# A REVIEW OF IMPACT BEHAVIOUR IN COMPOSITE MATERIALS

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**Abstract** - The damage of composite structure caused by impact events is one of the most critical damages that have been caused several design problems. Understanding damage and failure of composite materials is critical in order to produce a reliable and cost-effective design. Generally, the character of impact response influences the extent of structural degradation and type of damage. Therefore, it is important to identify the properties and physical parameters that determine the nature of impact response. We need to detect, characterise, size and localise the impact damage. This study presents types of damages in composite materials, impact damage and its classification in composite materials.

**Keywords** - Impact, Damage in composite materials, Acoustic Emission, Composites, Failure,

## I. INTRODUCTION

In the last decade, researchers have studied the effects of impact damage on the damage tolerance of composite structures that has been revealed several design problems. Several distinct features of composite materials make them to be essential materials in aerospace and automotive such as; excellent damping characteristics, light weight, resistant to corrosion destruction and stress-free attainment of complex forms. Understanding damage and failure of composite materials is critical in order to produce a reliable and cost- effective design. It is important to understand the damage mechanism in order to improve composite design structure and also choose method that minimizes costs of all operations. One of the most critical behaviour in composite structure is damage caused by impact events. There is several published work that considers about different type of impact on the edge and near the edge of composite structure [1-3] which might produce some severe damage in the centre of composite structure [4-6]. Damage refers to the collection of all irreversible changes in the materials brought by a set of energy scattered chemical or physical processes, resulting from the application of thermomechanical loadings. Generally, the character of impact response influences the extent of structural degradation and type of damage. Therefore, it is important to identify the properties and physical parameters that determine the nature of impact response.

## II. COMPOSITE MATERIALS APPLICATION IN AIRCRAFT

A composite material is a combination of two or more constituent materials which produces properties and characteristics and retains their individual characteristics as they act together. One of these constituents is called matrix and the other major components are reinforcement in the form of fibres or particulates to improve the matrix properties. The matrix of a composite can be a polymer, a metal, or a ceramic, and fibre categorised to Fibreglass, carbon, Kevlar, Natural fibre and etc. Composite structures are designed for a purpose; for example if the structure is supposed to work over a period of time, then the design must meet its functionality without losing integrity over that period; or if it expected to carry loads, then the structure must has sufficient load-suffering capacity. Based on the composite materials, designers enable to use optimum combination of resin and fibre reinforcement to develop a material designed for a particular application (Fig.1).

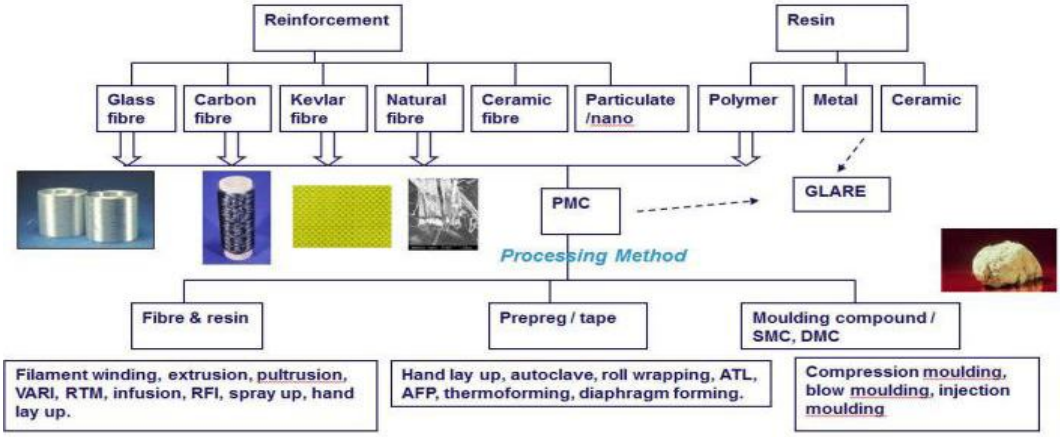



**Fig.1. A wealth of design option [7]**

Composite offers distinct features such as stiffness and strength characteristics, the absence of corrosion which leads to reduce the cost of the maintenance, low weight, simple design and lower energy consumption. These superior specific features make the composite materials distinctive compared with metals. As the composite structures are combination of the high strength and low weight, and since in aircraft and space product applications, one of the critical parameters in determining performance is the weight of structures, in the past few decades, the use of composites in structural applications has been increasingly used in aerospace and advanced transportation industries (Fig.2) [8-11].

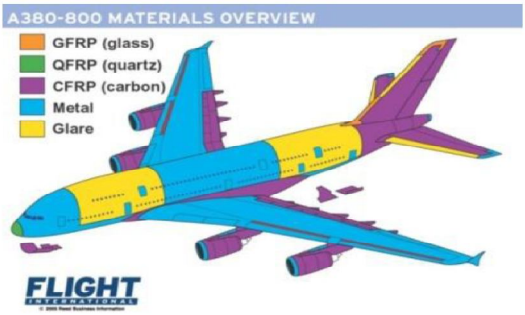



**Fig.2. Typical composite structures used in A380-800 commercial aircraft [12]**

The early use of composite materials in the aircraft industry dates back to the late 1950s and started with aircraft like the 707 and later DC-9 [13]. In the mid-1960s and early-1970s, due to high performance and high safety standards, composites were developed and applied in the aircraft on the empennages of the F-14 and F-15 fighter aircraft [14]. Carbon replaced fiberglass in the 1970s, although fiberglass was retained for many interior parts and fairings [13]. Carbon/epoxy was used for the speed brake in the fighter aircraft F-15 [15].

In the 1980s, one of the first high-performance composite materials was introduced on the 737 horizontal stabilizers and underwent extensive testing and in-flight evaluations [13]. In the mid-1990s, composite vertical and horizontal stabilizers for the 777 were developed, designed, and implemented into production, gathering the benefits of lightweight structures and improved aircraft performance [13].

In the early 2000 to 2013, composite materials were used in wings, stabilizers and fuselage barrels. Fing.3. depicts evolution of composites application in aerospace since 1970 and Fig.4.shows the percentage of composite materials in airframe since 1940 and

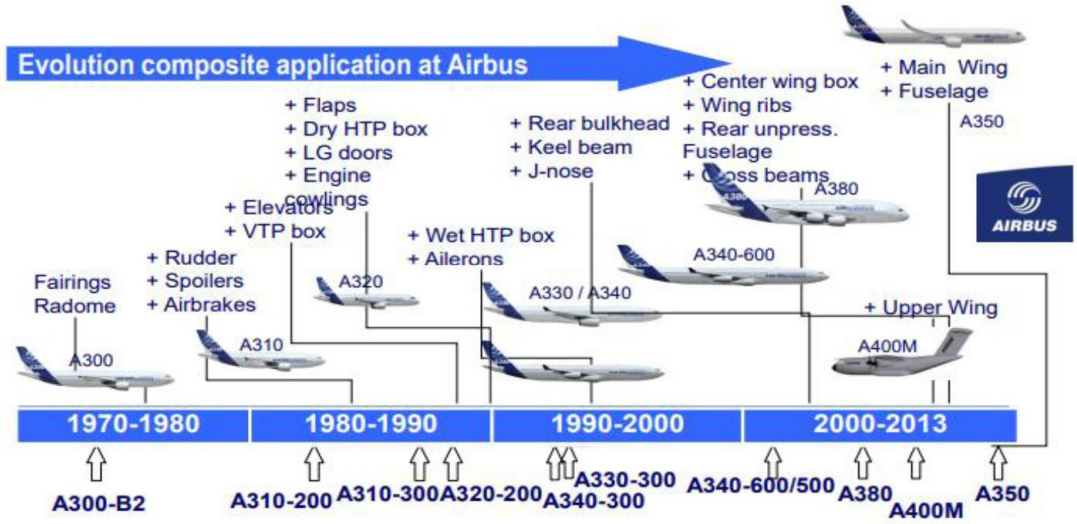



**Fig.3. Growth of the use of composite structure in aerospace [7, 13]**

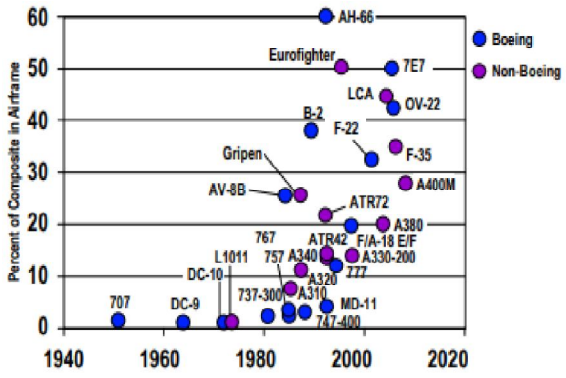



**Fig.4. The percentage of composite materials in airframe**

## III. DAMAGE IN COMPOSITE MATERIALS

Damage refers to the collection of all irreversible changes in the materials brought by a set of energy scattered chemical or physical processes, resulting from the application of thermomechanical loadings. Generally, damage mechanics deals with condition from initiation to distributed changes as well as the consequences of those changes on the response of the material to external loading [16-18].

Material flaws are the major sources of composite failures. Conventionally, fracture is known as a “breakage” of materials that can be manifest in the

basic forms of matrix cracking, fiber-matrix interfacial debonding [19-22], fiber fracture [23-25], fiber pull-out and separation of bonded plies (delamination) [26-28]. Fig.5. shows a schematic description of damage development in composite materials, although five recognizable damage mechanisms are shown on the basis of fatigue experiments [16], it provides the basic details for quasi-static loading as well.

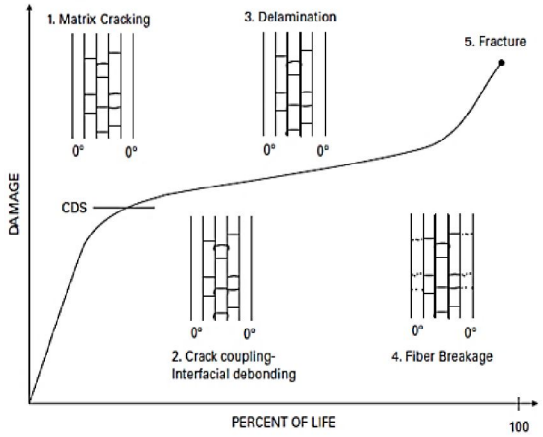



**Fig.5. Development of damage in composite laminates [16, 29](characteristic damage state :CDS)**

The field known as fracture mechanics deals with conditions for formation and enlargement of the surfaces of the material separation [16, 30-32]. The inability of the materials to perform its design function is knows as a failure. Fracture is one of the examples of possible failure. In reality, the failure event in a composite structure is influenced and ahead of the progressive incident and interaction of various damage mechanisms [16]. If the materials remains intact and functional and retain adequate properties under loading, it means it contains the structural integrity and durability. Fig.6 presents a durability analysis of composite structure [16].

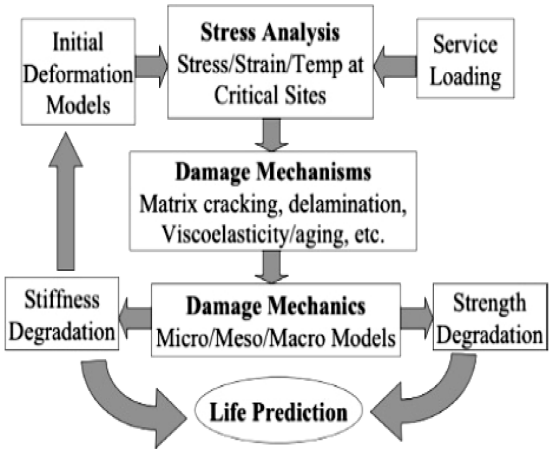



**Fig.6. A durability analysis scheme for composite structural components [16]**

The intralaminar damage is observed during the initial stages of the failure process in the form of matrix cracks. Matrix cracking is initiated long before the laminate loses its load-carrying capacity and gradually reduces strength of the laminate and the stiffness [33, 34]. In-service aircraft impact is considered as loads which may lead to an outsized internal damaged area of the laminate that is not detectable from visible observation. Fibres are able to absorb significant amount of energy in which the primary energy absorbing would be passing into failure of impacted composite laminates [35].

## IV. IMPACT ON COMPOSITE MATERIAL

Modern polymer composites based on carbon, glass, ceramic, aramid or polymer fibre in a polymer matrix are anisotropic and heterogeneous materials. They have a high strength and stiffness and low density and therefore excellent specific properties. Generally, materials with matrix properties dependent are much lower than those which are governed by fibre, however, matrix has an important role in composites behaviour; transferring stress, protecting fibre, and in some cases moderating brittle failure by providing alternative route for crack growth [36] .

Based on the characteristics of the structure and impactor, the impact response can vary in nature, i.e dynamic, quasi-statics and half-space. Generally, the character of impact response influences the extent of structural degradation and type of damage. Therefore, it is important to identify the properties and physical parameters that determine the nature of impact response. Many studies concerned impact modelling [37-39], damage monitoring [6, 40, 41]and the assessment of the post-impact residual properties [42-44].Mylsamy and Rajendran[45]founded the impact resistance value of 1.53 J in agave fibre epoxy composite with matrix crack growth.

It has been concluded that good chemical bonding between fiber and matrix led to improvement of the impact strength, flexural strength and flexural modulus of the composites. Sanjay et al.[46] evaluated the impact behaviour in hybrid composites by comparing laminates with different composition. The highest impact strength with 6J was founded in hybrid laminate. Abdul et al. [47] founded that the higher strength of glass fibers led to higher impact strength in glass/oil palm empty fruit bunches hybrid polyester composites. Hande and Omer [48]revealed that by adding high impact resistant fibres in outer layer, and placing high tensile strength fibres at the inner layer, higher impact values and tensile strength of composite materials can be attained respectively.
Generally, we need to detect, characterise, size and localise the impact damage. Characterisation refers to the different types of damages that is induced by impact in the composite materials which is most frequently caused matrix cracking, fibre fracture and delamination (Fig.7) [49, 50].

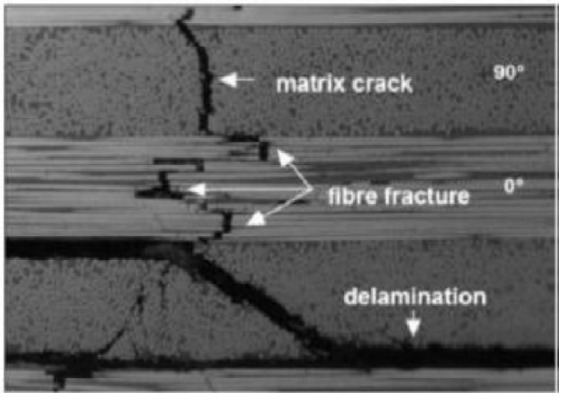



**Fig.7. Types of impact damage in the fiber-reinforced laminates [50, 51]**

Impact is a dynamic event which may involve a high contact load acting over a small area for a very period of short time [50]. During the operation of a composite structure impact is observing frequently. For instance in high-speed trains the front cab can suffer damage from objects such as birds or other animals or boulders. Although impact damage is non-visible, it affects the mechanical properties of composite that has to be taken into account and the proper evaluation should be performed.

Determining the effects of impact damage may be divided into two areas:

1) impact damage resistance which is related to the response and damage caused by impact [52, 53] , and

2) impact damage tolerance, associated with the reduced stability and strength of the structure due to the damage [54, 55].

The impact process can be characterised by the velocity of the rocket or the kinetic energy. Composites are sensitive to impact load, as they absorb impact energy mainly through fracture mechanics, rather than elasticity and plasticity [50]. Impact is two or more bodies collision, where the interaction can be plastic, elastic, fluid or any combination of these [56]. One of the fundamental quantities in impact dynamic is impact velocity [57].Generally, there are four types of velocity [58]:

- Low velocity
- High velocity
- Ballistic
- Hypervelocity

### 4.1. Low Velocity Impact (LVI)

Low velocity impacts does not always result in the puncturing of the composite and are expected to take place during life of the structure and manufacturing [49]. It can be occurred in the range 1-10 m/s depending on material properties, stiffness and projectile mass. When the time of impactor contacts is longer than the time for the lowest vibrational mode, low velocity impact happens [58]. Delamination and matrix damage area is proportional to the impact energy in LVI. Tougher materials have higher impact resistance than brittle; in fact, the higher toughness the lower delamination and matrix cracking. Typically, delamination occurs between plies of different orientation, and raises in size with thickness and mismatch angle of the plies (typically on 0°/90° or 45°/-45° interface) [59]. R.Mathivan and J.Jerald[60] characterized the type and extent of the damage with different impact velocity in the laminate for a range of thickness. Liu et al. [61] explored the effects of different failure criteria on the dynamic progressive failure properties of carbon fiber composite laminates. The results showed the consistent energy dissipation and impact responses using three criteria, except some difference in damage features for matrix cracking and delamination [62, 63].

There are several different techniques for testing composites using low velocity impact testing. Table.1 depicts the types of low velocity impact tester that are commonly used in research studies.

**Table.1.Types of low velocity impact tester [14, 64]**

| Methodology | Main Function |
|---|---|
| Izod and Charpy Impact Test | |
| By placing a notched specimen into a large machine with a pendulum of a weight. The pendulum is raised up to a certain height and allowed to fall. As the pendulum strikes, it impacts and breaks the specimen, rising to a measured height. | i. To test the impact toughness of the material<br>ii. To compare composites with different layups, including woven and unidirectional laminates. |
| Drop Weight Test | |
| A mass is raised to a certain height and released, impacting the specimen. | To test the impact behaviour of composite plates. |

Both Charpy and Izod impact testing are popular methods to determine the impact strength, or toughness, of a material. The clearest difference between Charpy and Izod methods is the specimen positioning. In the Charpy test the specimen is upheld as a horizontal beam, while in the Izod specimen is placed in a clamp in which the pressure of the clamping is one of the most influential factors in Izod impact strength measurement [65]. Denise et al.[66] performed three point bend, tensile, and Izod impact tests on aligned and continuous piassava fiber reinforced epoxy matrix composites. Jean Igor et al. [67] studied the resistance to impacts of polyester matrix composites and analysed the Izod impact resistance improvement with the inclusion of malvafibres. Glória et al. [68] evaluated the Charpy impact energy of epoxy matrix composites reinforced with up to 30% of giant bamboo fibres, and direct relation between incorporated fibre and exponential energy has been revealed. Rajbut et al. [69] used a drop-weight rig (DWR) for testing the impact response of laminated composite materials. González et al. [70, 71] presented finite element simulations ofdrop-weight and the compression after impact test in polymer–matrix composite laminates reinforced by unidirectional fibres.

### 4.2. High Velocity Impact

More severe damages is provided by high velocity impact which could lead to the immediate failure of the material and can be occurred in the range of 10-100 m/s [14]. A high velocity impact (>11 m/s) takes

place through sources such as: debris from the runway hitting the fuselage during take-off or landing, ice from the propellers striking the fuselage, hail, and bird strikes [58]. Composites are used in aircraft and land-based vehicles as a high survivability materials against impact from turbine blades, wrecking engine parts and other debris [14]. If the duration of the impactor is much smaller than the time period of the lowest vibrational mode to reach the structural boundaries, high velocity impact occurs [58]. Under the low velocity impact and static test conditions, damage extends over a wide area and is associated with shear-out damage, whereas under high-velocity impact conditions, damage is highly localised close to the impact zone and it is related to fibre tearing at the rear surface of the target sample and the pull out of material at the frontal surface. Therefore, in LVI the boundary conditions play a significant role, depending on the projectile-target contact duration [72].

Impactor with velocity up to 2500 m/s, will result in fibre breakage and perforations in specimen, and impactor with speed between 5 m/s and 15 m/s (low velocity impact), or with impact energy in ranging from 0 J to 5 *1025 J, the laminate usually experiences matrix cracking and delamination which is invisible damage [73].

Moallemzadeh et al. [74] described the influence of tension, compression and hybrid preload on E-glass/polyester composite plates under high velocity impact loading in a velocity range of 185 to 235m/s. Delamination and fiber fracture founded as a major fracture modes followed by matrix fracture. On the other hand, Schueler et al. [75] founded no perforation in specimen under impact velocity of 70-105m/s by investigation of the effect of uniaxial compression and tension preloads, on damage behaviour of carbon/epoxy prepreg panels. It has been determined that material properties affect the composite material performance for both categories; low velocity and high velocity impact [76]. Thus, four different stages based on the effect of the material properties during the impact damage process has been found by Dhakal et al. [77].

Stage 1 showed rapid load increase without visible damage, followed by matrix cracking in stage 2. The matrix cracking in stage 2 distributed rapidly and led to stage 3, which is interfacial debonding. In last stage, stage 4 the material experienced fibre breakage, delamination and perforation [78]. F.Chen et al. [79] presented a details of the impact behaviour of different fibre reinforced composites; laminates, three-dimensional (3D) woven fabric reinforced and non-crimp fabric (NCF) reinforced composites in which 3D woven composites showed the best damage resistance and tolerance in low-velocity impact (Fig.8.), while NCF composites had superior damage resistance in high-velocity impact. Laminate composites have the best in-plane mechanical properties (Fig.9.).

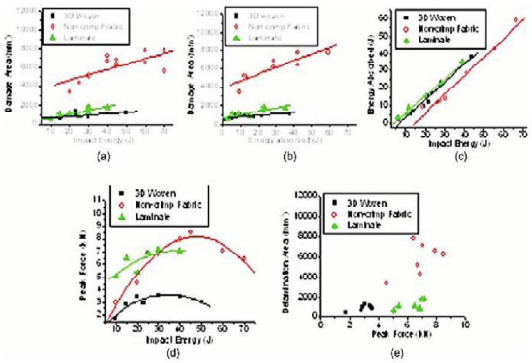


**Fig.8. Comparison of three materials in low-velocity impact: (a) damage area vs impact energycurve; (b) energy absorbed vs damage area curve; (c) energy absorbed vs actualimpact energy curve; (d) peak force vs impact energy curve; and (e) delamination areavs peak force curve[79]**

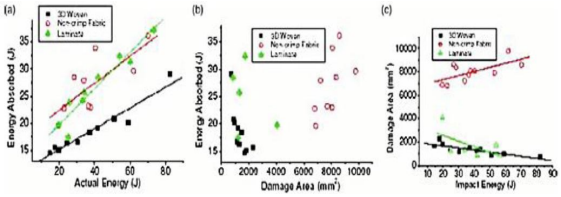


**Fig.9.Comparison of the three materials in high-velocity tests: (a) energy absorbed vs actualimpact energy; (b) energy absorbed vs damage area; and (c) impact energy vsdamage area[79]**

Some studies investigated experimentally on low and high-velocity impact behaviour of composite materials which are important and provide essential information [80-82]; but since impact phenomenon depends on plenty of parameters, and an extensive knowledge of its influence on materials requires a broad test programme which is time-consuming and expensive, therefore other researchers used analytical models [83, 84] and numerical [85, 86], to analyse the perforation of composite structures which is critical to reduce cost and time in design processes. However, most recent investigations have been the combination of both numerical and experimental model [82, 87].

### 4.3. Ballistic Impact

A shorter time of applied load (the projectile-target interaction time) to the materials when compared with LVI load time is known as ballistic impact [72]. It can be occurred in the range 50-1000 m/s [14]. Damage caused by ballistic impact (>500 m/s) is normally concerned for military applications [58]. Ballistic impact culminates in two damage threats:

1) damage to a target (e.g., helicopter skin); and
2) damage to behind-target objects due to after perforation wreckage that can carry high kinetic energy [72].

Ballistic tests are executed in gas gun facilities on ballistic ranges. Law-Enforcement Applications [88, 89], and ballistic testing methodology [90, 91] are an example of a ballistic range and layout. Earlier tests contained area of high explosive (HE) shells; Fragments size and weight information was recovered from the post-mortem analysis of witness plates or

packs [72]. Recently, high explosive incendiary (HEI) rounds are designed to release a deadly combination of blast pressure upon explosion and metal segments [92, 93]. Studies [93-95] found stainless-steel composite metal foam (CMF) as a superior substance for shielding that is currently used by the military. Fig.10 portrays a comparison of stress distribution in CMF and aluminium panelsin same thickness and mass.

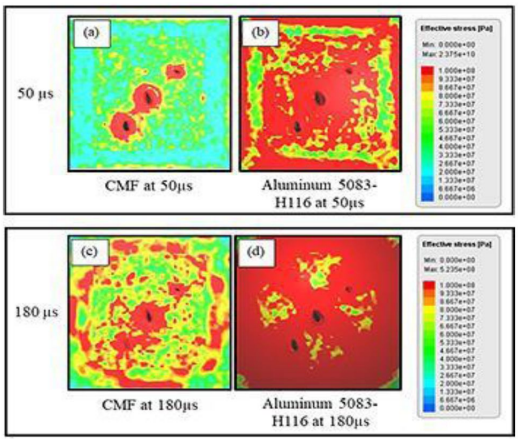



**Fig.10. Comparison of the stress distribution in CMF (a,c) and aluminum 5083-H116 (b,d) panels upon interaction with blast wave and fragment impacts resulted from HEI round at 50 µs (a,b) and 180 µs (c,d))[94]**

Rasuo and Bosko[96] analysed the survivability of a heavy transport helicopter tail rotor blade made of composite laminated materials after ballistic damage made by the bullet of 7.9mm calibre shoulder weapons. Fig.11. shows the typical ballistic damages to the helicopter windshield and the characteristic damage after ballistic impact on the rotor blade and tail rotor drive shaft[96, 97]. Since helicopters are highly vulnerable and greatly exposed to the threats due to their low speed, their vertical take-off and landing , flight altitude, etc; they are given special attention and are characterised by high frequency under impact loads and damage [50, 96].

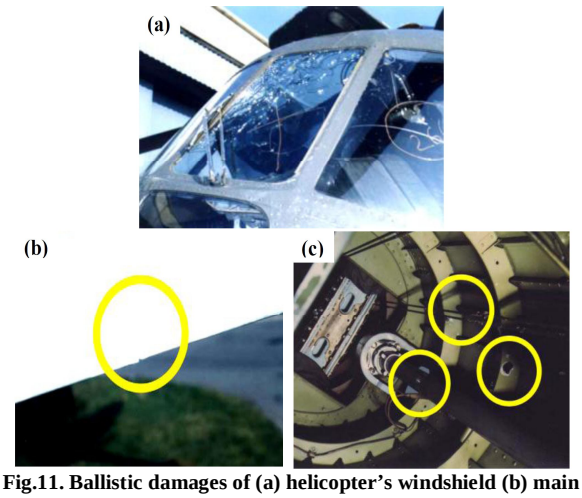



**Fig.11. Ballistic damages of (a) helicopter's windshield (b) main rotor blade (c)tail rotor drive shaft and vicinity structure[96]**

There is a connection between the material mechanical properties and the ballistic performance. Researchers evaluated ballistic performances as a function of fibres mechanical properties in composite armors made up of Kevlar 29 fabrics impregnated by thermosetting resin [98], Kevlar fabrics with polypropylene (PP) matrix [99], woven fabric in an epoxy matrix which was enhanced by carbon nanotubes and milled fibres [100], and hybrid thermoplastic composite armors reinforced with Kevlar and basalt fabrics [101].Also, there are some attempts that is targeted some geometrical characteristics of the damage zones to relate damage properties and the ballistic resistance of composite. For example N.K.Naik and P.Shrirao[102] compared ballistic impact behaviour of plain weave E-glass/epoxy and twill weave T300 carbon/epoxy composites. Different damage mechanisms and energy absorbing have been identified during ballistic impact.

### 4.4 Hypervelocity impact

In the hypervelocity impact, projectile energy is more dominant than its shape. Nevertheless, the impact energy concentration can be varied and some projectile shape influences can be found in this velocity range as well. For example, hypervelocity impact against Kevlar fabric was considered by Hayhurst[103]. It is necessary to understand both impactor and target materials behaviour under hypervelocity impact, in order to understand the damaged evolved, because each material has different reaction in different condition. Li [104] demonstrated a high resistance respond of porous materials to hypervelocity impact. Hypervelocity impacts are typically occurred in the range of 2km to 5km [14, 105]. Aerospace industry velocity of >2km/s are met in either pure hypersonic flight such as Space Shuttle orbit and re-entry or military applications such as proposed anti-ballistic missile (ABM) technology [105, 106].

Different studies considered the response of composite materials to hypervelocity impact [107-109]. For example Xue et al. [110] considered hypervelocity impact behaviour on SiC coated C/C (SiC-C/C) composites under 2km/s to 3km/s impact velocity. Later the same authors [109] revealed the residual length of carbon fibre reinforced carbon (CC composite) under hypervelocity impact and the correlations between the impact direction, damage distribution, and the residual flexural strength of the composites has been detected. The most common techniques that are used in studies to achieve hypervelocity experimentally, can be categorised as Electrostatic dust accelerators, Plasma accelerators, Light gas guns, Shaped charges, Exploding wire/foil accelerators [105, 111, 112].

High-velocity impact usually causes more damage, larger transverse deflection, and even perforation. There are two criteria that are used to distinguish a

low-velocity impact from a high-velocity one. One is based on the structural deformation and damage and the other on the structural response[113]. Fig.12. shows solution methods for different category of impact.

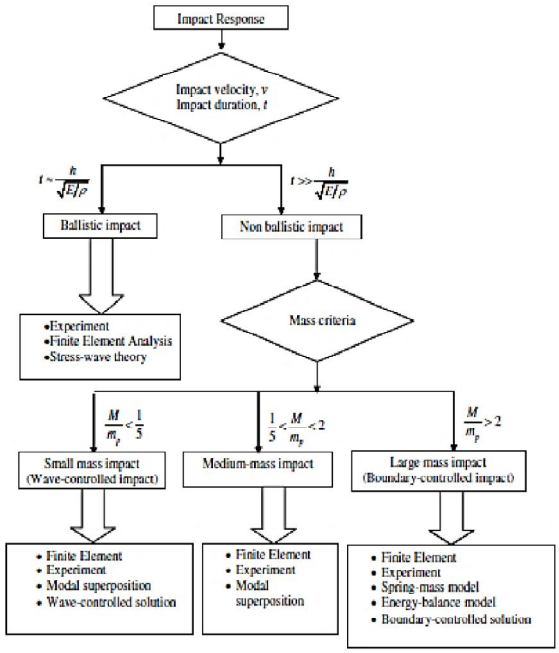



**Fig.12. Solution methods for different category of impact[113]**

## V. THE INFLUENCE OF VARIOUS FACTORS ON IMPACT CHARACTERISTICS

### 5.1. Projectile shape and mass

The impact characterization involves many parameters related to both the impactor characteristics such as shape and mass and the target material [114, 115].Based on the materials and degree of deformation during impact loading, the projectiles is categorised into three parts; soft, semi-hard or hard. Soft projectiles endure significant deformation during impact, semi-hard projectiles experience some deformation, while hard projectiles undergo small or negligible deformations and the response is controlled by the target response [58]. C.Evci and I.Uyandıran[116] investigated the effect of temperature and impactor diameter on the impact behaviour and damage development in balanced and symmetrical CFRP. Both low and high temperatures affected the properties and impact behaviour of composite materials.

The results showed direct relation between the increase of the delamination area, the threshold of penetration energy, main failure force, and impactor diameter at all temperature levels. As the temperature was lowered, the penetration threshold energy decreased. Sheikh et al. [117] studied the projectile velocity variation on multiple glass fiber reinforced laminated panels during ballistic impact. While Zhu et al. [118] examined the projectile velocity, acceleration and damage in basalt/vinyl ester composite. The result showed that the residual velocity increases with occurrence velocity after ballistic limit.

The perforation behaviour of unidirectional glass fiber reinforced cross ply laminate experimentally and with finite element analyses with different projectiles nose shapes such as ogival, conical, spherical and blunt was examined by Ansari and Chakrabarti[119] , and concluded that the thick composite plate was targeted in more damage compared to the thinner target plate due to ballistic impact for all types of projectile shapes. As the projectile nose shape changes from conical to blunt followed by ogival and spherical, the ballistic limit of the projectiles for all thicknessesand damage in the target increases. Fibers on the back surface have eroded in case of impact by blunt projectile than the other nosed projectile. The amount of damage in the target plate increases with increases in the incidence angle of the projectile. Mohan and Sundareswaran[120] evaluated energy absorbed, the ballistic limit and the damage area caused by different projectile nose shapes on the composite plates made of glass fibre and vinyl ester resin with the orientation of (0/90)s, and found that the truncated conical nose shaped projectile resulted in highest ballistic limit and largest damage area dominated by delamination.

### 5.2. Material properties

Both fiber and matrix properties influence the impact and damage tolerance of composite systems. Fibres provide the composite the majority of its strength and stiffness and play the main role in load-bearing constituent. Glass, carbon and Kevlar are known as the most common fibres. Carbon has the highest strength and stiffness values and is widely used in aircraft industry and many structural applications. However, it is also the most brittle with a strain to failure of 0.5 to 2.4% (Carbon's design ultimate allowable strain is only 0.4% currently). On the other hand, glass fibres have a higher strain to failure around 3.2% and also have a lower strength and stiffness and are less expensive than carbon fibres [121]. One or combination of the following composite materials is used in aircraft as shown in Table.2.

**Table.2.Composite materials [14]**

| Materials | Application |
|---|---|
| Carbon/epoxy | Used in primary structural and skin material |
| Kevlar/epoxy | Used in military applications, usually in primary structural and armour plating |
| Glass Fibre | Used in structural and skin material |
| Glass/phenolic | Used in interior fitting, furnishing and structures |
| Boron/epoxy | Used in composite repair patches, older composite structures |

The role of the matrix is to bind the reinforcement together so that the applied stress is distributed among the reinforcement and to protect the surface of the reinforcement from being damaged.Three major classes of composites based on their matrix phase have been shown in Table.3.

**Table.3.Classes of composites [14]**

| | |
|---|---|
| Polymer Matrix Composites (PMCs) | PMCS, also known as fibre reinforced polymers (FRPs), or resin-based composites (RBCs). For the matrix, it uses a polymer-based resin and fibres as the reinforcement. |
| Metal Matrix Composites (MMCs) | MMCs are advanced materials because the material properties - such as corrosion resistance, high stiffness and high strength-to-density ratio, and sometimes special electrical and thermal properties - are combined. This material is progressively used in the automotive industry, it uses a metal matrix and reinforcement made of advanced ceramic fibres. |
| Ceramic Matrix Composites (CMCs) | CMCs are used when a material that can sustain both high temperature service and corrosion resistance to harsh environments is needed. It uses a ceramic as the matrix and short fibres or whiskers as the reinforcement. |

Wang et al. [122] showed that graphite/PPS composites can be improved to the overall impact resistance of the material by addition of glass fiber plies. The maximum tolerated load and absorbed energy were found to increase with larger percentages of glass fibres. Morton et al. [123] compared the damage resistance of nine composite materials and showed that brittle systems have a higher damage area growth rate and lower threshold velocities than materials including a toughened matrix. Cantwell et al. [124] found that the damage in thin specimens is initiated in the bottom layers, whereas in thick specimens is begun on the top layers. They have shown that the critical force increases with the indenter diameter and is more significant in thinner laminates.

Mechanical properties of the matrix, fibers, and the fiber-matrix interface each have a particular effect on the residual compressive strength of impact-damaged composites. Chen et al. [125] showed that impact damage reduced the compressive strength of thin walled composite struts by a maximum of 45-55% when a graphite-epoxy material system was used. With a toughened epoxy matrix, the maximum strength reduction was approximately 10%.ChircorMihael et al. [126] investigated impact behaviour of composite materials with different types of measurement. They showed that in low velocity impact resistant the obtained deteriorations decrease as the resins' stiffness increases in all examined materials, though glass-epoxy bars have a high deformability before they break.

In medium velocity impact resistance showed considerable changes in Kevlar and carbon fibre composite after compression pre-stressingwhile raw materials remained with no changes (measured with C scanner). Carbon fibre performance was depends on fibre resistance, it showed better behaviour with higher fibre resistance. In high speed tests fiberglass multi-layered materials experienced a much bigger delamination compare with carbon or Kevlar fibres but, in an impact with a 5.56 mm perforating bullets/ missiles, they absorbed twice the energy.
Fig.13 illustrates delamination area of different type of fibre.
A comparative impact resistance of some fiber reinforced multi-layered composite that often used in the industry, presented in Fig.14.

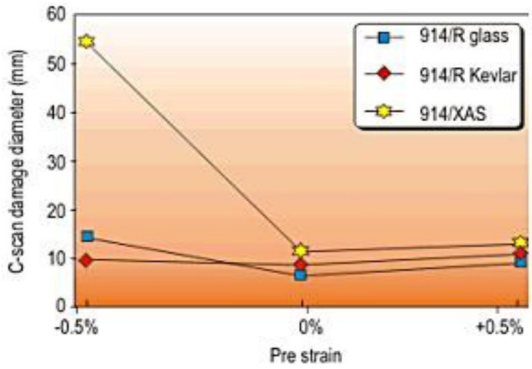



**Fig.13. Delamination area depending on extension/compression pre-deformation**

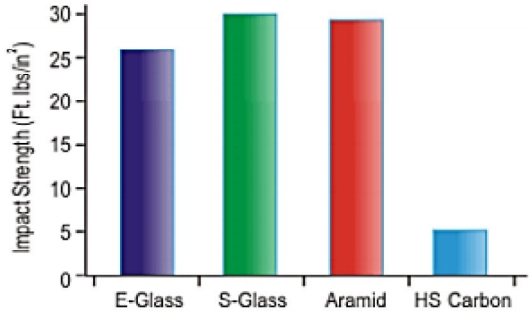



**Fig.14. A few impact resistance**

## CONCLUSION

In this contribution, the application of composite materials and their efficiency in aircraft industry and other cases was considered.The materials classification based on their properties and characters was explained and the impact behaviour on different types of material has been investigated. The modes of impact damage derived range from matrix crackingand delamination through to fibre failure and penetration. Damage modes interaction, types of velocity, and influence of various factors on impact behaviour must be considered and understood to predict any failure in composite materials.

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