Chapter 9
Imprecise Knowledge and Fuzzy Modeling in Materials Domain

Subhas Ganguly
National Institute Technology Raipur, India

Shubhabrata Datta
Calcutta Institute of Engineering and Management, India

ABSTRACT

This chapter highlights the usage of imprecise knowledge of materials systems using fuzzy inference systems. Experts have knowledge of complex materials systems in the imprecise linguistic form. But due to lack of phenomenological relations, material engineers are compelled to depend on empirical models for practical complex systems. This limitation could be overcome to a certain extent through the method of utilizing this imprecise knowledge with the help of fuzzy logic. The case studies presented here have demonstrated that systems with imprecise knowledge but with sparse data could be modeled successfully in this approach.

1. INTRODUCTION

A critical issue in design and development of new materials, for advance and complex systems, is that in most cases we do not have complete understanding of the fundamental basis of co-relationships of compositional and processing space, microstructure space and materials response space. The attributes of these variable spaces are too difficult for direct measurements and too difficult to describe their interaction when a particular physical phenomenon is occurring. They exhibit extreme nonlinear behavior across the different length and time scale. As a consequence imprecision and uncertainties are inherent characteristics of many materials phenomenon. Therefore the plausible methods for solving problems, where knowledge or information is imprecise, approximate and incomplete, are developing as an area of interest of the materials designers. Different modeling techniques are there to model the structure and properties of materials either from first principles or from other physical or chemical theories. But in most of the cases practical materials systems are complex enough to be modeled through such theories. Absence of precise scientific knowledge to describe such multivariate materials systems makes it

DOI: 10.4018/978-1-5225-0290-6.ch009

difficult to develop physical models. In some cases databases developed experimentally or from data warehouses of industries could be used to develop empirical relations among the variables. Such data driven models developed through statistical or computational intelligence based techniques viz. artificial neural network could also be used to extract useful knowledge from the data. In recent time, significant success has been achieved in implementation of informatics and machine learning in the effort to describe the features of different complex materials systems. Employment of computational intelligence or soft computing techniques for solving critical materials development issues lead to highly intelligent and more realistic results. Hybrid intelligent systems deal with the integration of two or more of the techniques. The combined use of techniques has been found to result in effective problem solving in comparison to the stand alone applications of such techniques. Hence stochastic models, though difficult to design and manipulate, can provide insights into real-world processes and offer new computational opportunities.

Thus there exist two distinct approaches, knowledge driven physical models and data driven empirical models. In between these two domains remains the sphere of modeling using imprecise knowledge. In case of materials systems there are many such complex cases where the knowledge can be expressed linguistically, but not through mathematical expressions. Fuzzy inference system based on fuzzy set theory is capable of converting such imprecise linguistic expressions to predictive models (Zadeh, 1965). Generally speaking model predictions are never certain. Understanding uncertainty in a model also is important to infer its solutions. So far many techniques are described for solving certain materials problems. The focus of the current chapter is the implementation of a computational technique to solve materials design problem where knowledge information is imprecise, approximate and incomplete by invoke of the tractable information processing and computational learning approaches. Fuzzy set theory, rough set theory, neural network, neuro-fuzzy hybridization, rough-fuzzy hybridization etc are such techniques to name a few. Here the fuzzy inference system and its hybridized form with neural network will be covered with an emphasis on their current abilities and limitations taking few real application example problems. The most important aspect of these techniques is that in addition to their capability to develop relationship between the variables, they can extract knowledge from data through developing comprehensible linguistic if-then rules. Both the aspects are described separately with case studies on their applications in the materials system.

2. IMPRECISE KNOWLEDGE IN MATERIALS SYSTEM

The expert knowledge of many complex materials systems are expressed through imprecise statements. It may be in the form of 'steel with high volume fraction of martensite have high strength' or 'high glass forming ability alloys are multi component alloy'. In these statements high volume fraction or high glass forming ability words are used to denote some imprecise description of states. In the present context these kinds of imprecise knowledge, commonly used in explaining materials system knowledge, are used to process the information and compute to solve some problem. It should be noted that we are not concerned here with words that are used to denote inherently impreciseness of the system rather the techniques to be used to solve the problem managing the concept of imprecise entities in the information processing and computing framework. Unlike the other engineering design task, materials design problems distinctly encompass the systematic interpretation and optimization of complex and nonlinear systems. These complexities mainly arise from the relationship among composition and process with the materials response or performance. The model based strategy for solving complex materials design

Related Content