DOI : 10.31357/fapsphd.2015.00617

A STUDY ON USE OF POLYPROPYLENE (PP) AND PP COMPOSITES IN THE MANUFACTURE OF CASTOR WHEELS AND THEIR EFFECT, ON PROCESSING, DYNAMIC AND STATIC CHARACTERISTICS

BY

RANATUNGA RAMANAYAKA MUDIYANSELAGE SISIRA KUMARA RANATUNGA

29 JUN 2016

Thesis submitted to the University of Sri Jayewardenepura for the award of the Degree of Doctor of Philosophy in Chemistry on

September 2015

DECLARATION BY THE CANDIDATE

The work described in this thesis was carried out by me under the supervisions of Prof. L. Karunanayake, Senior lecturer, Department of Chemistry, University of Jayewardenepura, Dr. S. Walpalage Senior Lecturer, Department of Chemical Engineering, University of Moratuwa and Dr. N. C. Ganegoda, Senior Lecturer, Department of Mathematics, University of Jayewardenepura and a report on this has not been submitted in whole or in part to any university or any other institution for another Degree/Diploma

…………………………………………

Signature of the candidate

R.R.M.S.K. Ranatunga.

Name with initials

CERTIFICATION OF SUPERVISORS

We certify that the candidate has incorporated all corrections, additions and amendments recommended by the examiners

Signature of the supervisor

....
Name with initials

Name and address

....
Laleen Karunanayake,PhD
Professor
Department of Chemistry
University of Sri Jayewardenepura

....
Signature of the supervisor

....
Name with initials

Name and address

Dr. Shantha Walpalage
B.Sc. Eng, PhD (UK), C.Eng., MIE(SL)
Senior Lecturer
Department of Chemical & Process Engineering
University of Moratuwa, - Sri Lanka.

....
Signature of the supervisor

Dr. N.C. Ganegoda
....
Name with initials

Name and address

DEPARTMENT OF MATHEMATICS
University of Sri Jayewardenepura
Nugegoda
Sri Lanka.

DECLARATION BY THE SUPERVISOR/S

"I /We certify that the above statement made by the candidate is true and that this thesis is suitable for submission to the University for the purpose of evaluation "

………………………………………………
Signature of the supervisor

………………………………………………
Name with initials

Name and address

Laleen Karunanayake, PhD ………………………
Professor ………………………………………
Department of Chemistry
University of Sri Jayewardene ………………………

………………………………………………
Signature of the supervisor

………………………………………………
Name with initials

Name and address

……………………… Dr. Shantha Walpalage
B.Sc. Eng, PhD (UK), C.Eng., MIE(SL)
Senior Lecturer
Department of Chemical & Process Engineering
University of Moratuwa, - Sri Lanka.

………………………………………………
Signature of the supervisor

Dr. N. C. Ganegoda
………………………………………………
Name with initials

Name and address

DEPARTMENT OF MATHEMATICS
University of Sri Jayewardenepura
Nugegoda
Sri Lanka.

TABLE OF CONTENTS

Table of Contents i

List of Tables vi

List of Figures.. viii

List of Abbreviations.. xiii

Acknowledgement.. xvi

Abstract xviii

ACKNOWLEDGEMENTS.. xvi

CHAPTER 1: INTRODUCTION.. 1

1.1 CASTOR APPLICATIONS 1

1.2 POLYPROPYLENE.. 2

1.3 FILLER.. 3

1.4 PP COMPOSITES AND APPLICATIONS 5

1.5 FINITE ELEMENT ANALYSIS (FEA) OF PP /PP COMPOSITES.. 7

1.6 OBJECTIVES OF THE STUDY 8

CHAPTER 2: LITERATURE REVIEW.. 11

2.1 POLYPROPYLENE (PP).. 11

2.1.1 CHEMICAL STRUCTURE OF PP 12

2.1.2 STEREO CHEMICAL CONFIGURATION OF PP (TACTICITY) AND CRYSTALLINE STRUCTURE 12

2.1.3 Different types of PP 15

2.1.4 Structure of PP impact copolymer 17

2.2 FILLERS.. 17

2.3 Selection of filler materials 20

2.3.1 Talc.. 21

2.3.2 Calcium carbonate *22*

2.3.3 Rice Husk Ash (RHA) *23*

2.4 RHEOLOGY OF POLYMER 24

2.5 POLYMER COMPOSITES 25

2.5.1 Mineral filler/ PP composites *26*

2.5.2 Wood and rice husk filled PP composites *29*

2.6 DYNAMIC MECHANICAL PROPERTIES AND MORPHOLOGY 35

2.7 CASTOR WHEEL INDUSTRY 36

CHAPTER 3: EXPERIMENTAL METHODOLOGY 38

3.1 MATERIALS AND INSTRUMENTATION 38

3.1.1 Materials *38*

3.1.1.1 POLYPROPYLENE HOMOPOLYMER AND IMPACT COPOLYMER 38

3.1.1.2 Talc powder 39

3.1.1.3 Uncoated calcium carbonate ($UCaCO_3$) 41

3.1.1.4 Coated calcium carbonate ($cCaCO_3$) 42

3.1.1.5 Rice Husk Ash (RHA) 43

3.2 METHODOLOGY 44

3.2.1 Formulation of PP/Talc composite *44*

3.2.2 Formulation of PP/$UCaCO_3$ composite *45*

3.2.3 Formulation of PP/$cCaCO_3$ composite *46*

3.2.4 Formulation of PP/RHA composite *47*

3.3 EXTRUSION 48

3.4 SAMPLE PREPARATION FOR TESTING 50

3.4.1 Sample preparation for MFI *50*

3.4.2 Preparing of Injection moulded test pieces *50*

3.4.3 Preparing of injection moulded articles (Castor Wheels) *51*

3.5 EVALUATION OF PROPERTIES 52

3.5.1 Tensile properties ... 52

3.5.2 Impact properties (Izod) ... 53

3.5.3 Melt flow properties ... 54

3.5.4 Dynamic Mechanical Analysis ... 55

3.5.5 Differential scanning calorimetry (DSC) ... 56

3.5.6 Scanning electron microscopy (SEM) ... 57

3.5.7 Fourier transform infrared (FTIR) spectroscopy ... 58

3.5.8 Castor wheel dynamic load and drop weight impact test ... 58

3.6 FINITE ELEMENT STRESS ANALYSIS OF A CASTOR WHEEL (FEA) ... 60

CHAPTER 4: RESULTS AND DISCUSSION ... 63

4.1 MATERIALS CHARACTERIZATION ... 63

4.1.1 PPC and PPH ... 63

4.1.1.1 Dynamic mechanical properties and morphology ... 63

4.1.1.2 Thermal properties of PP ... 74

4.1.1.3 Impact strength/kinetic energy ... 76

4.1.1.4 Stress strain behaviour of PP ... 78

4.1.1.5 Finite element analysis (FEA) ... 79

4.1.1.6 Wheel centre dynamic load testing ... 82

4.1.2 Morphology of filler materials used (Talc,$UCaO_3$, $uCaCO_3$ and RHA) ... 84

4.1.3 FTIR spectrum of Filler materials used ... 88

4.2 PROCESSING AND RHEOLOGICAL PROPERTIES OF PP COMPOSITES ... 91

4.2.1 PROCESSING AND MFI OF PP /RHA ... 93

4.3 PROPERTIES OF PP COMPOSITES ... 98

4.3.1 Tensile properties of PP and PP- composites ... 99

4.3.2 Dynamic mechanical properties of PP composites ... 106

4.3.2.1 Storage modulus of PP composites ... 107

4.3.2.2 Loss modulus of PP composites ... 111

4.3.2.3 Loss tangent (tan δ) of PP composites ... 114

4.3.3 Impact strength of PP composites *120*

4.3.4 PP composites morphology *126*

4.3.5 Thermal properties of PP composites *130*

4.3.6 Stress strain behaviour of PP and PP composites *138*

4.3.7 Finite element analysis of a castor wheel *140*

4.3.8 Castor wheel dynamic load testing *143*

CHAPTER 5: CONCLUSIONS **148**

CHAPTER 6: SUGGESTIONS FOR FUTURE WORK **150**

REFERENCES: **151**

APPENDICES **161**

List of Appendices

Appendix 1: PPC(P640 J) technical data sheet 161

Appendix 2: PPH (P700) technical data sheet 162

Appendix 3: DMA spectrum of PP + 10 % cCaCO$_3$ composites 163

Appendix 4: DMA spectrum of PP + 10 % UCaCO$_3$ composite 164

Appendix 5: DMA spectrum PP + 10 % RHA composite 165

Appendix 6: DMA spectrum of PP + 10 % Talc composite 166

Appendix 7: DMA spectrum of PP + 35 % cCaCO$_3$ composite 167

Appendix 8: DMA spectrum of PP + 35 % UCaCO$_3$ composite 168

Appendix 9: DMA spectrum of PP + 35 % Talc composite 169

Appendix 10: DSC thermograms of PP + RHA 2.5% composite 170

Appendix 11: DSC thermograms of PP + RHA 5% composite 171

Appendix 12: DSC thermograms of PP + RHA 7.5% composite 172

Appendix 13: DSC thermograms of PP + RHA 10% composite 173

Appendix 14: DSC thermograms of PP + RHA 12.5% composite 174

Appendix 15: DSC thermograms of PP + CCaCO$_3$ 10% composite 175

Appendix 16: DSC Graph of PP + UCaCO$_3$ 10% composite 176

Appendix 17: DSC thermograms of PP + CCaCO$_3$ 35 % composite 177

Appendix 18: Chemical compositions of Rice Husk Ash 178

Appendix 19: Publication List 179

List of Tables

Table 3.1: Comparison of properties of PPH and PPC (Reference: SCG Plastic) 39

Table 3.2: Chemical Composition of 325 mesh talc filler materials (Reference: 20 Microns Limited) 40

Table 3.3: Physical properties of 325 mesh talc filler materials (Reference: 20 Microns Limited) 41

Table 3.4: Properties of WT 200 U$CaCO_3$ filler material (Reference: Lanka Minerals & Chemical) 42

Table 3.5: Properties of c$CaCO_3$ (Lakcarb 10 C) filler material (Reference: Lanka Minerals & Chemical) 43

Table 3.6: Material weights of PP/Talc composites 45

Table 3.7: Material weights of PP/U$CaCO_3$ composites 46

Table 3.8: Material weights of PP/c$CaCO_3$ composites 47

Table 3.9: Material weights of PP/RHA composites 48

Table 3.10: Temperature settings of extruder 49

Table 3.11: Injection moulding machine temperature settings 51

Table 4.1: Comparison of thermal properties of PPC and PPH 76

Table 4.2: Notched izod impact strength at different temperatures [Reference: SCG Plastics] 76

Table 4.3: Kinetic energy given to break the wheel centre at different temperatures ... 77

Table 4.4: Maximum stress values of wheel centre of PPH and PPC obtained from FEA 81

Table 4.5: Chemical Composition of Rice Husk Ash 86

Table:4.6 particle size and specific gravity of fillers used 87

Table 4.7: Comparison of Tensile strength and elongation at beak of PP composites with PPCat 5% and 10% filler loading 105

Table 4.8: Glass transitions values (T_g) of PP composites of RHA, talc, $UCaCO_3$ and $cCaCO_3$ 118

Table 4.9: Thermal properties of PPC and PP composites at 10% filler loading . 133

Table 4.10: Maximum stress values of castor centre at different PP composites obtained from FEA 142

List of Figures

Figure 2.1: The chemical structure of PP 13

Figure 2.2: Illustration of the stereo chemical configuration of PP 13

Figure 2.3: Process flow chart for manufacturing of PP different types(12) 16

Figure 2.4: Filler, primary particles, Aggregates and Agglomerates.(19) 19

Figure 2.5: Theoretical structure of talc.(17) 22

Figure 3.1: Process flow chart of making castor with PP composite 44

Figure 3.2: Diagram of the single screw extruder 49

Figure 3.3: Extrusion of PP composites 50

Figure 3.4:Sketch of injection moulding machine temperature Zones 51

Figure 3.5: Schematic diagram of a tensile test piece as per ASTM D 638 53

Figure 3.6: Schematic diagram of an izod impact test piece as per ASTM D 256 54

Figure 3.7: Castor wheel dynamic testing machine 59

Figure 3.8: Temperature measuring points on the castor wheel centre 3.5.9 Drop weight impact (DWI) testing of castor wheel centre. 60

Figure 3.9: 3D model of the castor wheel centre 61

Figure 3.10: Finite element model of ¼ of castor wheel centre 62

Figure 4.1: DMA spectrum of PPH injection grade (EL – Pro P 700 J) 64

Figure 4.2: DMA spectrum of PPC injection grade (EL – Pro P640 J) 64

Figure 4.3: A schematic representation of the formation of PPC.(80) 67

Figure 4.4: (a) Conceptual diagram and (b) Scanning Electron microscope of PPC [Reference:http://www.primepolymer.co.jp/english/technology/material/pp/04.h ml Accessed 31st May 2015] 68

Figure 4.5: SEM image of (a) PPH (EL- Pro P700J) and (b) PP C (EL – Pro P640J) .. 69

Figure 4.6: Storage modulus of PPH and PPC temperature range -60 to 60 ^{0}C............71

Figure 4.7:Loss modulus of PPH and PPC over temperature range -60 to 60 ^{0}C. 72

Figure 4.8: Loss Tangent (tan δ) over the temperature range of -60 to 60 ^{0}C.............73

Figure 4.9: DSC thermograms heating and cooling of PPH at heating and cooling rate of 10 °C /min...75

Figure 4.10: DSC thermograms heating and cooling curves of PPC at heating and cooling rate of 10 °C /min...75

Figure 4.11: Failure of wheels centre at the drop weight impact testing.....................77

Figure 4.12: Stress and strain behaviour of PPC and PPH at 23 and 60 ^{0}C 79

Figure 4.13: Distribution of stress density obtained from FEA...................................80

Figure 4.14: Failure of wheel centre at dynamic load application 83

Figure 4.15: Radar chart of izod impact, yield strength of PPH and PPC and dynamic and drop weight impact load test results...84

Figure 4.16: SEM images of (a) RHA , (b) Talc (c) $cCaCO_3$ (d) $UCaCO_3$ (X1000)....85

Figure 4.17: FTIR Spectrum for (a) $UCaCO_3$ (b) $cCaCO_3$...89

Figure 4.18: FTIR Spectrum for (a) RHA (b) Talc 90

Figure 4.19: (a) Effects of the filler loading on the MFI (b) Regression graph 94

Figure 4.20: Effects of the filler loading on the MFI (c) PP composites of Talc, $cCaCO_3$ and $UCaCO_3$ regression graph of (d) PP/Talc (e) PP/$UCaCO_3$ (f) PP/$cCaCO_3$...........97

Figure 4.21: Effects of the filler loading on the tensile strength (a) PP composites of Talc, $cCaCO_3$ and $UCaCO_3$ (b) PP composites of RHA 103

Figure 4.22: Effects of the filler loading on the elongation percentage at break.........104

(a) PP composites of Talc, cCaCO3 and UCaCO3 104

(b) PP composites of RHA 104

Figure 4.23: Comparison of storage modulus of PP composites of $UCaCO_3$ $cCaCO_3$, Talc and RHA at 10% filler loading 108

Figure 4.24: Comparison of storage modulus of PP composites of $UCaCO_3$ $cCaCO_3$ and Talc at 20% filler loading 109

Figure 4.25: Comparison of storage modulus of PP composites of (a) $UCaCO_3$ and (b) $cCaCO_3$ at 10% and 35% filler loading 110

Figure 4.26: Comparison of loss modulus of PP composites of talc, $cCaCO_3$ and $UCaCO_3$ at 10% filler loading 112

Figure 4.27: Comparison of loss modulus of PP composites of Talc, $cCaCO_3$ and $UCaCO_3$ at 35% filler loading 113

Figure 4.28: Comparison of tan δ of PP composites of RHA, Talc, $cCaCO_3$ and $UCaCO_3$ at 10% filler loading 116

Figure 4.29: Comparison of tan δ of PP composites of RHA, Talc, $cCaCO_3$ and $UCaCO_3$ at 35% filler loading 116

Figure 4.30: Comparison of tan δ of PP composites of Talc, $cCaCO_3$ and $UCaCO_3$ at 20% filler loading 117

Figure 4.31: Comparison of Izod impact strength of PP composites at different filler loading (a) Talc, $UCaCO_3$ and $cCaCO_3$ (b) RHA 121

Figure 4.32: Toughening mechanism of polymer composites with rigid filler particles(56) 124

Figure 4.33: SEM images of (a) PP + 10% Talc composites (b) PP + 10% RHA composites 127

Figure 4.34: SEM images (c) PP + 10 %UCaCO3 Composite (d) PP + 10 % cCaCO3 composites. 128

Figure 4.35: SEM images of PP composites of 129

(a) 5% $cCaCO_3$ 129

(b) 10% $cCaCO_3$ 129

(c) 15% $cCaCO_3$ 129

(d) 20% $cCaCO_3$ and.......... 129

(e) 25% $cCaCO_3$ 129

Figure 4.36: Percentage of crystallinity of PP and PP composites at 10 % filler.......... 133

Figure 4.37: Exothermic crystallization peaks for PP and PP composites at 10 % filler cooling rate of 10 °C /min 134

Figure 4.38: Exothermic crystallization peaks for PP and PP composites of $UCaCO_3$ $CaCO_3$ and cat 35 % filler at cooling rate of 10 °C /min 135

Figure 4.39: Crystallization peaks for PP and PP/RHA at different filler loading 136

Figure 4.40: Stress –strain curve of PPC and PP composites at 50 mm/min strain at temperature 23 °C 139

Figure 4.41: Stress –strain curve of selected Virgin PP and PP composites at 50 mm/min strain at temperature 60 °C.......... 140

Figure 4.42: Distribution of stress density obtained from FEA.......... 141

Figure: 4.43 Castor wheels running times at dynamic load test at different filler loading % 144

Figure: 4.44 Castor wheels running times of different PP composites at dynamic load test.......... 144

Figure 4.45: Maximum temperature development in the wheel centre at dynamic load failure.......... 146

Figure 4.46: Failure of PP composites wheel centre at the dynamic load test(a) PP +cCaCO3 (b) PP +UCaCO3, (c) PP + RHA (d) PP +Talc 146

LIST OF ABBREVIATIONS

ABS	Acrylonitrile butadiene styrene copolymer
ASTM	American society for testing and materials
ATR	Attenuated Total Reflection
BRHA	black rice husk ash
$cCaCO_3$	Coated calcium carbonate
DMA	Dynamic mechanical analysis
DSC	Differential scanning calorimetry
EB	Elongation at break
EP	Ethylene propylene
EPDM	Ethylene propylene diene monomer
EPR	Ethylene propylene rubber
FEA	Finite element analysis
FRH	Flour rice husk
FTIR	Fourier transfer infrared spectroscopy
iPP	Isotactic polypropylene
IPPC	Impact polypropylene copolymer
IR	Infrared
LDPE	Low density polyethylene

LLDPE	Linear low density polyethylene
MA	Maleic anhydride
MA-PP	Maleic anhydride /PP homopolymer
MA-SEBS	MA/Styrene– ethylene– butadiene–styrene triblock copolymer
MFR	Melt flow rate
MFI	Melt flow index
PE	Polyethylene
PPB	Block copolymer polypropylene
PPH	Polypropylene homopolymer
PPC	Polypropylene copolymer
PP	Polypropylene
PS	Polystyrene
PVC	Poly vinyl chloride
PMMA	Poly methyl methacrylate
RHA	Rice husk ash
SA	Stearic acid
SBS	Styrene butadiene styrene copolymer
SEM	Scanning electron microscopy
TPV	Thermoplastic vulcanisates
$UCaCO_3$	Uncoated calcium carbonate
WF	Wood flour

WRHA	White rice husk ash
$\Delta H\text{--}_f$	Enthalpy of PP in composite
ΔH_f^0	Enthalpy of 100% crystalline PP
W_p	Weight fraction of PP in composite
T_m	Melting temperature
T_{om}	Onset melting temperature
T_{oc}	Onset crystallisation temperature
T_c	Crystallisation temperature
T_g	Glass transition temperature
J/m	joules per meter
MPa	Mega pascal
E'	Storage modulus
E"	Loss modulus
$Mg_3Si_4O_{10}(OH)_2$	Hydrated magnesium silicat

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisors Prof. L. Karunanayake, Department of Chemistry, University of Jayewardenepura Dr. S. Walpalage Department of Chemical Engineering, University of Moratuwa and Dr. N. Ganegoda Department of Mathematics, University of Jayewardenepura for their relentless guidance and unflagging interest shown right throughout my study.

I would like to thank Mr. Bandu Samarasekara, University of Moratuwa, Dr.Nilmini Liyanage, Dr.Upul Rathnayaka, Dr.Sushantha Siriwardena and the staff of Rubber Institute of Sri Lanka, Mr. Chinthana Manoratne of Industrial Technology Institute for their sincere assistance given in testing and analysing data throughout my study.

I also would like to thank the University of Moratuwa, University of Jayewardenepura and Elastomeric Engineering Company limited, Horana, for allowing me to use the facilities available at their polymer laboratories.

I wish to thank the management of Elastomeric Engineering Company limited for giving me an opportunity and freedom to conduct Research study.

My deep appreciation of the generous gesture of thanks goes out all my friends and colleagues who helped me in numerous ways in the field.

I express my heartfelt gratitude to my loving mother and late farther who guided me along the correct path of education with much sacrifice and dedication.

I owe gratitude to my loving wife Priyadarshani who supported me in every possible way and our sons Dumindu, Savindu and Yuvindu for their patience during this course of study and my family members specially my brother Dr. Kamal Ranatunga for their constant help extended to me in achieving the goal.

Last, but not least, I wish to place on record my gratitude and thanks to staff of Elastomeric Engineering Company limited, too numerous to individually mention, for their assistance and encouragement rendered to me make this a success.

A STUDY ON USE OF POLYPROPYLENE (PP) AND PP COMPOSITES IN THE MANUFACTURE OF CASTOR WHEELS AND THEIR EFFECT, ON PROCESSING, DYNAMIC AND STATIC CHARACTERISTICS

Ranatunga Ramanayaka Mudiyanselage Sisira Kumara Ranatunga

ABSTRACT

Present study is to explore the potential of using virgin Polypropylene (PP) materials (PP homopolymer, (PPH) and PP impact copolymer PPC)) and PP composites of rice husk ash (RHA), uncoated $CaCO_3$ ($UCaCO_3$) talc and stearic acid coated $CaCO_3$ ($cCaCO_3$) for low speed dynamic load applications such as manufacture of light weight castor wheel centre. Industrial grade PP, talc, $UCaCO_3$ and $cCaCO_3$ materials were used for the study. RHA was obtained by uncontrolled combustion of rice husk. Composites of PP/Talc PP/$UCaCO_3$, and PP/$cCaCO_3$ were compounded at 5, 10, 15, 20, 25, 30 and 35% by weight . Composites of PP/RHA were compounded at filler loadings 2.5, 5, 7.5, 10 and 12.5 %. . Extruded pellets of PP and PP composites were tested for melt flow index (MFI). Injection moulded specimens were used for testing tensile strength, izod notched impact strength and dynamic mechanical analysis (DMA). Surface morphology of fillers and PP composites were examined using scanning electron microscopic (SEM) images. Thermal properties of PP and PP composites were studied using differential scanning calorimetry (DSC). Chemical characteristics of filler materials were determined by fourier transform infrared spectroscopy (FTIR). Castor wheel centres were injection moulded to a rubber ring and tested for dynamic load and stress generation using finite element analysis (FEA).

As per DSC results, the degree of crystallinity is higher in PPH (45%) compared to PPC (37%). DMA suggested that PPH is stiffer than PPC which has a multiphase structure. The ethylene propylene rubber (EPR) phase (T_g peak of EPR phase at -35.2 ^{0}C) which is amorphous in nature provides good impact strength, whereas, matrix made of PP (T_g peak at 15.4 ^{0}C) provides stiffness. A shoulder peak of PPC at temperature around 88 ^{0}C has been attributed to the α-relaxation in the crystalline phase. Drop weight impact test results suggested that impact property of PPH is 22 times lower at low temperature compared to that of PPC. Since a balance between impact strength and stiffness is required for optimum performance, PPC is more suitable for light weight dynamic load applications at low temperatures.

PP composites of Talc, RHA and $UCaCO_3$ show significant drop in elongation at break resulting brittle failure. DMA and impact test results suggested that PP composites of RHA, Talc and $uCaCO_3$ have very poor impact properties, whereas, PP composites with $cCaCO_3$ at 20% prevent T_α transition in the crystalline phase due to lowest stress developed in PP matrix under deformation. The shear yielding bare minimum improving the toughness. PP composite of locally available low cost $cCaCO_3$ is the most suitable material for light-weight dynamic load applications.

Novel FEA model suggested for wheel centre in present study can be applied universally to predict most vulnerable failure area and the stress and displacement of thermoplastic materials at different temperature applications.