Fire Technology, 58, 1071–1073, 2022

Manufactured in The United States
https://doi.org/10.1007/s10694-021-01200-3

Letter to the Editor

Fire Protection and Materials Flammability Control by Artificial Intelligence

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Published online: 4 January 2022

Fire safety has become a major challenge of materials developers because of the massive production of organic materials, often combustibles, and their use for different purposes. In this sense, fire safety is critically considered in the development of engineering materials [1, 2]. The multiplicity of parameters contributing to the development of formulation of flame-retardant materials from one side and the sustainability concerns from the other side make the innovations cumbersome. Typically, there are variety of flame-retardant materials that are different in terms of the type, the amount, and the size, along with processing (e.g., extrusion, and additive manufacturing), and practical (e.g., ultimate price, recyclability, and life cycle) parameters that should be optimized to reach a desired product. On a parallel front, the instructions, standards, and safety requirements bring about further difficulties and limitations with materials design and fire protection. For instance, Scientific Committee on Consumer Safety (SCCS) claasifies materials as non-food products and risky materials as well as consumer services, to highlight health considerations. Correspondingly, fire suppression, fire fighting, fire extinguishing or other terms are defined, but controlling all parameters contributing to consumer safety and customer services requires identification and integration of materials and safety factors into an intelligent system capable of searching, ranking and classifying them in a very disciplined yet quick manner for emergency needs. The performance of a material under fire, both fire reaction and fire resistance, significantly depends on the shape and the geometry of structures, more specifically on the fire dynamics during a defined fire situation along with the material, ventilated, and under-ventilated situations. The selection of testing methodology, would also affect the success of strategies used for fire protection. These all would

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necessitate a bewildering of scenarios to be identified, classified, and examined by researchers working in the field, which wastes a great deal of time, investment, and practice.

Artificial intelligence (AI), and its derivatives, i.e., machine learning (ML) and deep learning, in a well-programmed and responsible manner, has emerged as a game changer over the last decade and revolutionized materials discovery, design, development, and optimization (see Fig. 1) [3]. There are two specifications associated with AI-based engineering of materials giving it an edge over conventional materials design. First, the intellectual nature of AI enables one to develop a realm of possible scenarios as obtained from hidden patterns AI was able to uncover from the limited number of experiments with examined variables (X) and the desired outcome(s) (Y). Second, and upon analysis, AI-based tools can identify pathways to tailor possible structures to the desired material with predesigned Y, which can be manufactured by different arrays of X variables [4]. Thus, the user could potentially consider all concerns as a priory, including materials availability, components' synergy, economic requirements, and environmental factors, to develop a specified product with optimized Y (Y_{opt}) through a variety of pathways applying optimized X series ($X_{i,opt}$) to the process/system. Such a large pool of data/information with almost countless possibilities would help scientists working on the development of flame-retardant materials, fire propagation, fire protection, and even fire evacuation strategists to find the most reliable solution as quickly as possible through multi-objective optimization.

Practically, fire protection should be more specifically viewed from a material scientist angle who could develop an AI system in pursuit of creating a new fire-retardant material. For example, a coating for load-bearing steel elements, organic coating or paints applied on the exterior face of a building, or structural composites used in construction may face fire and; therefore, should respond to fire safety/extinguishing systems intelligently. Such an AI system is required to be trained to satisfy a list of criteria. Such criteria may include a coating that (1) can satisfy building code requirement of attaining a fire resistance of 1–4 h, (2) has

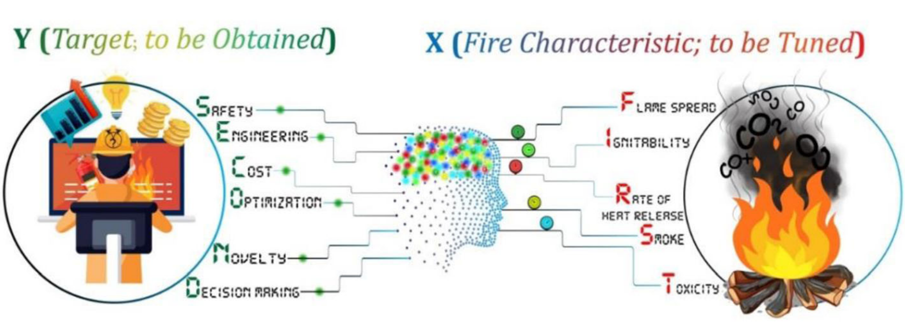

Figure 1. Illustration of the potential of AI in fire protection, ''target flammability/fire protection'' to ''materials design'' inverse (SECOND to FIRST) paradigm.

good synergy with steel surfaces and hence does not debond or fail with rising temperature, (3) can be easily installed, (4) can be of friendly (not toxic) materials, (5) easily manufactured, and (6) cost effective, among others. As the reader can see, satisfying the above criteria is inherently complex—especially if the trade-offs between each criterion are to be minimized [5].

Herein where our AI system becomes handy. Once such a smart system is properly developed and validated, it could identify pathway to arrive at a new coating with near-optimum, if not optimum, properties. Here is also where such an AI-based system is required to be capable of laying out its rationale for such picked material (noting that the majority of AI systems remain Blackboxes). Without the latter, our trust in such a system may not be complete (e.g., since if it to remain a Blackbox, we would not be able to understand how the system arrived at its new coating). In parallel, AI systems are likely to have the capability to predict scenarios never being tested, which makes the way to innovation in fire protection smooth. This way, AI presents us with a new opportunity to create a virtual environment for testing, research and development. The same environment could also identify a merciful space search – where latent variables rarely tested exist to allow us to pursue new experiments with high benefit to cost ratio. Overall, **S**afety, **E**ngineering, **C**ost, **O**ptimization, **N**ovelty, and **D**ecision making (**SECOND**) are requirements to be fixed as targets in call for finding precise materials and engineering parameters needed for fire protection from the lesson learned from an AI-based tool, e.g., **F**ire spread, **I**gnitabilty, **R**ate of heat transfer, **S**mok, and **T**oxicity (**FIRST**), enabling inverse fire protection strategy (see Fig. 1).

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