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Mini Review

To Similarity of Gas-Solid Spin Combustion and Chains of Volcanos

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Abstract

Everyone has seen volcanoes in movies, on TV or in nature, but no one has proved the real connection of volcanoes with wildlife. We are going, however, to do so in part. The mini-review presented below focuses on this particular goal of us. In wildlife, among living cells, microorganisms and viruses, the behavior of individual objects or their populations is explained by the instinct of self-preservation of both individuals and the population as a whole. We have considered 2 objects as the examples from an in animated nature related by topological similarity: spin combustion and movement of volcano chains along the surface of the Earth and found that they both exhibit very similar behavior which can be interpreted as a manifestation of the instinct of self-preservation in an in animated nature. Thus, the clustering and synchronization inherent in both spin combustion and volcano chains represent themselves the laws of self-preservation in non-living nature. These laws may serve as a basis for further joint studies of living and non- living nature in the same key, or in the same way.

Introduction

The term "spin combustion" was originated during the former Soviet Union, in the scientific community of researchers of Self-propagating High-Temperature Synthesis (SHS). Despite the facts that a lot of investigators have been included in SHS and have performed huge volumes of works both in theory and experiment, these volumes were analyzed actually separately from each other and from the geophysics data [1], (Figure 1). Since theorists were not deeply sophisticated in the intricacies of experiment, they sometimes rudely and with no reasons simplified their theories, and vice versa, experimenters did not delve deeply into the intricacies of the theories created to confirm or disprove numerical calculations. Only at the end of last century - the beginning of current century there was a breakthrough in this impasse, when one of the authors (a theorist originally) of the mini-review presented has published an article on the experimental determination of parametric regions of the spin combustion of hafnium in nitrogen [2] (see Figures 2 & 3).

Experimental data [2] finally made it possible to analyze qualitatively the main pattern of spin combustion, and namely: to reveal a topological similarity in the spread of each of the combustion front foci (or spin heads in other words). The foundations of a new branch of mathematics, topology, have already been formulated by that time [3] and have helped me as the author [2] to correctly evaluate the results received. Experimental data [2] were later confirmed also in numerical calculations [4,5]. It was also found [6] that actually microscopic gas vortices are associated with each head of spin combustion. Moreover, on the neighboring heads of a double-headed spin mode, an upward vortex from the first head is alternated by a downward vortex to the second head. As a result, a flow cell similar to the well-known Benard cells in liquids is forming. The transitions from a single-headed spin mode to double and triple-headed distributions of temperature in combustion fronts are accompanied by the jumps in conversion degree of solid reagents [5], (Figure 2). The jumps happen with the preservation of topology, conservatively. Double-headed or triple-headed spin combustion distributions continue to move along the same trajectory of the single-headed spin mode initiated at the time of ignition. Such effects are in fact identical to those observed in complex systems [7] and have been named [8] as clustering and synchronization for them. New aspects of clustering and synchronization in inorganic systems [6] are that unlike classical complex systems [7] to which living objects belong such as: populations of living cells. Microorganisms or viruses, while the spin combustion as well as moving chains of volcanos considered is inherent in inorganic nature and is characterized by clustering and synchronization without living cells. Combustion, as a science has today been already developed [9-36] mainly in an isolation from the study of spin and other complex modes of fronts propagation. Therefore, it is very important for us now to estimate correctly its state. We have to understand actually, what has been already done, and what should be done next. Let's point out briefly the milestones of current combustion achieved by today.

Mini Review

Combustion synthesis of sulfides has been studied in [9]. It has included both the theory and experiments. X Ray Dynamic phase analysis (XRDPA) of SHS products has revealed [10] that non-equilibrium and non-stoichiometric compositions (so called max phases) are produced by the majority of SHS reactions. These overbalanced compositions are non- equilibrium not only by mass balance during reactions but also by electric and thermal balance in them. Thus, SHS reactions produce as a rule, non-stoichiometric compositions with an electric charge generated before the maximum temperature has been achieved [11,12]. The reason of an earlier charge emission in heterogeneous SHS is explained [13] by the fact that diffusional Peclet ($Pe^{arg}{}_{Zn2+}$) numbers for charge carriers greatly exceed this number for thermal diffusion (Pe_T). Current kinetic classification of reactions of thermal explosion is presented [14-16] dependent on small nonzero Todes numbers. Classification [14-16] interprets the most SHS systems in an outdated way, as a gas free combustion. From the standpoint of purely kinetic research, this approach is understandable and explainable. Nevertheless, there are numerous examples of systems that indicate an important contribution of gases to the composition of SHS products. For example, the syntheses of metal nitrides, and titanium carbide [6] TiC [2,6,11,12] take place certainly with the participation of gases.

Accordingly, in the general sense, SHS cannot be considered as a gas-free combustion. The peculiarities of gas dynamics during SHS are taken into account most correctly and consistently in models [4] and [6] only. The presented review aims, among other things, to once again remind the gas-dynamic features of many SHS systems, which in general cannot be completely ignored.

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Figure 1: Chain of two volcanoes (one of which is active) moving on Kuril Islands.

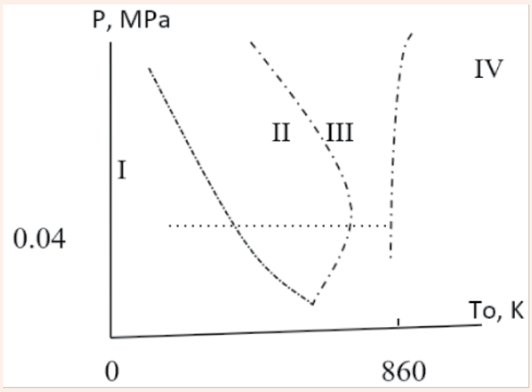

Figure 2: Parametric ranges of Combustion modes of hafnium in nitrogen detected [2] experimentally: I- single headed spin combustion, II- double headed spin combustion. III- triple headed spin combustion, IV- no combustion. P – nitrogen pressure (in MegaPascals), T_0 – ignition temperature (in Kelvins).

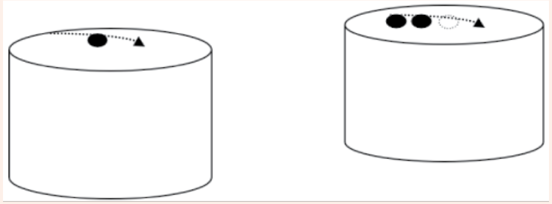

Figure 3: Single headed spin mode ignited initially (left) transforms into double headed and/or triple headed combustion modes (right).Clustering and synchronization of solutions has been confirmed in calculations [4].

One alternative to ignoring the gas phases [14-16] may consist of [17] in considering the so-called gas transport reactions. The author [17] simply experimentally recognizes a gas transport in the multicomponent (Ta, Ti+C) Spark Plasma Sintering (SPS) reactions and claims it as one of the characteristics of these reactions. No gas dynamics has been experimentally studied in SPS while the effect of gases influence is widely known in SPS [18]. Other experimenters [18] are doing the same, apparently due to the difficulties of experimentally studying gas dynamics. Experimental data on the reactions kinetics [19-24] as well as numerical simulations [25] and SPS [26] or other results [27-36] let us conclude that plane (or close to plane) combustion fronts of these reactions may often be unstable and instead of them, the correspondingly curved combustion fronts producing vortexes may take place. Experimental data on SPS Theories, and namely numerical calculations [6-8] in this respect, have an undeniable advantage. As a rule, only potential flows are considered in reference books and textbooks such as [17] or implicitly, [29] and in [30-32]. Accordingly, some calculations [27,28] represent laminar gas flows related to some reactions. Nevertheless, we have numerically also revealed formation of vortexes with the help of the velocity-vortex method [13] of analysis of gas dynamics. Mechanical activation is now also considered as a reaction parameter [33-36] greatly affecting activation energies and, correspondingly, reactions rates. Nevertheless, to be more accurate, it is a parameter of the sintering conditions, but not of reactions taking place during combustion. The paper has been presented in accordance to the following plan: 1). Spinning combustion at the thermal limit of steady state combustion modes; 2). Topological similarity between spin combustion and chains of volcanos, the effects of clustering and synchronization in them; 3). No gas dynamic similarity between spin combustion and moving chains of volcanos [37-50].

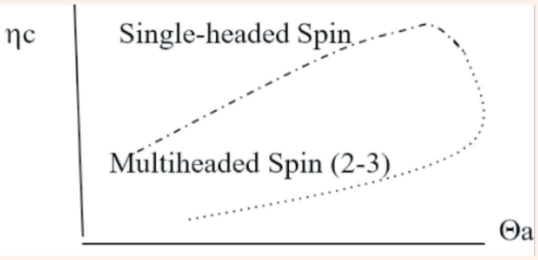

Figure 4: The figure shows the spin conversion degree ηc dimensionless as a function of the initial temperature Θa dimensionless in gas-solid spin combustion.

Figure 4 has schematically shown the spin conversion degree ηc dimensionless as a function of the initial temperature Θa dimensionless in gas-solid spin combustion. As one may see, the transition from a single-headed spin mode to double- or triple-headed spin combustion modes is always accompanied by a jump in conversion degree of solids at the same initial combustion temperature. As one may see, the conversion degree jump is a fast leap from the higher degrees of conversion (0.5-0.6) to smaller ones (0.02-0.5). As a result, the conversion degree discontinuity may cause jump to a much greater overbalanced heat removal from the heads of spin combustion and finally to a termination of the combustion at all. This is the main problem concerning ignition of low caloric reactions such as synthesis of intermetallides etc.

Conclusion

Moving chains of volcanos as well as the spin combustion may be considered and studied in the frames of concept of complex systems [7]. Nevertheless, in accordance to estimates [4] there is no gas dynamic similarity between spin combustion and moving volcanos since the Reynolds numbers for them are strongly different and distinguished by the orders of magnitude. The data presented and analyzed let us conclude that there is only the topological similarity between spin combustion and chains of volcanos moving on the Earth.

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