HYBRID-FUZZY TECHNIQUES WITH FLEXIBILITY AND ATTITUDINAL PARAMETERS FOR SUPPORTING EARLY PRODUCT DESIGN AND RELIABILITY MANAGEMENT

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DOCTOR OF PHILOSOPHY

(MANUFACTURING ENGINEERING)

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy in Manufacturing Engineering

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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LIST OF SYMBOLS

ω	Attribute weight
μ_A	Membership function of the fuzzy set A
v_A	Non-membership function of the fuzzy set A
$S(\acute{\alpha})$	Score function
$H(\acute{\alpha})$	Accuracy function
$S_e(A)$	Exponential score function
$ER(A)$	Exponential related function
λ	Attitudinal parameter
λ_c	Flexibility and adjustability feature
γ	Experts (DMs) associated weights vector
$R_{mxn}(a_{ij})$	Intuitionistic fuzzy decision matrix
ERM_{mxn}	Exponential related matrix
Ω^n	The set of real numbers
$\otimes$	Circled time operator (multiplication sign)
$\forall i$	For all

LIST OF ABBREVIATION

AHP Analytic Hierarchy Process

AI Artificial Intelligence

CC Closeness Coefficient

DEMATEL Decision-making Trial and Evaluation Laboratory

DMs Decision Makers

ER Exponential Related function

FMEA Failure mode and effect analysis

GTIFOWGA Generalized Triangular Intuitionistic Fuzzy Ordered Weighted Geometric Averaging operator

GTIFGA Generalized Triangular Intuitionistic Fuzzy Geometric Averaging operator

IFE Intuitionistic Fuzzy Entropy

IFS Intuitionistic Fuzzy Set

IFN Intuitionistic Fuzzy Number

IFWG Intuitionistic Fuzzy Weighted Geometric operator

IF-TOPSIS$_{EF}$ Intuitionistic Fuzzy TOPSIS model based on Exponential Related function

IFPIS Intuitionistic Fuzzy Positive Ideal Solutions

IFNIS Intuitionistic Fuzzy Negative Ideal Solutions

MADM Multi-Attribute Decision Making

MAGDM Multi-Attribute Group Decision Making

NIFIGOWA Normal Intuitionistic Fuzzy Induced Generalized Ordered Weighted Averaging operator

TOPSIS Technique for Order Preference by Similarity to the Ideal Solution

TIFN Triangular Intuitionistic Fuzzy Number

TIFWGA Triangular Intuitionistic Fuzzy Weighted Geometric Averaging operator

TIFOWGA Triangular Intuitionistic Fuzzy ordered weighted geometric averaging operator

TIFHWGA Triangular Intuitionistic Fuzzy Hybrid Weighted Geometric Averaging operator

RPN Risk Priority Number

RCF Root Cause of Failure

VIKOR VlseKriterijumska Optimizacija I Kompromisno Resenje

DEFINITION OF SOME KEY WORDS

Intuitionistic Fuzzy Sets: are sets whose elements have degrees of membership and non-membership. Intuitionistic fuzzy sets have been introduced by Krassimir Atanassov in 1986 as an extension of Lotfi Zadeh's notion of fuzzy set, which itself extends the classical notion of a set. See details of the fuzzy set theory in APPENDIX 5.

Reliability: can be described as the probability that an item will continue to perform its intended function without failure for a specified period of time under stated conditions.

Product Reliability or Design for Reliability: describes the entire set of tools that support product and process design (typically from early in the concept stage all the way through to product obsolescence) to ensure that customer expectations for reliability are fully met throughout the life of the product with low overall life-cycle costs.

Multiple attribute decision making (MADM): MADM which is a sub-discipline of operation research, is concerns with problems of prioritizing, screening, ranking or selecting alternative(s) from among a finite set of candidates with multiple attributes, usually conflicting, by considering them simultaneously to select the best candidate (Braglia1 et al., 2003). Many of our everyday decision-making problems involve the consideration of multiple criteria or attributes. See details of the MADM in APPENDIX

Group decision-making (GDM): GDM is a situation where individuals are tasked to collectively make a choice from a list of alternatives with respect to some attributes. The GDM, for the purpose of this thesis, will be regarded as Multi-Attribute Group Decision Making (MAGDM).

TOPSIS: TOPSIS is a multi-attribute technique which is based on obtaining the alternative that approaches an ideal alternative, by considering the positive ideal alternative and the negative ideal alternative.

Reliability and validity in Research: Reliability and validity in research are two concepts that are important for defining and measuring bias and distortion, where *Reliability* refers to the extent to which research assessments are consistent, *Validity* refers to the accuracy of the research assessment.

Attitudinal Parameter: Attitudinal Parameter is the mathematic symbol used in this research study, to describe the emotional disposition of design stakeholders (decision-makers) when making decisions.

Product design: Product design is the translation of intellectual wisdom, requirements of the entrepreneurs, or needs of the consumers, into a specific product.

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ABSTRAK

Tujuan utama kerja-kerja penyelidikan yang dibentangkan dalam karya ini adalah untuk menentukan dan membangunkan teknik berasaskan novel AL lebih kepada aspek sokongan kejuruteraan pembangunan produk, khususnya kebolehpercayaan produk pada peringkat awal reka bentuk produk di bawah reka bentuk untuk falsafah kebolehpercayaan dan konsep reka bentuk masalah penilaian apabila maklumat yang diperlukan adalah kasar dan tidak lengkap. Oleh itu, untuk mencapai matlamat yang disebut di atas, yang telah digubal dalam usaha untuk mengisi jurang yang dikenal pasti dalam kesusasteraan yang terdiri daripada keperluan untuk kaedah holistik, fleksibel dan boleh laras untuk memudahkan dan menyokong penilaian konsep reka bentuk produk dan kebolehpercayaan produk di produk fasa reka bentuk awal. Keperluan untuk pemerbadanan watak sikap daripada DMS ke dalam penilaian kebolehpercayaan produk dan konsep reka bentuk dan akhirnya, keperluan untuk mengambil kira beberapa ciri-ciri kompleks saling berkaitan dalam kebolehpercayaan produk dan konsep reka bentuk proses penilaian. Gabungan kaedah penyelidikan telah digunakan yang merangkumi kajian meluas kesusasteraan, pelbagai pendekatan kajian kes, dan temu duga peribadi pakar, di mana data itu, dikumpulkan yang menyediakan maklumat bagi kajian kes sebenar. Dengan teknik yang baru berasaskan AI (iaitu model TOPSIS kabur intuitionistic yang berasaskan fungsi eksponen yang berkaitan (IF-TOPSIS$_{EF}$) dan kumpulan Multi-atribut (MAGDM) kaedah membuat keputusan yang berdasarkan pada umum segi tiga intuitionistic kabur pemurataan geometri (GTIFGA) operator), kaedah yang lebih mantap untuk penilaian kebolehpercayaan produk dan konsep reka bentuk masing-masing telah dicapai seperti yang dipaparkan dalam analisis perbandingan dalam tesis. Kaedah baru telah menyediakan yang lebih lengkap dan pandangan holistik proses penilaian, dengan melihat penilaian kebolehpercayaan produk dan konsep reka bentuk dari senario yang berbeza bergantung kepada kepentingan DMS. Dengan menggunakan kaedah di atas, tesis telah dapat dinilai sesetengah sistem mekanikal kompleks dalam kesusasteraan dan dalam kehidupan sebenar termasuk peyarap Mesin Crane dan Forklift Truck untuk perubahan reka bentuk dengan tujuan mendapatkan pengetahuan kebolehpercayaan yang sesuai dan maklumat yang diperlukan pada fasa reka bentuk produk baru yang , dan yang kemudiannya boleh membantu dan meningkatkan konsep reka bentuk produk selepas semua maklumat yang berguna seperti telah ditambah ke dalam reka bentuk baru. Dengan pelaksanaan kaedah baru, dan kemungkinan terbukti dan rasional seperti yang dipaparkan dalam hasil penilaian terhadap sistem mekanikal kompleks dalam kesusasteraan dan kajian kes yang sebenar, tesis ini, oleh itu, boleh membuat kesimpulan bahawa teknik berasaskan-AI dicadangkan, telah menyediakan satu alternatif baru untuk kebolehpercayaan produk dan konsep reka bentuk kaedah penilaian sedia ada yang lebih baik dan.

ABSTRACT

The main aim of the research work presented in this thesis is to define and develop novel Hybrid Fuzzy-based techniques for supporting aspects of product development engineering, specifically product reliability at the early phase of product design under the design for reliability philosophy and concept designs assessment problems when the required information is rough and incomplete. Thus, to achieve the above-stated aim, which has been formulated in the effort to filling the identified gaps in the literature which comprise of the need for a holistic, flexible and adjustable method to facilitate and support product design concept assessment and product reliability at the early product design phase. The need for the incorporation of the attitudinal character of the DMs into the product reliability and design concept assessment and finally, the need to account for the several interrelated complex attributes in the product reliability and design concept assessment process. A combination of research methods has been employed which includes an extensive literature review, multiple case study approach, and personal interview of experts, through which data were, collected that provided information for the real-life case study. With the new Hybrid Fuzzy-based techniques (i.e. the intuitionistic fuzzy TOPSIS model which is based on an exponential-related function (IF-TOPSIS$_{EF}$) and the Multi-attribute group decision-making (MAGDM) method which is based on a generalized triangular intuitionistic fuzzy geometric averaging (GTIFGA) operator), a more robust method for the product reliability and design concepts assessment respectively have been achieved as displayed in the comparative analysis in the thesis. The new methods have provided a more complete and a holistic view of the assessment process, by looking at the product reliability and design concept assessment from different scenario depending on the interest of the DMs. Using the above methods, the thesis has been able to evaluated some complex mechanical systems in literature and in real-life including Crawler Crane Machine and Forklift Truck for design change with the purpose of gaining appropriate reliability knowledge and information needed at the early product design phase, and that can subsequently aid and improve the product design concepts after all such useful information have been added into the new design. With the application of the new methods, and their proven feasibility and rationality as displayed in the assessment results of the complex mechanical systems in literature and that of the real-life case studies, this thesis, therefore, can conclude that the Hybrid Fuzzy-based techniques proposed, has provided a better and a novel alternative to existing product reliability and design concepts assessment methods.

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