

DISCOVERY OF “QUANTUM NUMBERS” IN THE CARDIO-PULMONARY INTERACTION STUDIED IN THERMODYNAMICS WITH FINITE SPEED

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Abstract: The paper proposes an extension of Thermodynamics with Finite Speed (TFS) to Biological Systems, with Cardio-Pulmonary System study as the first objective. It is an extremely important system in the functioning of any blood beings (including humans). For stationary states, three fundamental *state parameters* were introduced: *Heart frequency*, F_i , *Lung frequency*, F_p , and *their ratio*, R_f , in order to describe the *self-organized interaction* between them. With these new parameters of state one could also describe Processes “between” stationary states, as it was already done for several Thermal Machines by using TVF and *instantaneous average parameters* such as *instantaneous average internal energy*, U_{mi} , *instantaneous average entropy*, S_{mi} . Since the *heart and lungs frequencies* are proportional to the energy consumed by each of them, these two quantities „are similar” to U_{mi} . Their ratio, R_f , is also proportional to the ratio of these energies and will characterize the *interaction of the two subsystems*. Using these new parameters, an analytical formula linking the two properties was sought, by studying the experimental behavior of R_f in time. Numerous experiments have led to a very interesting and important conclusion, stating that R_f is a function of a “quantum number” N (integer). Based on the experimental findings, a new formula correlating the *Speed of Lungs*, F_p , with the *Speed of Heart*, F_i , in their *continue interaction* was “invented”. This formula is absolutely essential for TFS extension to Biological Systems. It will allow to find *analytical expressions for Power and Efficiency of Heart and Lungs* as a function of a *single speed*, F_i , as it was previously done for a wide range of Thermal Machines (as a function of the piston speed that is the main parameter in TFS). Designers can now use these analytical formulas for more efficient and optimized design of artificial hearts and lungs customized for each patient.

Keywords: “Quantum Numbers” in the Heart-Lungs Interaction, Thermodynamics with Finite Speed, Cardio-Respiratory System, Self-organization of Heart-Lung Interaction, Quantum Formula of the correlation between Heart and Lung Frequencies, Stationary States and Processes with quantum jump in the Cardio-Respiratory System.

1. INTRODUCTION

Once *Finite Speed Thermodynamics* (FST) [15] and the *Direct Method* (DM) [15, 17] validated for Classical Stirling Engines and Solar Stirling Engines [7-15, 26-28], its extension to refrigerating machines study [17, 29] provided an analytical formula for the *isentropic efficiency of a compressor working with vapor* [17, 29]. As Stirling machines are *closed systems*, and compressors and internal combustion engines are Closed / Open / Closed systems, this achievement is part of the trend of extending FST to *Open Systems*. The present work tries to extend FST and DM to other open systems, this time apparently to a completely different domain, namely to biological systems.

Thus, optimizing the cost of transport facilities tree [1, 2], it was found that *blood vessels are naturally optimized* in animals, birds, fish and humans in the Cardio - Respiratory - Internal Organs - Brain - Muscle. Then, the question raised was whether one can extend Finite Speed Thermodynamics (FST) or / and Finite Time Thermodynamics (FTT), or both of them unified [4, 41-43, 54-56, 60] to the study of Cardio Respiratory system [3, 5, 6]. The analogy with Thermal Machines consists of considering the heart as a “*liquid pump with valves*” (Open / Closed / Open System) and *lungs as an “air compressor”*, so two “*thermal-biological machines*” in *continuous interaction*.

2. USE OF CONCEPTS FROM FINITE SPEED THERMODYNAMICS (FST) IN EXPERIMENTAL STUDY OF HEART-LUNG INTERACTION

Similar concepts to those used in Finite Speed Thermodynamics were introduced in the study of Cardio Respiratory system. Thus, corresponding *instantaneous mean state parameters*, namely $F_i = \text{frequency of Heart}$ and $F_p = \text{frequency of Lung}$ will characterize the stationary (or quasi-stationary) states of the heart and lungs, subsystems in continuous interaction in the Cardio-Respiratory System. Then the *ratio of these frequencies*, $R_f = F_i / F_p$, is introduced to characterize the *interactional state* between these *two oscillating subsystems*, heart - lung. These "instantaneous mean state parameters" adapted from the analogy with Finite Speed Thermodynamics [12-16, 21, 23-40], were further used in thousands of experiments that involved their measuring in different regimes (steady state regimes) corresponding to various positions of the body: horizontal (in bed), on chair, vertical (standing), moving horizontally, moving up and down stairs. The aim of these experiments were to find a formula for the frequencies ratio, R_f , depending on various parameters (position as steady state, or before/after the position change).

Firstly, it was found that R_f is an integer in many stationary states (and quasi-stationary) equal to 3, 4, 5, 6, 7, 8 ... or half-integer, such as 2.5; 3.5; 4.5; 5.5; 6.5; 7.5; 8.5, ... Based on these results, "first quantum formula" for heart-lung interaction was proposed as:

$$F_i = F_p \cdot (3 + N/2); N = 0, 1, 2, 3, 4, 5, 6, 7, 8, \tag{1}$$

where $3 = R_{f_0} = F_i/F_p = \text{frequency ratio at the awakening of SP every morning}$, (based on thousands of experiments / measurements for the last three years). Thus, R_{f_0} is for SP “fundamental steady state after night sleep”. Note that for particular conditions, i.e. during summer, near a swimming pool with thermal water, the ratio $R_f = F_i/F_p$ can be even less than 3 (ground state ratio), i.e. it can be 2.5. Therefore relation (1) was corrected as follows:

$$F_i = F_p \cdot (3 \pm N/2); N = 0, 1, 2, 3, 4, 5, 6, 7, 8 \tag{2}$$

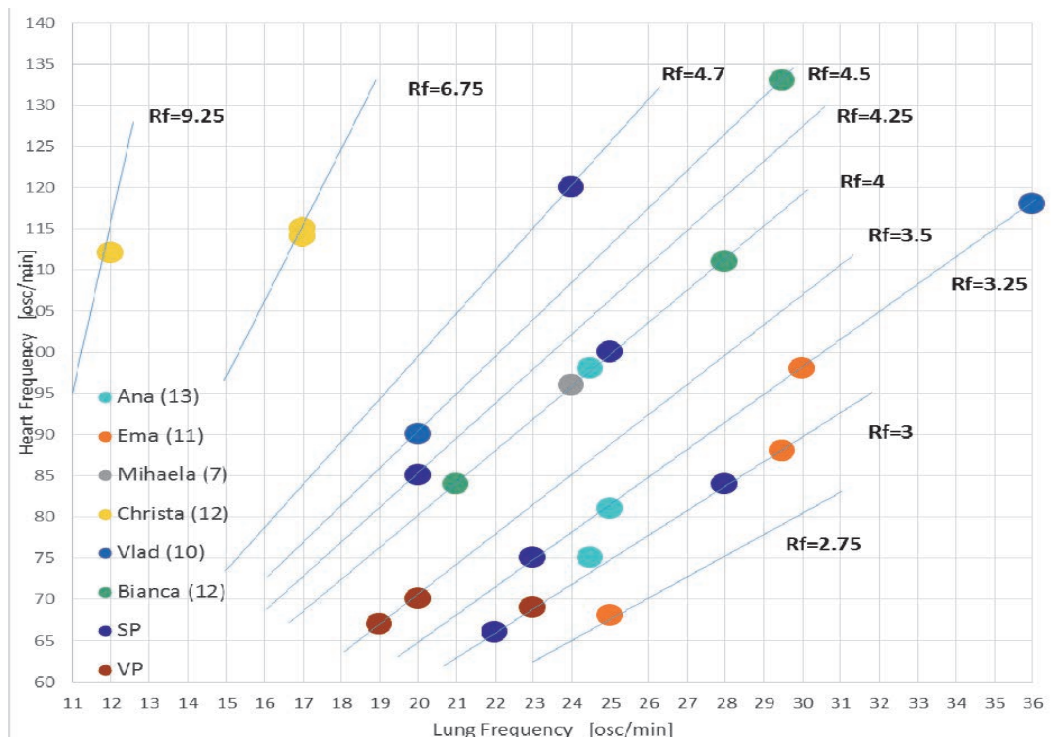


Fig. 1. Correlation between heart and lung frequency, with highlighting of R_f lines.

One can see that for $N = 1$ and sign (-) in front of $N/2$, interactional heart–lung condition is characterized by $R_f = 2.5$. It results that this interactional state is strongly influenced by thermal regime (ambient air temperature and exposure to direct sunlight). It was supposed that same thing

could also happen to others, so on the basis of experiments performed on dozens of people, it was found that the following formula is better and simpler than relations (1) or (2), and also *general for any person* (as verified on children aged between 7 and 13 years and adults):

$$F_i = F_p \cdot (2 + N/2); N = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 \quad (3)$$

Then a scheme of operation of cardio-respiratory system was developed, inspired by the Finite Speed Thermodynamics applied to Thermal Machines [17]. Also previous work providing the PV/Px diagram, that led to the validation of this scheme for 13 Stirling machines (and 17 operating regimes) [7, 15, 27, 53, 57, 59] inspired us to develop such a diagram for the cardio-respiratory system [18]. Based on this diagram, a qualitative and quantitative description of heart-lung functioning became possible, with the aim of finding analytical formulas for the power consumption of the system and its performance as a function of its "operation speed". Unlike thermal machines, there are now two different operating speeds, one for each subsystems, heart and lungs, so an analytical relationship between them had to be found.

After several attempts, the finding (very daunting at first) that the points in a chart $F_i = f(F_p)$ or vice versa $F_p = f'(F_i)$ cannot be statistically processed pushed further the experimental research on hundreds of states and dozens of subjects. Systematic experimental measurements protocol aiming to emphasize the emergence of stationary and quasi-stationary states suggested by Prof. Dr. Eng. Florin Danes was prepared. Also, measurement accuracy was improved by doubling the time measurement of F_p (for a more precise value).

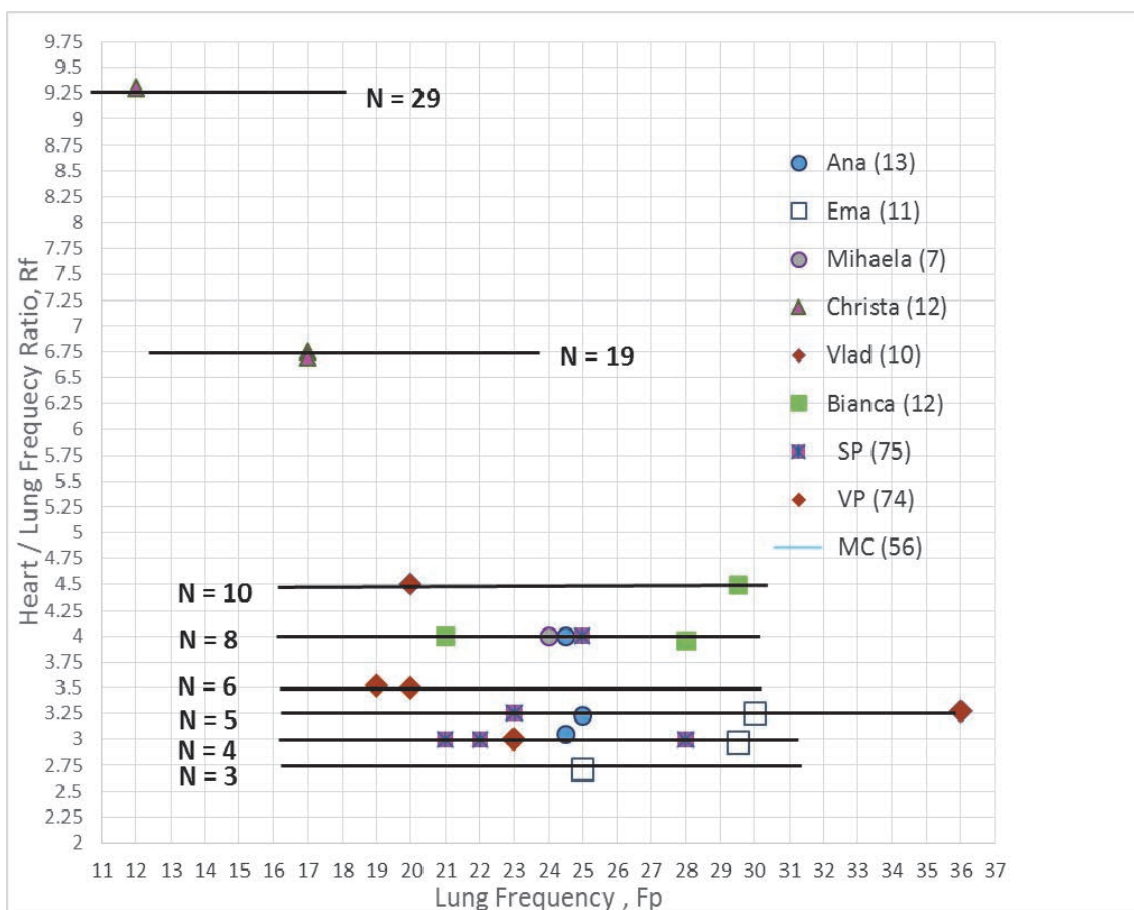


Fig. 2. Heart/Lungs Frequency Ratio and quantum numbers .

The occurrence of the "quantum numbers" in these experiments, that have integer and semi-integer values, and also numbers (Integer + N/4) type for R_f , raised the idea of similarity to the interaction between the electron and proton [51] in the hydrogen atom. Then, this interaction was studied in [61], where the "quantum leap" of the electron after interaction with a photon (either

received or released by the hydrogen atom) by exposure to sunlight was examined. Based on this "analogy" a more general and precise formula is proposed by the following expression:

$$F_i = F_p \cdot (2 + N/4); N = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 \quad (4)$$

The results obtained by applying relation (4) are shown in Figures 1 and 2.

Any process with change of F_i , F_p or both of them during the passage between two stationary states occurs with quantum leap. It is expressed by the passage from an integer value of number $N = N_1$ to another integer value $N = N_2$ either by increase of N in processes with physical or mental effort (which requires more power consumption of the heart and lungs) or by decrease of N , when effort reduction or rest are involved (sitting, lying in bed, etc.).

These processes with quantum leap between different energy levels are graphically illustrated in a new type of diagram $R_f = f(F_p)$. It shows that in any process with quantum leap between two stationary states the quantum number will change its value, namely $N_1 \rightarrow N_2$. This variation of the quantum number N describes the passage of the Heart-Lungs System from an interacting state with specific order and energy level to another interacting state with another order and energy level.

A diagram $R_f = f(F_p)$ is shown in [18] where by using one of the previous relations (1) - (4), the total power consumption of the cardio-respiratory system of a person was expressed as a function of a single speed, just as it was previously done for Stirling machines, where are actually 3 speeds (the speed of a working piston w_p , the speed of the moving piston w_a , and the gas velocity through the Regenerator w_R), all expressed according to just one speed, namely the working piston speed, w_p .

There are also 3 speeds for the cardio-respiratory system, namely (1) heart speed, F_b , (2) lungs speed, F_p and (3) the speed of the blood, which is the "working medium" between them. The blood acts as a carrier of O_2 during the inhalation phase and then of CO_2 and H_2O (metabolism products) during the exhalation phase.

3. CONCLUSION AND PERSPECTIVE

The formulas (1)-(4) represent a very important discovery related to the interaction between heart and lungs, two oscillating biological subsystems that are self-organizing ones in the stationary states for optimum operation. This optimum is most probably assured by minimal source of entropy, namely by generating the minimum supplementary irreversibility necessary of that operating mode. Optimum operation also involves a high degree of order, for the physical and spiritual "comfort" of the human body not only in sleep, when the system is resting and recovering, but also in stationary states associated to stable position (in bed, on chair, standing, constant walking, uniform work (repetitive). Music and dancing are activities in which heart, lung and movements rates harmonize producing a feeling of comfort, pleasure, relaxation, in which all frequencies of movements of the various subsystems are harmonizing.

Formula (1) is approximate but formulas (2)-(4) are more accurate. Virtually all stationary states have complied with formula (4). Approx. 50% of stationary and quasi-stationary states respected formula (1), where systematic measurements (after experimental protocol) made by Prof. Dr. Eng. Silvia Danes and Research Chem. Georgeta Botez. Formula (4) has been 100% verified by double accuracy experiments in F_p measurement on several subjects.

By applying and using the formulas (1-4) for determining the Power [18] and Efficiency of the heart and lungs, it will be possible to study and optimize various activities, such as work, sport, recreational gymnastics, fitness, jogging, alternative therapies of body maintenance and "repair", relaxation, fun, music, dance, Bowen, Reiki, Reflexotherapy, Physiotherapy, thermal baths, Yoga, meditation, prayers.

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DESCOPERIREA “NUMERELOR CUANTICE” ÎN INTERACȚIUNEA CARDIO-PULMONARĂ STUDIATĂ ÎN TERMODINAMICA CU VITEZĂ FINITĂ

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Rezumat: Lucrarea propune o extindere a Termodinamicii cu Viteză Finită (TVF) la Sistemele Biologice, având ca prim obiectiv studiul Sistemului Cardio-Pulmonar, extrem de important în funcționarea oricărei ființe cu sânge (incluzând oamenii). Pentru stările staționare, au fost introduși 3 parametri de stare fundamentali: frecvența Inimii, F_i ; frecvența Plămânilor, F_p și Raportul lor, R_f , în vederea descrierii interacțiunii auto-organizate dintre ele. Cu acești noi parametri de stare pot fi descrise și Procese “între” Stări Staționare, aspect tratat deja pentru multe Mașini Termice, folosind TVF și cu parametrii medii instantanee, precum Energia internă medie instantanee, U_{mi} , Entropia medie instantanee, S_{mi} . Deoarece frecvența Inimii și cea a Plămânilor sunt proporționale cu Energia consumată de Inimă, respectiv de Plămâni, aceste doua cantități “sunt similare” cu U_{mi} . Raportul R_f va fi, de asemenea, proporțional cu Raportul acestor Energii și va caracteriza interacțiunea celor două subsisteme. Folosind acești noi parametri, s-a căutat o formula analitică pentru corelarea celor doua proprietăți, pe baza studiului experimental al comportării lui R_f în timp. Numeroasele experimente realizate au condus la ceva extrem de interesant și important, anume: R_f este un “Număr Cuantic”. Pe baza acestei descoperiri experimentale s-a “inventat” formula care corelează Viteza plămânului, F_p , cu Viteza Inimii F_i , în interacțiunea lor continuă. Această formulă este absolut esențială pentru extinderea TVF la Sistemele Biologice. Ea va face posibilă găsirea unor expresii analitice pentru Puterea și Randamentul Inimii și al Plămânilor, ca funcție doar de o singura viteză, F_i , așa cum s-a făcut anterior pentru o gama largă de Mașini Termice, ca funcție de viteza pistonului (parametrul principal în întreaga TVF). Proiectanții vor putea folosi de acum înainte astfel de formule analitice pentru o proiectare mai eficientă și pentru un design optimizat al inimilor artificiale și ai plămânilor artificiali, personalizate pentru fiecare pacient.