Review on Fiber reinforced /modified Bismaleimide resin composites for Aircraft Structure Application

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Abstract: Bismaleimide (BMI) is a high performance thermoset material which possesses similar characteristics as that of Polyimides which include high strength and rigidity at high temperature. It can be used for high temperature application up to 260°C. It stands between epoxy and polyimide in its thermal stability and moisture absorption properties. The resin is brittle in nature which necessitated modification with various modifiers viz epoxy, phenol Novolac, Polydimethylsiloxane (PDMS), Allyl phenol, Amines, Carbon nanotubes (CNT), ceramic materials etc. at chemical level to reduce its brittleness. The bismaleimide is used as a matrix in composite materials is reinforced with fibers viz carbon, Kevlar, Basalt, glass fibers. Various authors studied the bismaleimide composite material for its application in Aircraft and missile structures which requires thermal stability and high strength at high temperature. In this article the fiber reinforced modified bismaleimide resin composite materials are reviewed with an intend to explore the wide application of the resin system.

1. Introduction:

The demanding needs of the Engineering materials for high strength and high temperature application made an insight into the advanced materials. The advanced materials are Phenolics, Novalac epoxy, Bismaleimide, Polyimides. Bismaleimide are thermoset materials which inherently possess superior properties than epoxy resin and finds application in aircraft structure, missile structures etc. Bismaleimide resin is known for its excellent mechanical and thermal properties. The BMI has a brittle network hence necessitated the resin modification with comonomers viz aromatic amines, Phenolic resin etc to impart improved impact strength and toughness into it without affecting the thermal properties of it. This has created a large scope for investigating the materials and manufacturing composites based on the resin with modification, and with fiber reinforcement. The resin has been often copolymerized with Allylphenol which makes reduces the brittleness in it. Further to the development of modified resin it been incorporated by fibers to further enhance the thermo mechanical properties in it. In this journal the bismaleimide resin, its modifier, and fiber reinforced resin for composite materials is reviewed. Also the advancement in the resin composite is also reviewed which includes the Carbon nanotubes grafting into the fibers thereof.
1.1 Bismaleimide Resin

Bismaleimide is an important compound with maleimide groups connected to nitrogen atoms on either side by a linker which can be used as reagents for crosslinking thermoset polymers. It is synthesized by condensation of Phthalic anhydride with an aromatic diamine at a molar ratio of 2:1. The most important bismaleimide monomer is 4-4’ bis(maleimido) diphenylmethane (BMI) has a melting point of 155º C, often copolymerized with 2-2’ diallyl bisphenol A (DBA).

These resin are usually insoluble in ordinary organic solvent and soluble in high boiling polar solvents. The most curatives are aromatic diamines.

1.2 Toughening of Bismaleimide:

The presence of highly ordered stacking of polar carbonyl group in BMI makes it more brittle with less fracture toughness which can be modified with suitable modifiers for enhancing the properties. Hence BMI has been toughened by various chemicals and by various methods to improve the properties of the resin system for its enhanced application. The common toughening agents/mechanisms are allylphenol[47] copolymers, Michael’s addition copolymers, thermoplastic, thermoset, elastomer, hyperbranched polymer additions, particle strengthening.

With allyl phenol and allyl phenol compounds, the rigid and brittle aromatic units in BMI is reduced by its reaction by Diels-Alder type reaction in which adducts of bi and tris are obtained from excess BMI which is commonly called as Alder-ene reaction. Various work on it have been done by various researchers for improving the toughness of the resin system. With the
Michael reaction the nucleophilic addition of a carbon ion or a nucleophile to an unsaturated carbonyl compound forming mild C-C bond. The reaction between diamines and BMI is by Michael’s addition reaction where the diamines are nucleophiles.

1.3 Bismaleimide with Thermoplastic/ thermoset/ elastomer/Hyperbranched polymer Addition.

BMI are modified with thermoplastic modifiers like polyetherimides, poly ether ketone, poly ether sulfone [49] for reducing its brittleness and improving the toughness of the system thereof. Thermoset like epoxy [48]/Novolac epoxy [52] can increase the processability of bismaleimide with suitable diamine addition to it and hence enhance the thermo mechanical properties of the system. Elastomers [50] modifiers include the flexibility, lap shear in the system but with reduced strength. The properties are also improved by the addition epoxy [58] and siloxane [51] to BMI resin system. Also BMI has been modified with high performance polymers and nano particles [54] for retaining its properties at high temperature. Continuous Fiber is reinforced with modified BMI composites for its use in advanced application opened a diverse study of the composites which is reviewed in the journal.

2. Fiber reinforced BMI composites

BMI resins are used to manufacture composites through Autoclave and Out of Autoclave techniques like Resin Transfer moulding, Hot melt impregnation, through solvents. Different types of fibers are reinforced in BMI system exploring the wide possibility of its structures for different application. Though the resin infusion is enabled by Resin transfer moulding process, the resin can also be dissolved in solvents and prepeg’s are made which is then compressed to form composite materials. In this various work on fiber reinforced BMI composites are reviewed for its properties and application.

The fiber that are reinforced with BMI resin system are carbon fibers, Kevlar fibers, Glass fibers, Basalt fiber, quartz fiber, Carbon nano fibers and hybrid fibers, each contributing to diverse properties and application. The fiber reinforced are used as received or it treated with acids, silane, plasma or by grafting carbon nanotubes etc in it.

2.1 Carbon Fiber Reinforced modified BMI composites:

Bismaleimide has been commonly modified with diallylbisphenol A [56] and the resin system is incorporated into fiber reinforcement for manufacturing composites. Various investigation were done on carbon fiber reinforced BMI composite material of which John Montesano et al. (2012) [3] reported that the off-axis tensile fatigue behaviour of a woven carbon fiber/bismaleimide laminate is investigated at various temperatures. Fatigue tests at the same test temperatures all showed that the fatigue response developed in three distinct stages. During the initial stage of cycling at the off-axis side of the malinate there is a sudden increase in permanent strain and mean strain with slight increase in the axial stiffness. The author showed that the mean
strain developed is not a function of temperature change which is a significant finding and unique to this study.

Li Yuan et al, [4] reported that, the three-component resin system consisting of 4,4'-bismaleimidodiphenylmethane (BMI), O,O'-diallyl bisphenol A (BA) and organic rectorite (OREC) was prepared to develop a novel fiber reinforced BMI/BA/OREC composite. The morphologies of composites were characterized using a scanning electron microscope (SEM) which indicated that the appropriate content of OREC can significantly improve the mechanical properties such as the flexural strength, the interlaminar shear strength and the modulus of flexural elasticity of fiber reinforced BMI/BA composite. The proper addition of OREC could enhance the water resistance and the hot-air aging property of the fiber reinforced BMI/BA composites due to the barrier and high thermal stability of OREC.

Author X.J Xian and C.L. Choy [6] studied the fracture toughness and fatigue fracture behaviour of carbon-fiber-reinforced with modified bismaleimide (BMI) composites. These composites were found to have higher fracture toughness, better damage tolerance and longer fatigue life than carbon-fiber composites with epoxy matrices. The improved performance is due to the presence of thermoplastic particles in the modified BMI matrix leading to better adhesive bond between them with pronounced deformation by plasticity. The change of fiber orientation in the composites reduced the crack propagation and hence increasing its fatigue life.

Author P T. CURTIS, [8] conducted studies on twelve different carbon fibers (each of them with different fiber failure strain percentage) reinforced with epoxy, bismaleimide and thermoplastic matrices its mechanical properties. The fiber with intermediate modulus leads to the improvement of Tensile strength in both plain and notched specimen with an increase in stiffness. Also he inferred that the larger diameter fiber has lead to the improvement of compressive strength and improving its hot/wet performance which is desirable in aerospace applications.

The effects of environmental changes on the thermal and mechanical properties of the composite were studied by various authors under different conditions. The change in moisture and hygrothermal effects in mechanical properties as well as its Glass transition temperature has been studied by Author Michelle Leali Costa et al [9] who conducted a comparative studies the two different laminate consists of Epoxy/Carbon fiber and Bismaleimide/Carbon fiber. He observed that in both the laminate system with an increase in moisture content at a specified temperature there is reduction in interfacial bonding and hence reduced Interlaminar shear strength ILSS. the glass transition temperature has also been reduced with increasing moisture content due to greater mobility of molecules leading to the transition in both the resin system by analyzing its Dynamic mechanical behaviour.

It is also being studied by Author M. Akay et al.[15] the effect of ageing in the carbon fiber reinforced bismaleimide (Cycom 5250-4) composites on the thermo mechanical behaviour. The thermal ageing process involves placement of cut specimens in air circulating oven set at 210°, 230° and 250 °C for various periods of time up to 2000 h. He observed the activation energy in the range of 151–270 kJ/mol lead to the twofold deterioration of flexural and interlaminar shear strengths as a result of matrix loss and microcrack but with an increase of Tg.(325° C) for both
laminate types (54% and 58% fibre volume content laminates) from 245° and 275° C respectively, beyond 500 h ageing.

Further Author L F M da Silva[7] et al, investigated the effect of thermal variation from -55° to 200° C twill weave carbon fiber/ BMI composite. The strength and modulus haven’t varied in the temperature range making it suitable for temperature applications up to 200° C. The transverse strength when compared to longitudinal strength is low which is undesirable when it is subjected to loading in through thickness direction.

A comparison between 2D and 3D carbon fiber fabric with BMI resin composites is made by Author Shen Chou et al [10] reported that due to the Z directional fibers in 3D fabric network the crack propagation is restricted which lead to the improvement of shear strength and also the Impact strength has been increased to a level of 66% to 68% more than that of the 2D composites. The experiments were conducted at varying temperatures ranging from 25° C to 275° C.

Author Divya K. Chakravarthi et al.[12] reported the potential importance of lightweight application of carbon fiber composites for next-generation structures. In their work they optimized the addition of Ni coated Single walled carbon nanotubes (Ni-SWNTs) with bismaleimide (BMI)–carbon fiber composite based on their dispersion, surface area interaction and its resistance. Atomic force microscopy analysis improved dispersion of Ni-SWCNT in carbon/BMI composites improving the electrical conductivity with an optimal value of less than 4% of addition. Also showing good lightning strike protection with minimal fiber pullouts under mechanical testing.

Author Vernon T. Bechel et al, [13] reported the microcracks developed in crass ply and quasiisotropic laminates of carbon/BMI composites where the specimen is thermally treated at cryogenic temperature with liquid nitrogen LN. The cycle of immersion is varied and the microcrack formation is studied. The micro cracks were formed on the surface and edged which sparsely penetrated the centre after 400 cycles of its immersion in LN and returning back to room temperature. The tensile strength showed a decline in the layup and adjacent one having same orientation.

Author Li-Rong Bao et al.,[14] 2002, studied the effect of temperature on Moisture absorption and hygrothermal aging in a woven and woven/un-i-weave composites. The samples are experimented at different at different temperature. The diffusion is of two stage process. In the first stage there is diffusion followed by relaxation of the chemical in the second stage. It is found that the structural relaxation occurs below 70° C and degrades above 90° C signifying the change in temperature effecting the moisture absorption.

The authors Yuan-Fei Fu et al.[16] used Silane surface modification method for the surface treatment of carbon fiber to improve the interfacial adhesion of the carbon fiber reinforced bismaleimide (BMI) composite. Experimental results revealed that silane treatment largely reduced the friction and wear of CF/BMI composites. The silane treatment method binds organic functional groups on carbon fiber surfaces, which increase the interlock between the fiber and BMI matrix, accordingly the TPB properties of CF/BMI composite are improved. Under the same test conditions, silane treated CF/BMI composite registers low friction coefficient and wear.
The authors M. I. Faraz et al.,[17] fabricated Novel carbon nanofiber (CNF) -filled bis-maleimide composites by a thermokinetic mixing method. The thermal and mechanical properties of composites containing 1 wt % and 2 wt % CNFs were investigated. A new BMI prepolymer was reinforced successfully with CNF by using an innovative melt compounding technique. The reinforcing of CNF caused restriction of polymer chain mobility which was confirmed by the increase of the storage modulus and the glass transition temperature as measured by DMA.

Author Satoshi Kobayashi et al.,[18] studied the Microscopic damage behavior of high temperature CFRP, carbon/BMI (bismaleimide) under tensile loading was investigated experimentally.10 kinds of laminate configurations were tested at both 25°C and 180º C. Microscopic damage in laminates at room temperature were observed by optical microscopy. Microscopic damages in both [0/90°]s and [0/90°]2s laminates grow in the same manner. The number of matrix cracks increased as the laminate strain increased.

Author Pei Sun et al. (2011) [19] studied the hygrothermal aging on carbon fiber/Bismaleimide composites. The Interlaminar shear test was conducted on the samples at different temperature and it is found that the ILSS decreased with increasing temperature with hygrothermal aging attributing to the plasticization, voids, micro cracks and interfacial debonding.

Toshiyuki Shimokawa et al., [20] as part of their investigation of the potential of high temperature composite materials for the next-generation SST(Supersonic transport), the authors’ group assessed open-hole (OH) tensile and compressive static strengths at RT(Room temperature) and 120°C . The Authors further investigated the fatigue strength or S-N relationships of CF/BMI composite materials with a quasi-isotropic stacking sequence at RT(Room temperature) and 150°C. He concluded that the Furthermore, the OHT fatigue strength is less dominated by the number of load cycles, while the OHC and OHTC fatigue strengths moderately depends on the number of load cycles. An open hole greatly reduced static strength attributing to the presence of hole either for tension load or compression load which was smaller at 150°C than at RT.

C. L. Heisey et al., [22] studied the adhesive behaviour of plasma treated polyacrylonitrile based carbon fiber with phosphorous containing Bismaleimide resin composites using micrbond pull-out test. It’s been concluded that the BMI adhered well with the surface treated fiber than with the untreated fiber due to increase in surface free energy, wettability with more active site for chemical interaction with the matrix.

Bor Z. Jang, [23] improved the interfacial adhesion of the carbon fiber reinforced with Bismaleimide resin by using different gases for cold plasma treatment. He proposed that Ammonia and Ammonia/Argon plasmas provides better strengthening of fiber than the other plasma. The matrix system has Bismaleimide, epoxy with model polypropylene. The plasma polymerized polypropylene improved the adhesive strength of the matrix.

Sergey Evsyukov et al., 2019 [24] developed a ternary blend of Bismaleimide (BMI) monomers, viz m-xylxyene bismaleimide,4,4’-bismaleimidodiphendinylmethane and 2,2-4’ bissbenzophenone and o-o’-diallylbisphenol A as co-monomer is processed by Resin infusion/transfer is in the
temperature range of 90-110°C. The modified resin is used in the fabrication of carbon fiber laminate resulted in Flexural strength of 3650 Kg/cm², (157 MPa for BMI:DABA at 100:80 weight ratio [2]) with Fracture toughness of 0.63 MPa/m² mechanical properties, Tg of 285 ° C.

Yuan-Fei Fu et al. [16] used Silane surface modification method for the surface treatment of carbon fiber to improve the interfacial adhesion of the carbon fiber reinforced bismaleimide (BMI) composite. Experimental results revealed that silane treatment largely reduced the friction and wear of CF/BMI composites. The silane treatment method binds organic functional groups on carbon fiber surfaces, which increase the interlock between the fiber and BMI matrix, accordingly the Tribological behaviour of CF/BMI composite are improved. Under the same test conditions, silane treated CF/BMI composite registers low friction coefficient and wear.

Siyang Liu et al (2018) [3] investigated Bismaleimide containing Pthalide cardo and Cyano group PCBMI is mixed with o-o' diallyl Bisphenol A (DABA) for its thermal properties by varying the molar ratio of PCBMI/DABPA. The resultant composites exhibited excellent thermal stability, heat resistance and mechanical properties and also had an excellent interfacial bonding and aging resistance.

M. Simpson et al [27] reported that results of thermogravimetric analysis simultaneously done with mass spectrometry shows that the curing volatiles are entrapped in PMR -15 laminates which were post-cured with and without bagging films. These volatiles have an impact on thermomechanical response of the laminate, which increases the thermal strain with formation of thermal microcracking. The Post-cured laminates in the bagging films have more volatiles and in the case of laminate post cured in the absence of these films, the rate of desorption of cyclopentadiene lead to a variability in cross-linking density and hence thermomechanical response of the matrix through the thickness of the laminate.

S.P. Wilkinson, et al, (1993), [28] improved the toughness of Bismaleimide by thermoplastic modifier of 15 % to 20 % polyether sulphone. The modified resin was impregnated with unidirectional carbon prepreg. Mode I and mode II fracture toughness test was performed using end notched specimen. The values of \( G_{IC} \) improved from 359±17 J/m2 which is for unmodified resin to 489±25 J/m2. The interlaminar strengthening is attributed to the resin rich zone within the interlayer thus toughening the composites.

Author Jing Zhou et al.(2016), [29] stated that Mode-I interlaminar fracture toughness could be significantly improved in carbon fiber/bismaleimide composites using a microwave curing which brings about remarkable 133.5% and 61.2% increase in fracture toughness and fracture Resistance. This is due to enhanced interfacial adhesion which have big potential applications in low-cost manufacturing of high performance aerospace structures.
R. Biji et al. [30] studied the shape recovery of the carbon fiber reinforced 2,2-bis 4\{-4\{-maleimidophenoxy\}phenyl\}propane (BMIP) and Diallylbisphenol A with poly(tetramethyleneoxide)(PTMO). The ternary blend is chemically characterized with FTIR. The polymer had good shape recovery due to the presence of PMTO which increased the factor by its increasing content and showed a recovery of 88% to 98% in a minute.

Qi Yu et al., [40] studied the impact of vacuum thermal cycling on the properties of the carbon/BMI composite where they conducted tests on finding the dynamical mechanical behaviour, Flexural strength, Interlaminar Shear strength, Tg, Surface roughness and Tensile strength under different thermal cycles (48,95,198,283). The DMA showed that there is an increase in Tg from 48 cycles to 283 cycles with increase in cross linking density with a reduction in toughness and tensile strength of the composite. The Flexural strength and ILSS showed a similar trend of increase in strength to a certain cycle and decreasing after 198 cycles. The surface roughness also increased initially and decreased to further increase in thermal cycles.

Lirui Yao et al., [34] compared the interfacial adhesion of carbon fiber with epoxy and bismaleimide resin. With each of the resin system the author included three different carbon fiber which are sized, desized and partially sized. The partially sized carbon fiber showed better adhesion with improved toughness than the other two variations in the fiber with epoxy resin system whereas all the three variations of carbon fiber in BMI has shown no effects in improvement of adhesion as well the properties.

Joshua W. Ehrlich et al [55] produced carbon fiber/BMI composite with resin infusion moulding by optimizing the moulding process parameters. He studied the composites with different layups of carbon fiber and analyzed the tensile performance parameters. The layer with $[0^\circ]\_4$ outperformed than the other composite layup of $[90^\circ]\_4$ and $[+45^\circ, 90^\circ, 90^\circ,-45^\circ]\_4$ in Tensile test with increased tensile stress and strain.

Mohammad H. Haque et al [57] studied the behaviour of unidirectional carbon fiber bismaleimide composite’s weight loss through TGA and its flexural strength at 260 C in air for 3000h. The thermal ageing and the flexural strength of $[0^\circ]\_16$ outweighed the $[90^\circ]\_16$

The first specimen showed good consistency in its properties till 100h at 260 C and lost its flexural strength by 95% whereas the same amount of loss in properties is observed in the $[90^\circ]\_16$ after 1200h of thermal ageing.

2.2 Glass Fiber Reinforced modified bismaleimide composites:
Author K. Ambika Devi et al, (2008)[1] reported that the novolac epoxy (EPN)–2-2-diallyl bisphenol-A (DABA) system was modified by reactive blending with bisphenol-A bismaleimide (BMI) to improve its high temperature properties. The incorporation of BMI into the epoxy–phenol system(EPB) into glass fibers yielded a matrix system with improved glass transition temperature and comparable mechanical properties. The toughening of the system using polyether sulphone improved its mechanical properties with a marginal penalty on its glass transition temperature. The reactive blending of bismaleimide with an epoxy–allylphenol system provided a co-cured matrix system with improved high temperature resistance in comparison to the epoxy–phenol system.

E. Drukker et al, [21] studied the effect of thermal gradient in glass fiber reinforced BMI composite on the mechanical, physical and chemical properties. He conducted Interlaminar shear strength test by varying the depth to thickness ratio. The thermal gradient of 150 is introduced between the top and bottom plates and is analyzed for its interlaminar strength, glass transition temperature. Its been concluded by the authors that the at higher curing temperature the glass transition temperature increases with decrease in mechanical properties due to the micracks, brittleness due to the decrease in ether band leading to reduction in flexible link.

Author Anna Razgon et al,[36] reported that Bismaleimide polymer composites were coated with adherent, uniform, crack-free, titania films. The deposition was made on the glass fiber MBI prepreg by adopting liquid phase deposition technique (LPD). The use of Thermogravimetric (TGA) analysis revealed of the effect of such coatings and the ageing phenomenon on BMI/Glass fiber stability and the scope of finding the difference between thermo-oxidative from purely thermal degradation processes in the coated composite provided a good model for future work.

Yehai Yan et al,[37] modified BMI resin with allyl novolac which reduced the viscosity of the resin system for its use in Resin transfer moulding and impregnated with woven glass fiber. From the DSC study the curing cycle of the resin system is derived. The author compared the Flexural strength of the neat resin with fiber reinforced resin at varying temperature (Room temperature, 200 C, 300 C where the latter one proved with improved result. The modified resin provided higher glass transition temperature proving its retention at high temperature.

Yian Zhao et al, [38] studied the effect of E-glass/BMI composites immersed in sea water maintained at room temperature, 50º C and 80º C. The sample is aged in the sea water and the samples are tested for Mode I and II and mixed mode of interlaminar strength. The fracture toughness, R curve and its glass transition temperature are noted. Also J integral method is employed to determine the delamination length to avoid the discrepancy through naked eye inference. Its been concluded by the author that there is loss in properties at 80º C due to plasticisation of the matrix with initial resistance to delamination due to the same. The viscoelastic response of the E-glass/BMI [39] is studied by the author and showed that below 50º
C, the moisture absorbed dried and cured specimen rebound its Tg and its flexural properties as that of the dried sample.

Ping Liu et al [45] modified the BMI/DABA resin with polysiloxane in suitable amount and reinforced with glass fiber. The composite is tested for is wettability of resin in fiber, dielectric properties and interfacial adhesion. The resultant Glass fiber/modifies BMI (G/mBMI) showed an increase of 20-40% increased interfacial adhesion. The modified resin has Si-OH groups in polysiloxane increased the wettability of resin to fibers.

2.3 Kevlar Fiber Reinforced modified bismaleimide composites:

T. K. Lin et al [42] studied the effect of Kevlar fiber treated with chlorosulfonation/allyamine with three different bismaleimides of which BMI PP has provided proven results with IFSS at 0.2% for 150s with chlosulfonic acid treatment. At higher level of acid with greater time of exposure the composites yielded lesser results. The T peel strength has improved due to ethylenediamine introduction into the fiber, increases the reaction sites with BMI due to the presence of amino group in it.

Min Su et al [43] studied the effect of Kevlar fiber treated with oxygen plasma for its better bonding and adhesion with BMI matrix by controlling the plasma treatment power and time and optimized it. The plasma treatment Kevlar fiber/BMI has proven results in ILSS, dielectric properties and its moisture resistance. The author has given 700 W for 5 min as the optimal value for Kevlar plasma treatment.

Wei Chen et al, [44] investigated a model BMI composite with carbon nanotubes grafted Kevlar fiber for its mechanical performance. The Tensile strength and ILSS of the modified fiber has increased by 12% and 30% respectively than the original fibers.

2.4 Hybrid Fibers/ Novel fibers Reinforced modified bismaleimide composites:

Author Dong Liu et al [5] reported that, the radio frequency oxygen plasma was used to strengthen the interfacial adhesion of PBO fiber/ bismaleimide composite. The interlaminar shear strength (ILSS) was improved to 57 MPa or by 29% after treatment at 50 W. Oxygen atoms and polar groups were increasingly introduced onto the fiber surface, which contributed much to better wettability. Physical interactions between the fiber and the matrix might play leading roles in strengthening the adhesion. The modification effects did not degrade within the storage time of 1-50 days, indicating that the oxygen plasma created stable structures on the fiber surface. The composites had low water absorptions and high retentions of more than 90% in the ILSS, therefore the composites had good humid resistance before and after treatment. The author also studied the argon plasma treated.

Hao Jiang et al,[35] studied the effect of curing initiators Dicumyl peroxide (DCP) or hexamethylenetetramine (HTMA) on BMI /Allyl phenol (BAN) with and without PVA fibers.
oin reducing the curing time as well on its mechanical properties. The Results revealed that the BAN/ PAN showed less curing time with the addition of DCP along with the increased Flexural strength when compared with the HTMA initiator. Also the BAN/PVA fiber with DCP has reduced viscosity and hence improved the processability of the resin system with no holes/bubbles in the cured matrix.

L.R. Grace et al [41] studied moisture adsorption behaviour of Quartz fiber/BMI composite with three different ply of six, twelve, forty where they deviated from fickian diffusion model but well agreed with 3D HDM model irrespective of the laminate thickness. The diffusion occurs 13 times faster along the edges of the fiber rather than through the thickness. The recovery of moisture absorption parameters after 16.5 months before reaching the saturation is also done.

Joung-Man et al [31] studied the Interfacial shear strength (IFSS) of the carbon, SiC, Glass fiber/BMI with two stage and three stage curing by conducting fragmentation test on tensile and compressive test specimens with acoustic emission(AE) monitor and obtained the stress-strain curve. The three stage curing of the fibers with BMI showed an increased IFSS with a wider vertical micro cracks. The tensile mode of failure is a sharp diamond in three stage curing when compared to the dull failure observed in 2 stage curing due to its incomplete curing whereas in the compression, there is no matrix failure but the slippage of carbon fiber occurred. In the case of Glass and sic fiber there is no fiber fracture due to its high strain to failure ratio. With AE the amplitude distribution of separated and closer one in tension and compression is found respectively.

Nannan Ni et al,(2015)[13] reported that a new type of hybrid composite with aramid nonwoven fabrics (ANF) modified with semi-crystalline polyvinylidene fluoride (PVDF) between carbon-fibre reinforced bismaleimide (BMI) laminate which improved the damping properties with higher flexural modulus and loss factor simultaneously improving mechanical properties. The interlaminar shear strength of the co-cured composite with PVDF film was 26.2% more than that of the control sample. The flexural Strength and flexural modulus is 4.1% and 10.8% more than that of control samples.

Y.Z.Wan et.al [32] studied the Mechanical performance of hybrid bismaleimide composites reinforced with three dimensional, hybridized carbon(T300) and Kevlar 49 fabrics. The mechanical properties like load – displacement behaviour, flexural strength and modulus, shear strength and impact properties of the composite system were studied in room temperature and dry condition. The experimental study revealed that the flexural property increased with loading of carbon in carbon-Kevlar in the ratio of 3:2 and then dropped. The maximum strength of 665±33.3MPa and highest flexural modulus of 42.5±1.4GPa at carbon-Kevlar ratio of 3:2 was observed.

3 Conclusion:
The potential modification of the resin and its incorporation in different fiber with an extent of different manufacturing processes opened a greater scope of future work for researchers in developing Novel material as well as Novel composites for advanced applications.

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