International Journal of Scientific Research and Engineering Development-– Volume 4 Issue 2, Mar- Apr 2021

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RESEARCH ARTICLE OPEN ACCESS

CFD ANALYSIS FOR USAGE OF PEEK MATERIAL FOR WHEELS

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Abstract

Automobile sector plays a key role in development of any economy. But it faces a lot of competition. So, one of the motto of automobile designer is to improve the mileage of the vehicle by reducing its weight. PEEK has emerged as a material which can be used for wheels of automobiles without hindering their strength. In the present work CFD analysis of wheels made of aluminium alloy with PEEK material has been carried out for various compositions of glass fibre. It was concluded that PEEK 90HMF20 can be best material for the replacement of Aluminium material.

Keywords: *PEEK material, alloy wheel, vehicle, strength, safety factor*

Introduction

In automotive industries, designers have a wide range of materials and processes to select from. Material mechanical properties and manufacturing parameters play decisive roles and the weaknesses and strengths of each manufacturing process need to be available to designers in these respects. Due to sophisticated wheels design, casting has become the dominant manufacturing process. Alloy wheel material has evolved too: car wheels alloys now contain 7 to 12% silicon content, and varying contents of magnesium in addition to aluminium, in order to meet the demand for metal-mould casting properties, corrosion and fatigue resistance.

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. Polyetheretherketone is the most attractive among high performance polymers, even if its use is limited by the high cost of supplying and processing and by the high sensibility to the molding processes.

Udasi and Kumbhare, 2014, Swamy& Reddy, 2016, Kumar et al., 2015, Gandhari & Subramaniam, 2020, Tadesse, 2017 worked for the development of PEEK material for wheels of automobiles and it was concluded that PEEK has capabilities to replace aluminium in automobile tyre industry as it has light weight and safety factor is better than aluminium..

Geometric Modeling

According to the dimensions of actual wheel, profile of the component was drawn using CATIA. After completing the drawing, the wheel model was then import in the ANSYS 13 for analysis.

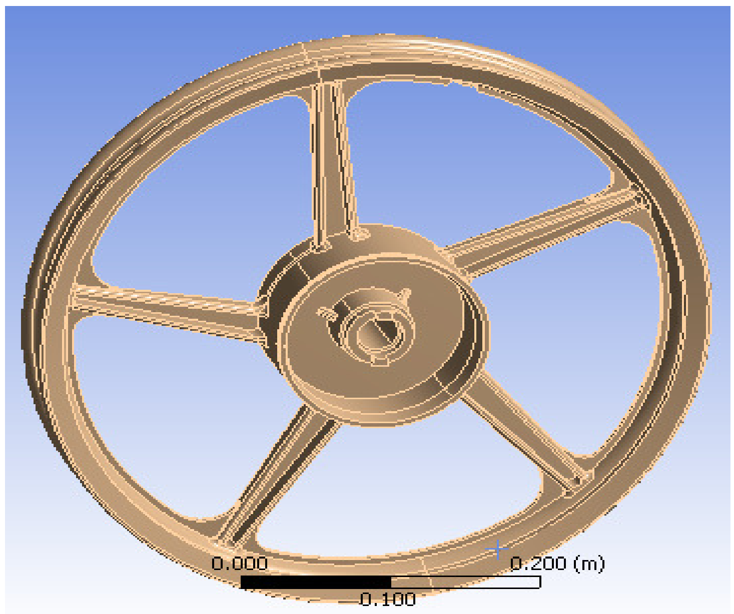


Fig.1 Aluminium Alloy wheel.

Pre processing and Boundary Conditions

After geometric modeling, the geometry was meshed and boundary conditions were specified and the analysis was carried out in ANSYS 13.

For Aluminium Alloy

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.

Table: 1 Mechanical Properties of Aluminium Alloy

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

The mechanical properties were defined from the material list of ANSYS software data list. Static analysis was carried out in ANSYS software by specifying mechanical properties on Aluminium alloy wheel. The conditions specified were:

Max. Inflation pressure on rim circumference= 2100 KPa

Hub fix

Rotation velocity in Z –direction –200 rad/sec

Cylindrical support on outer hub area

Compression only support on rim circumference

For PEEK Material

From obtained values of 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

Table: 2 Mechanical Property of PEEK Material

Mechanical property	**Value**	**Unit**
Density	1320	kg m^-3
Tensile Yield Strength	46.8 × 10-6	Pa
Compressive Yield Strength	1470 × 106	Pa
Tensile Ultimate Strength	118 × 106	P
Young's Modulus	100 × 106	Pa
Poisson's Ratio	22	
Bulk Modulus	3.6 × 109	Pa
Shear Modulus	0.39	Pa

For PEEK With 30% Glass FIbre

Again 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 PEEK polymer with 30% Glass FIbre on wheel if wheel does not deform the we can easily replace Aluminium alloy wheel with PEEK polymer wheel.

Table: 3 Mechanical Property of PEEK With 30% Glass FIbre

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

Results and Discussion

Aluminium Alloy Wheel

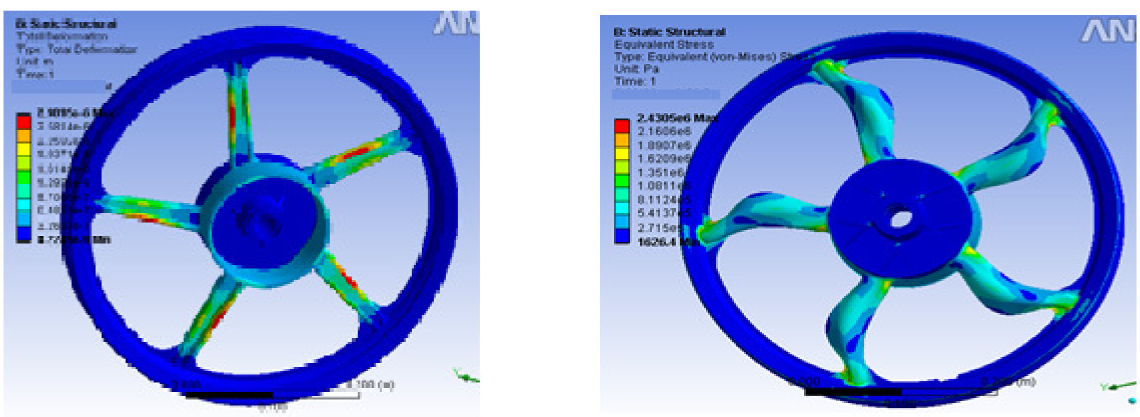
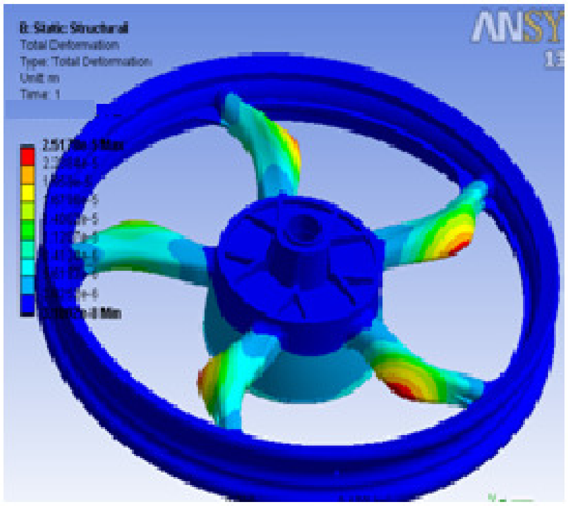


Fig 2 Analysis of Aluminium Alloy Wheel

	Total Deformation	Equivalent Stress
Minimum	$4.2245*10^{-9}$ m	1626.4 Pa
Maximum	$2.9035*10^{-6}$ m	$2.2305*10^{6}$ Pa

From the above analysis, it was found that the wheel does not deform i.e. it can sustain under Max. inflation pressure on wheel 2100 KPa.

Analysis of Aluminium Alloy using PEEK Material



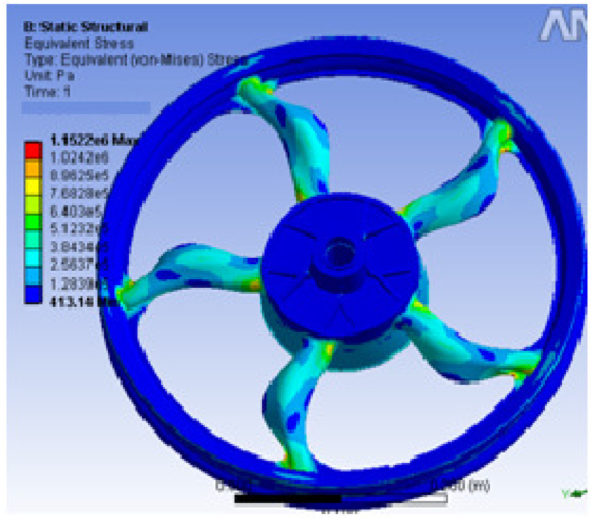
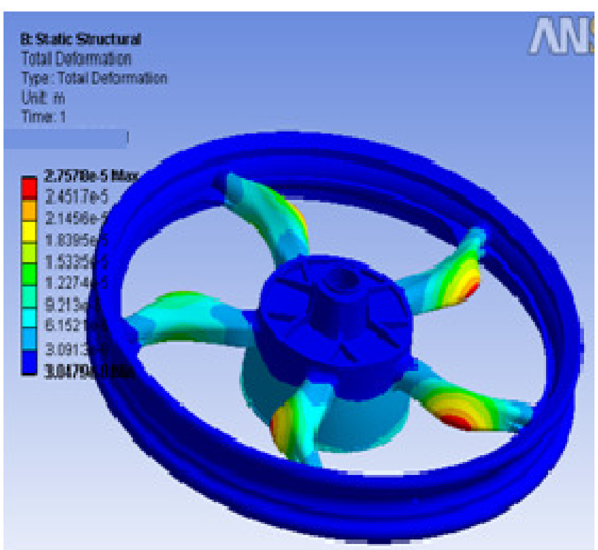


Fig .3: Analysis of Aluminium Alloy using PEEK Material

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

As can be seen from above fig that maximum deformation occurred on the axle of the wheel i.e it does not sustain under Max. inflation pressure on wheel 2100 KPa.

Analysis of Aluminium Alloy using PEEK Material With 30% Glass Fibre



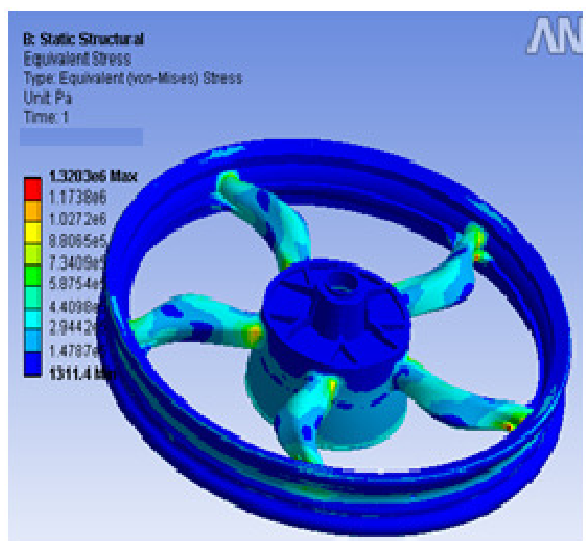


Fig .4 Analysis of Aluminium Alloy using PEEK Material With 30% Glass FIbre

Table 4 Analysis of Aluminium Alloy using PEEK Material With 30% Glass FIbre

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

From above it can be said that the rib of the wheel does not sustain under Max. Inflation pressure on wheel 2100 KPa. So the wheel was redesigned.

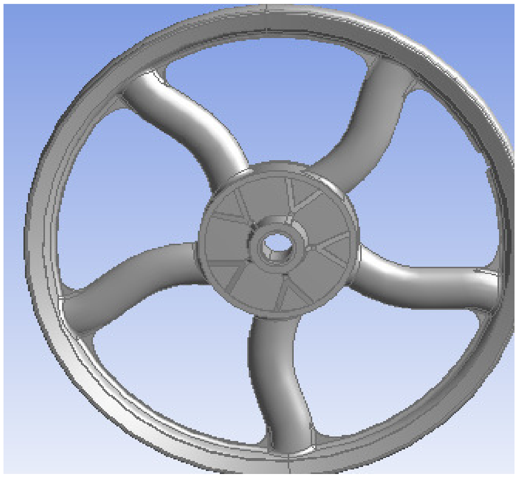


Fig.5 Redesigned Aluminium Alloy wheel

And the same procedure was repeated for analysis of change model under same condition

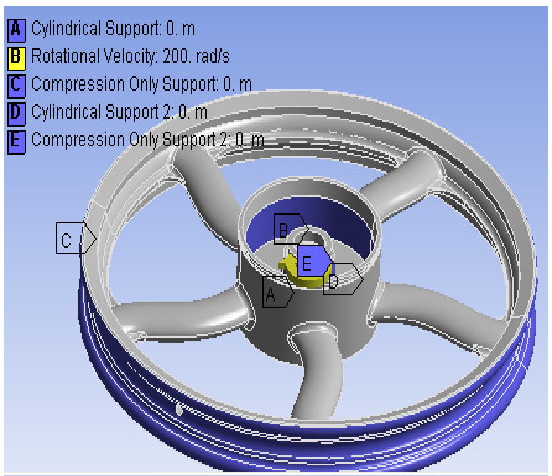


Fig 6 Static Analysis of Redesigned Aluminium Alloy using PEEK

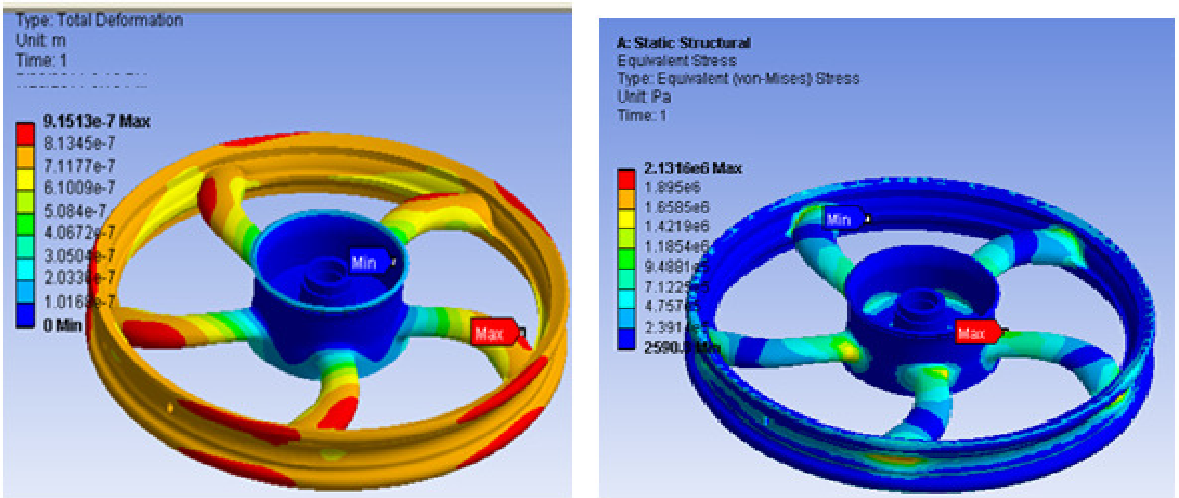


Fig.7 Static Analysis of Redesigned Aluminium Alloy using PEEK

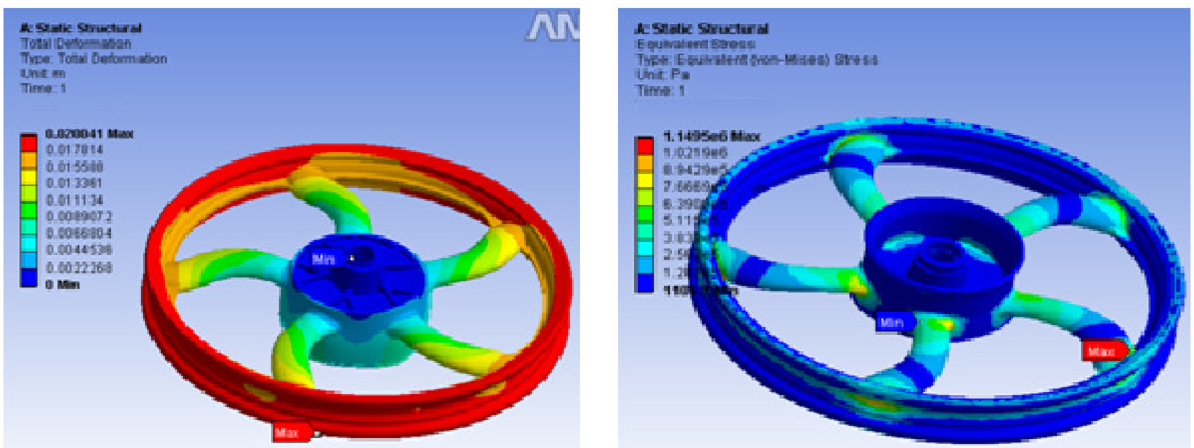


Fig.8 Static Analysis of Redesigned Aluminium Alloy using PEEK With 30% Glass Fibre

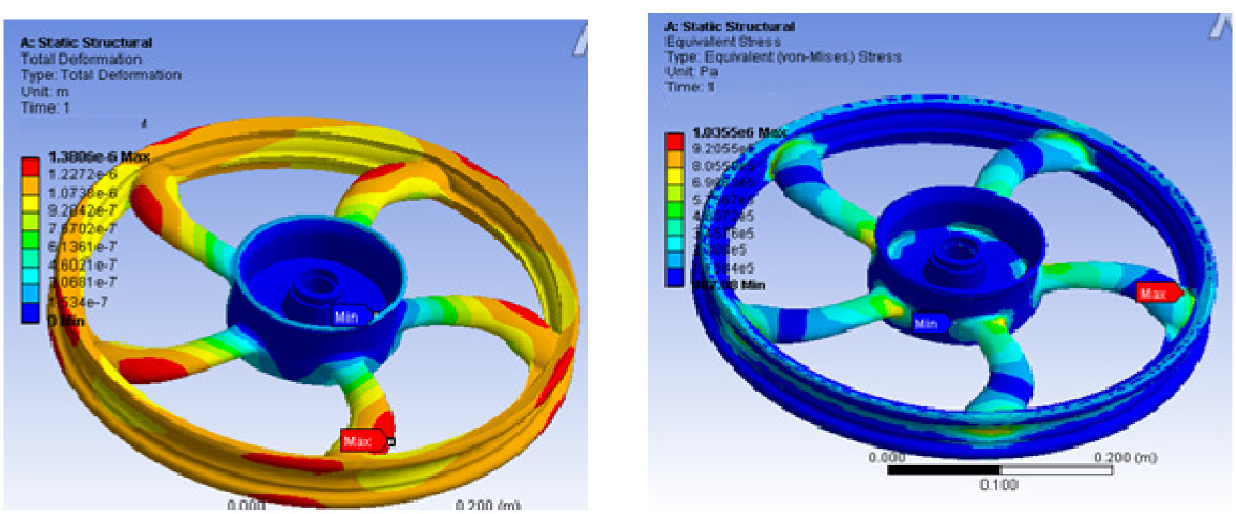


Fig.9 Static Analysis of Redesigned Aluminium Alloy using PEEK 90HMF20

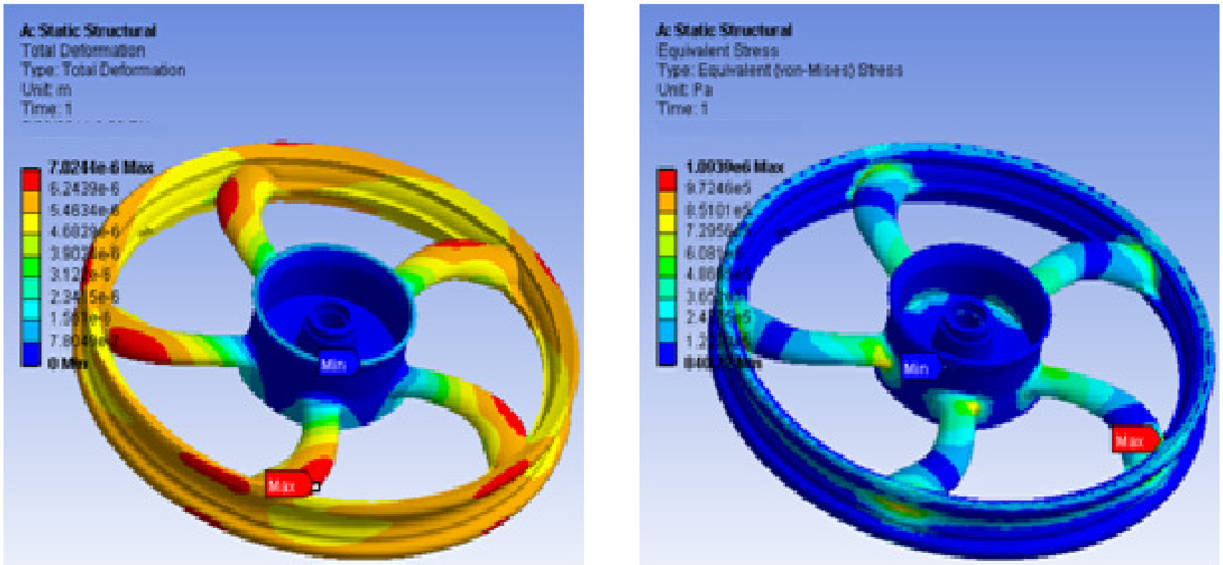


Fig.5.10 Static Analysis of Redesigned Aluminium Alloy using PEEK 90HMF40

Comparison Analysis Data of Different Material

Table: 5 Comparison Analysis Data of Different Material

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

Conclusions

Parts made out of Victrex materials are economical to produce, and facilitate overall systems cost reductions by eliminating secondary operations for parts, such as machining, as well as facilitating reduction in part count when compared with metal parts. From the analysis it can be said that PEEK 90HMF20 is best material for the replace of Aluminium material.

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