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"Application of PEEK Material in Alloy Wheel and its Static Analysis"

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Abstract- **Thermoplastic composites have great significance in automotive market due to their recyclables and high performance. PEEK composites actually 'Polyetheretherketone' have been extensively studied because of the excellent taluminium spokesological behavior among plastics. PEEK polymer, is increasingly used in many industrial applications as a replacement for metal and other components. In this experiment, attention is given to mechanical properties of PEEK, So as to analyze performance of the prototype components in actual field condition and shows encouraging results by using Finite element methods.**

Keywords: FEM, Polymers, Alloy, PEEK

I. INTRODUCTION

The automotive industry faces increasing pressure to maximize performance while minimizing weight and cost. Even with small cars, the trend is moving towards safer and more fuel efficient vehicles. Companies are under constant pressure to reduce overall system costs while increasing product performance, reliability and ease of manufacturing. In highly stressed automotive applications like bearings and gaskets, conventional materials can no longer satisfy the increased temperature requirements and/or are no longer competitive as a result of high processing costs. The global automotive industry is being driven by environmental and safety standards, increased longevity due to extended warranty and lower costs of production. Consumers are demanding less frequent maintenance, more comfortable driving experiences, and better fuel economy, with no deterioration in performance.

Thermoplastic composite materials consist of thermoplastic resins as matrix, reinforcement with traditional fibers as thermo sets matrix. They have shown great promise as materials for current and future automotive, aerospace and industrial applications. Thermoplastic resins offer a number of advantages over conventional thermosetting resins like lower cycle time, high service temperature, excellent chemical and impact resistance, low coefficient of thermal expansion, excellent fire, smoke and toxicity performance, good fatigue performance, low wastage, and recyclability. They have a very low level of moisture uptake which means that their mechanical properties are less degraded under hot and wet conditions..

PEEK polymer continues to successfully replace steel, aluminum, bronze, titanium, and other high performance materials, because it offers an ideal combination of mechanical, thermal and taluminium spokesological properties, combined with excellent resistance to grease, oils, acids and all other automotive fluids.

II. EXPERIMENTAL

2.1 Design Procedure

International Research Journal of Engineering & Applied Sciences
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Page 21-28

With the help of the measuring instrument Vernier caliper, micrometer, radius gauges and slip gauges, we have first taken all the dimension of the Aluminium alloy wheel. According to the dimension, profile of the component is drawn on the screen of the computer using CATIA. After completing the draw the wheel model is then imported in the ANSYS 13 software. Before importing it is first save in IGES and STEP.

2.2 ANALYSIS FOR ALUMINIUM ALLOY

2.2.1 Analysis Procedure

First of all we have taken the Aluminium alloy material composition i.e. LM 13. Material composition of LM13 is Al-Si (BS: LM13) alloy was used as the matrix material. The alloy contains 11.00 wt.% Si, 1.00wt.% Mg, 1.50 wt.% .Ni, 1.00 wt.% Cu, 0.80wt.% Fe, 0.50 wt.% Mn and balance was Al. LM13–10 wt.% SiCp composite was prepared by dispersing hard particles in Aluminum matrix using stir-casting technique.

From the design data book –Mechanical property

Mechanical property	Value	Unit
Density	2770	kg m^-3
Coefficient of Thermal Expansion	0.000023	C^-1
Specific Heat	875	J kg^-1 C^-1
Compressive Yield Strength	$2800*10^{5}$	Pa
Tensile Ultimate Strength	3100*	Pa
Reference Temperature	22	C
Young's Modulus	$7.1 *10^{10}$	Pa
Poisson's Ratio	0.33	
Bulk Modulus	$6.9608*10^{10}$	Pa
Shear Modulus	$2.6692*10^{10}$	Pa
Relative Permeability	1	

Table 2.2.1 Mechanical properties of aluminium alloy

These mechanical properties are defined into the material list of ANSYS software data list. For the Static analysis, component drawing is called in ANSYS software and then mechanical properties are defined on Aluminium alloy wheel.

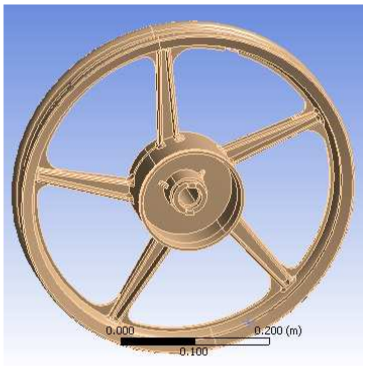


Fig 2.2.1 Aluminium Alloy Wheel

2.2.2 Static Analysis:

(A) Under –

(I) Maximum Inflation pressure on rim circumference –2100 KPa
(2) Hub fix
(3) Rotation velocity in Z –direction –200 rad/sec
(4) Cylindrical support on outer hub area
(5) Compression only support the rim circumference

2.2.3 Analysis Result

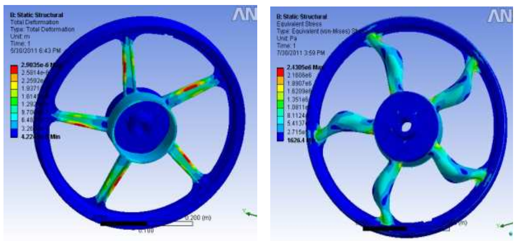


Fig 2.2.2 Static analysis & deformation comparision for Aluminium

2.2.4 Result and Discussion

	Total Deformation	Equivalent Stress
Results		
Minimum	$4.3145*10^{-9}$ m	1626.7 Pa
Maximum	$2.9145*10^{-6}$ m	$2.2319*10^{6}$ Pa

Table 2.2.2 Total deformation and equivalent stress for aluminium alloy

From the above fig. it does not deform i.e. it can sustain Max. Inflation Pressure on wheel of order 2100 KPa.

2.3 ANALYSIS DATA OF PEEK MATERIAL

2.3.1 Analysis Procedure

Under same Maximum. Inflation pressure on wheel –2100 KPa, Hub fix and Rotation velocity in Z –direction –200 rad/sec and after defining the mechanical property of different grade of PEEK polymer on wheel if wheel does not deform the we can easily replace Aluminium alloy wheel with PEEK polymer wheel .From the journal Published online by the VBRI press in 2011 _ received: 6 Dec 2010, Revised: 12 Jan 2011 and Accepted: 16 Jan 2011 _by Nitu Bhatnagar, Sangeeta Jha, Shantanu Bhowmik.

Mechanical property	Value	Unit
Density	1320	kg m^-3
Coefficient of Thermal Expansion	46.8×10^{-6}	C^-1
Specific Heat	1470×10^{6}	J kg^-1 C^-1
Compressive Yield Strength	118×10^{6}	Pa
Tensile Ultimate Strength	100×10^{6}	Pa
Reference Temperature	22	C
Young's Modulus	3.6×10^{9}	Pa
Poisson's Ratio	0.39	
Bulk Modulus	$6.9608*10^{10}$	Pa
Shear Modulus	1.4×10^{9}	Pa

Table 2.3.1 Mechanical properties of PEEK material

Different properties are defined into the material list of ANSYS software data list. For the Static analysis same component drawing is call in ANSYS software and then material is define on wheel.

2.3.2 Static Analysis: -

PEEK-MATERIAL

(B) Under –

- (I) Maximum Inflation pressure on rim circumference –2100 KPa
- (2) Hub fix
- (3) Rotation velocity in Z –direction –200 rad/sec
- (4) Cylindrical support on outer hub area
- (5) Compression only support on rim Circumference

2.3.3 Analysis Result

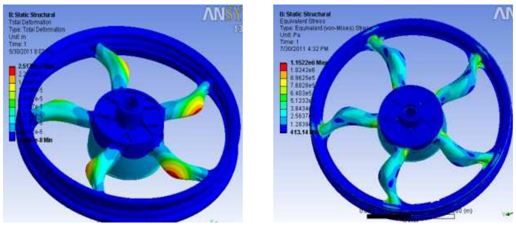


Fig 2.3.1 Static analysis & deformation comparision for PEEK material

2.3.4 Result and Discussion

	Total Deformation	Equivalent Stress
Results		
Minimum	$3.1092*10^{-8}$ m	413.14 Pa
Maximum	$2.5178*10^{-5}$ m	$1.1522 *10^{6}$Pa

Table 2.3.2 Total deformation and equivalent stress for PEEK material

As shown in above fig. it indicated that maximum deformation occurred on the aluminium spokes of the wheel i.e it does not sustain under Max. Inflation pressure on wheel –2100 KPa

2.4 ANALYSIS DATA OF PEEK WITH 30% GLASS FIBER MATERIAL

Mechanical property	Value	Unit
Density	1520	kg m^-3
Tensile Yield Strength	$1.9*10^{7}$	Pa
Compressive Yield Strength	$1.18*10^{8}$	Pa
Tensile Ultimate Strength	$1.*10^{8}$	Pa
Young's Modulus	$4.06*10^{9}$	Pa
Poisson's Ratio	0.45	
Bulk Modulus	$1.3533*10^{10}$	Pa
Shear Modulus	$1.4*10^{9}$	Pa

Table 2.4.1 Mechanical properties of PEEK material with 30% glass fibre

2.4.1 Analysis Result

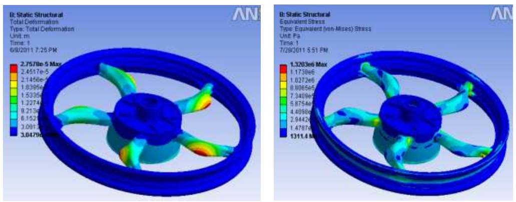


Fig 2.4.1 Static analysis & deformation comparision for PEEK material with 30% glass fibre

Table 2.4.2 Total deformation and equivalent stress for PEEK material with 30% glass fibre

	Total Deformation	Equivalent Stress
Results		
Minimum	4.9879*10-9 m	726.48 Pa
Maximum	$4.5815*10^{-6}$ m	$1.1908*10^{6}$ Pa

	Total Deformation	Equivalent Stress
Minimum	$3.0479*10^{-8}$ m	1311.4 Pa
Maximum	$2.7578*10^{-5}$ m	$1.3203*10^{6}$ Pa

2.4.2. Result and Discussion

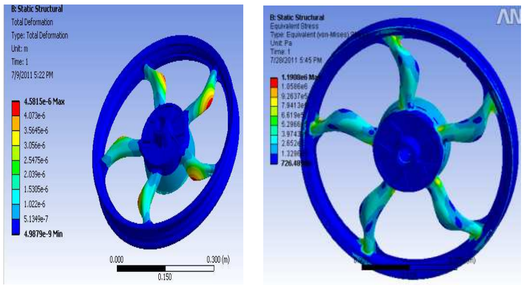
As shown in above fig. it indicates that maximum deformation occurred on the aluminium spokes of the wheel i.e. it does not sustain Max. Inflation pressure on wheel of order 2100 KPa.

2.5 ANALYSIS DATA OF PEEK 90HMF20 MATERIAL

Mechanical property	Value	Unit
Density	1370	Kg/ m^3
Tensile Yield Strength	$2.8*10^{8}$	Pa
Compressive Yield Strength	$2.7*10^{8}$	Pa
Tensile Ultimate Strength	$1.*10^{8}$	Pa
Young's Modulus	$2.2*10^{10}$	Pa
Poisson's Ratio	0.4556	
Bulk Modulus	$8.2583*10^{10}$	Pa
Shear Modulus	$7.557*10^{9}$	Pa

Table 2.5.1 Mechanical properties of PEEK 90HMF20 material

2.5.1. Analysis Result



2.5.2. Result and Discussion

As shown in above fig. it indicated that maximum deformation occurred on the aluminium spokes of the wheel i.e it does not sustain under Max. Inflation pressure on wheel –2100 KPa.

2.6 ANALYSIS DATA OF PEEK 90HMF40 MATERIAL

Mechanical Results property	Value	Unit
Density	1450	kg m^-3
Tensile Yield Strength	$3.3*10^{9}$	Pa
Compressive Yield Strength	$3.1*10^{8}$	Pa
Tensile Ultimate Strength	$1.*10^{8}$	Pa
Young's Modulus	$4.5*10^{9}$	Pa
Poisson's Ratio	0.48	
Bulk Modulus	$3.75*10^{10}$	Pa
Shear Modulus	$1.5203*10^{9}$	Pa

Table 2.6.1 Mechanical properties of PEEK 90HMF40 material

2.6.1 Analysis Result

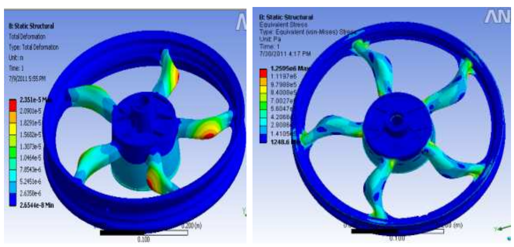


Fig 2.6.1 Static analysis & deformation comparision for PEEK 90HMF40 material

2.6.2. Result and Discussion

As shown in above fig. it indicated that maximum deformation occurred on the aluminium spokes of the wheel i.e it does not sustain under Max. Inflation pressure on wheel –2100 KPa.

III. Redesigning The Alloy Wheel

So to minimize this deformation, we have change the shape of the spokes section according to required for PEEK alloy wheel as shown in below fig. in order to give the maximum strength at the spokes area.

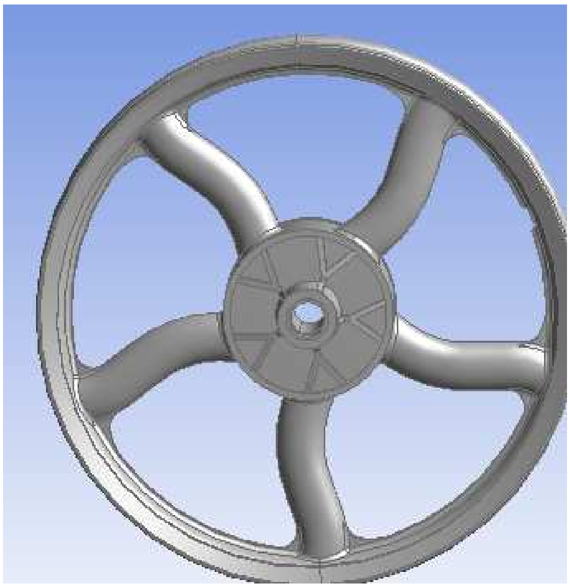


Fig 3.1 Design of alloy wheel using PEEK material

And the same procedure is repeated for analysis of changed model as shown in above figure. under same condition

Static Analysis

(C) Under –
(1) Maximum Inflation pressure on rim circumference –2100 KPa
(2) Hub fix
(3) Rotation velocity in Z –direction –200 rad/sec
(4) Cylindrical support on outer hub area
(5) Compression only support on rim circumference
(6) Compression only support on inside circumference of hub area

	Total Deformation	Equivalent Stress
	Results	
Minimum	2.6544*10-8 m	1248.6 Pa
Maximum	$2.351*10^{-5}$ m	$1.2595*10^{6}$ Pa

Table 3.1 Total deformation and equivalent stress for PEEK material under static analysis

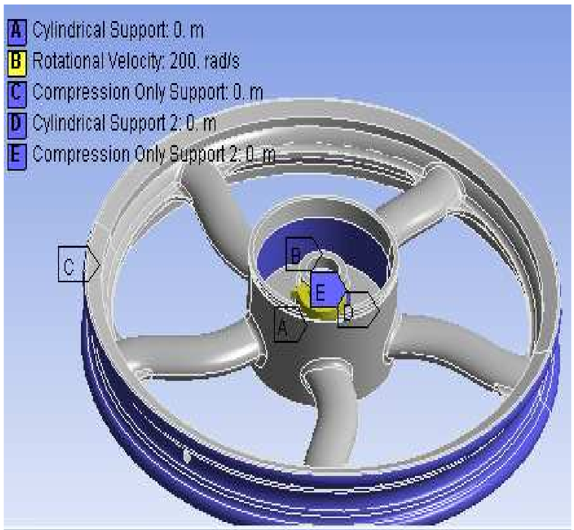


Fig 3.2 Analysis of wheel

3.1 Analysis Result of PEEK material

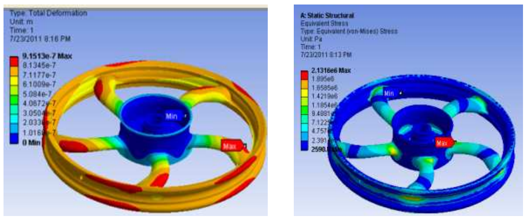


Fig. 3.3 Analysis result of PEEK material

	Total Deformation	Equivalent Stress
	Results	
Minimum	0. m	2590.3 Pa
Maximum	$9.1513*10^{-7}$m	$2.1316*10^{6}$ Pa

Table 3.2 Total deformation and equivalent stress for PEEK material under static analysis

International Research Journal of Engineering & Applied Sciences
www.irjeas.com, Volume 1, Issue 1, Jan 2013 – Mar 2013, ISSN: Applied for
Page 21-28

3.2 Analysis Result of PEEK With 30% Glass Fiber

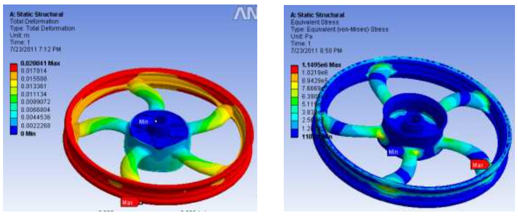


Fig. 3.4 Analysis result of PEEK material with 30% glass fibre

3.3 Analysis Result of PEEK - 90HMF20

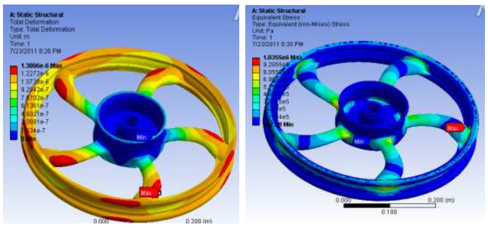


Fig. 3.5 Analysis result of PEEK 90HMF20

	Total Deformation	Equivalent Stress
Results		
Minimum	0. m	887.08 Pa
Maximum	$1.3806*10^{-6}$ m	$1.0355*10^{6}$ Pa

Table 3.3 Total deformation and equivalent stress for PEEK 90MHF20

3.4 Analysis Result of PEEK - 90HMF40

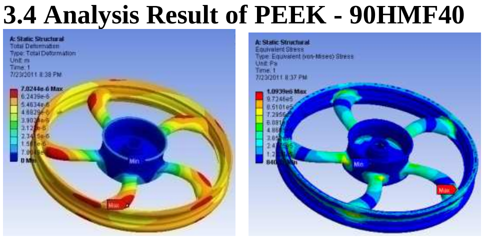


Fig. 3.6 Analysis result of PEEK 90HMF40

	Total Deformation	Equivalent Stress
Results		
Minimum	0. m	840.22 Pa
Maximum	$7.0244*10^{-6}$ m	$1.0939*10^{6}$ Pa

	Total Deformation	Equivalent Stress
Results		
Minimum	0. m	1104.1 Pa
Maximum	$8.3276*10^{-6}$ m	$1.1495*10^{6}$ Pa

Table 3.4 Total deformation and equivalent stress for PEEK 90MHF40

IV. Comparison Analysis Data of Different Material

MATERIAL		ANALYSIS DATA BEFORE REDESIGN OF ALLOY WHEEL		ANALYSIS DATA AFTER REDESIGN OF ALLOY WHEEL	
		Total Deformation	Equivalent Stress	Total Deformation	Equivalent Stress
Aluminum Alloy	Minimum	$4.2245*10^{-9}$ m	1626.4 Pa	0. m	2126.4 Pa
	Maximum	$2.9035*10^{-6}$ m	$2.2305*10^{6}$ Pa	$1.804*10^{-6}$ m	$2.8711*10^{6}$ Pa
PEEK	Minimum	$3.1092*10^{-8}$ m	413.14 Pa	0. m	2590.3 Pa
	Maximum	$2.5178*10^{-5}$ m	$1.1522 *10^{6}$ Pa	$9.1513*10^{-7}$m	$2.1316*10^{6}$ Pa
PEEK With 30% Glass Fiber	Minimum	$3.0479*10^{-8}$ m	1311.4 Pa	0. m	1104.1 Pa
	Maximum	$2.7578*10^{-5}$ m	$1.3203*10^{6}$ Pa	$8.3276*10^{-6}$ m	$1.1495*10^{6}$ Pa
PEEK - 90HMF20	Minimum	$4.9879*10^{-9}$ m	726.48 Pa	0. m	887.08 Pa
	Maximum	$4.5815*10^{-6}$ m	$1.1908*10^{6}$ Pa	$1.3806*10^{-6}$ m	$1.0355*10^{6}$ Pa
PEEK - 90HMF40	Minimum	$2.6544*10^{-8}$ m	1248.6 Pa	0. m	840.22 Pa
	Maximum	$2.351*10^{-5}$ m	$1.2595*10^{6}$ Pa	$7.0244*10^{-6}$ m	$1.0939*10^{6}$ Pa

V. Conclusions

From the above table it is clear that PEEK 90HMF20 is best material for the replacement of Aluminium.

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