Vehicles and Transportation Technologies at Vocational School of Higher Education for Technical Sciences at IGDIR UNIVERSITY, Turkey. He is also an Assistant Professor of Bioengineering & BioSciences at the same university. He has nearly 30 years of total experience in academia and in industry.

He has served as a scientific referee and panelist for ASME, TUBITAK and many scientific institutions, organizations and universities, including NASA.

He has published numerous international and national academic scientific articles, books, and book chapters, and serves as an editor for international academic journals. He also serves on the scientific committees of many international conferences, publishing conference and congress proceedings and giving presentations.

"Mechanical Engineering, Energy Transfer, Thermodynamics, Fluid Mechanics, Heat Transfer, Higher Mathematics, Evaporation, Heat Pipes, Space Sciences, Automotive, Bioengineering, Medical Engineering Applications, Neuroengineering, Medical Technique" are his academic and scientific fields of study; "Heating-Ventilation Air Conditioning Applications, Pressure Vessels, Heat Exchangers, Energy Efficiency, Steam Boilers, Power Plants, Cogeneration, Water Purification, Water Treatment, Industrial Equipment and Machinery, Welding Manufacturing, Sheet Metal Forming, Machining" are his industrial experience fields.

As of 2026, he has been awarded the Nobel Scientist Award by the international platform organization Scientific Laurels.

Asst. Prof. Dr. Emin Taner ELMAS is also a musician, saz (baglama) virtuoso player and ney (Nay, Turkish Reed Flute) performer. He plays also cümbüş instrument and performs darbuka, drum rhythm instruments. He has a YouTube Music Channel (Emin Taner ELMAS) which includes some of his sound recordings of him playing the saz-baglama and blowing the ney. He composed the poem written by the great poet Âşık Veysel ŞATIROĞLU under the name of "Raşit Bey" in memory of his father Judge (Hâkim) Raşit ELMAS as "Raşit Bey Türküsü", wrote it down, notated and published it as an academic article and broadcasted this song on his own music channel. He wrote the poems entitled "Canım Babam" and "Geldim Babam" which he wrote also in memory of his father and published in an academic literature journal, and composed instrumental musics for these poems. He also composed an instrumental song called "Annem Annem Türküsü" and gave it to his mother, Lawyer Tuna ELMAS, as a gift on Mother's Day, 11.05.2025. He also has a poem titled "Ney and Neyzen." He also wrote and presented a poem titled "Esra Kardeşim" to his sister, Esra ELMAS, an archaeologist and English teacher. He has published books including "Saz-Bağlama Tuning System Method" ("Saz- Bağlama Akort Sistemi Metodu") and "Ney and Neyzen; Ney's Pitches, Frets, Sound Stages, Octaves, Structure, Performance, Ney Maintenance and Basic Music Theory" (Ney ve Neyzen; Ney'de Perdeler, Ses Devreleri, Oktavlar, Yapısı, İcrası, Ney Bakımı ile Temel Musiki Nazariyatı) and My Collection of Literary and Musical Art Works – I Story / Anecdote / Essay / Poetry / Verse / Prose / Humorous; witty - satirical; poetic stories / Lyrics / Composition (Edebiyat ve Musiki Sanat Eserleri Külliyatım – I Hikâye / Anekdot / Deneme / Şiir / Manzume / Nesir / Mizahi; nükteli – hicivli; şiirsel hikâyeler / Güfte / Beste). He continues his artistic studies by writing various articles, books, poetry, lyrics and also realizing musical composition and repertoire works.

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