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学位論文内容の要旨

The material(s) used to produce a component or product often determine(s) its economic, functional, and sustainable characteristics. On the other hand, there are different types of materials (metals and alloys, composites, natural materials, plastics, ceramics, and foams), and each type consists of a large number of members. Therefore, selecting an optimal material for a given component or product is not only an important problem but also a difficult one to solve. Usually, the entities called material indices are used to solve a material selection problem. A material index is a function that consists of some of the material properties (mechanical properties, electrical properties, magnetic properties, and sustainability properties) and applicable only to a machine element (e.g., beam). In real-life, a component cannot be characterized by a single machine element; it is a combination of several machine elements (e.g., a combination of beam, plate, and column). Therefore, there is uncertainty regarding the material indices themselves while selecting an optimal material in a real-life setting, i.e., a material index-free procedure makes a material selection process a more pragmatic one. In addition, the data regarding a material property (e.g., data regarding the tensile strength) exhibits a great deal of variability. Therefore, uncertainty associated with the data of material properties needs to be quantified before starting the process of selecting an optimal material either by a material index-based procedure or by any other means. Based on the abovementioned contemplation, one of the objectives of this thesis is to shed some light on the uncertainty quantification of material properties. The other objective is to develop a material selection model that does not depend on any material indices.

Accordingly, the following chapters have been incorporated in this thesis. Chapter 1 describes the background of the thesis and reports a literature review on the uncertainty and material selection methods. It also describes the experimental works for determining the properties of the relevant materials. Chapter 2 describes the mathematical entities needed to define the uncertainty in statistical, probabilistic, and possibilistic means. In addition, the mathematical entities needed for the formal computation while selecting a material is also described. Chapter 3 shows the experimental results regarding the mechanical properties, namely, tensile strength, modulus of elasticity, and stain to failure of a natural material called Jute. The uncertainty associated with the properties mentioned above has been quantified by

using the statistical, probabilistic, and possibilistic approaches. It has been found that out of the three approaches, the possibilistic approach quantifies the uncertainty more reliably. Therefore, when one uses a material property for making a decision, its uncertainty can be put into the formal computation using a possibility distribution (e.g., a triangular fuzzy number) rather than using a probability distribution (e.g., Weibull distribution) or statistical approach. Based on this conclusion, the uncertainties associated with the tensile strength, modulus of elasticity, density, CO_2 footprint, recycle fractions, and water usages of 197 types of Aluminum alloys, 45 types of Titanium alloys, and 30 types of Magnesium alloys are represented by possibility distributions, as reported in Chapter 4. In addition, a decision model is also developed in Chapter 4 to select an optimal material out of the three alternatives namely, Aluminum, Titanium, and Magnesium alloys. In this decision model, the objective functions (e.g., maximize tensile strength, minimize CO_2 footprint, and so on) are set by the possibility distributions, too. Three of the possibility distributions (i.e., objective functions) are for maximizing the tensile strength, modulus of elasticity, and recycle fractions, respectively, and the other three are for minimizing the density, CO2 footprint, and water usages. The compliance between the possibility of distribution of a material property of a type of alloys (e.g., possibility distribution of the tensile strength of Aluminum alloys) and the possibility distribution of the corresponding objective function (e.g., possibility distribution of maximizing the tensile strength) are used to make a decision. It is found that the decision model selects an optimal material even though the material properties are uncertain and the underlying material indices are not known. In Chapter 5 discusses the implications of this study in eco-product development. It also describes how the stakeholders (research organizations and researchers, designers, producers) should interact centering the material related decision making processes. Finally, Chapter 6 provides the concluding remarks of this thesis.

論文審査結果の要旨

本論文では、工業材料特性の不確定性の定量化とその応用として工業材料の選択手法について研究し、有用な知見が示されている。　特に、現在様々な製品に使用されているJuteという天然素材の不確定性を統計的、確率分布的、および可能性分布的な手法を用いて定量化し、各手法による結果の比較を行った。その結果、可能性分布が材料特性の不確定性の定量化に最も効果的であることを明らかにした。その知見を踏まえて、可能性分布で定量化した目的関数や材料特性情報を活用した工業材料選択手法を新たに考案した。この選択手法を用いて３つの合金集合（アルミニウム合金１９７種、チタン合金４５種、マグネシウム合金３０種）の中から目的に合った最適な合金種を選択する過程を示すことができた。選択過程においては特に、密度、引張強度、ヤング率、リサイクル率、材料製造・リサイクルにおけるCO2排出量という材料特性に関する情報や目的関数を効果的に取り入れることができた。本論文は工業材料の機能や環境への負荷を考慮した、より実用的な製品開発工程をサポートする上で工学的、産業的に大変有用である。

よって、提出された学位論文の内容及び該当する学術論文の質等を考慮し、申請者は北見工業大学博士（工学）の学位を授与される資格が有る者と認める。