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A Study on Testing Techniques and their Consequences on Excavator Engine Hood Durability

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Abstract

Composites have found their way into almost every industry. This paper provides a critical overview of the impact of testing behaviour on the performance and design of excavator engine hoods. It examines how various testing like tensile, flexural, density, water absorption, flammability, etc., methodologies and procedures influence the durability, efficiency, and overall functionality of engine hoods, which are crucial components in construction machinery. By analyzing different testing approaches, including their methodologies, criteria, and outcomes, the study aims to identify key factors that contribute to the optimization of engine hood design. The paper highlights the importance of rigorous testing in ensuring the reliability and safety of excavator engine hoods under diverse operational conditions. Through a detailed review of current practices and their implications, this overview seeks to offer insights into improving testing strategies and advancing the development of more robust and efficient engine hood solutions.

Major Findings: *This paper major findings highlight the significance of thorough testing for dependability and safety in construction equipment by examining the effects of different testing approaches on the functionality and design of excavator engine hoods.*

Keywords: Excavator Engine Hood, Machinery Efficiency, Mechanical Testing Protocols

1.0 Introduction

Sustainability is a major focus within the manufacturing sector. To reduce weight and cost, companies are increasingly using composite materials instead of traditional materials. Polymer composites offer exceptional electrical, thermal, and mechanical properties, enabling a wide range of exciting applications across various sectors. Key benefits of polymer composites include low weight, low cost, environmental stability, corrosion resistance, easy processing and fabrication. Fibres are commonly added to polymer matrices to enhance their physical and mechanical properties, with a particular emphasis on improving the mechanical characteristics. Traditionally, inorganic fibers have served as fillers to enhance the mechanical properties of various polymers, both organic and inorganic. However, the vast selection of fiber types and polymer formulations available can render the process of identifying the most suitable combinations for specific applications both complex and expensive[1-3]. It has long been known that Glass Fibre (GF) and Carbon Fibre (CF) can enhance the electrical properties of polymers. However, it can be difficult to determine which mix of fibers and polymers is best for a given application due to the vast array of options available. When compared to more traditional materials like metal, natural materials frequently have unique qualities. Composite materials, though not a new concept, emerged as a distinct discipline in the 1960's. Since then, industries have increasingly sought out stiffer, stronger,

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and lighter materials. By combining different materials into integrated composites, designers can create tailored solutions with enhanced performance levels unachievable through individual components alone[4,5]. Although they have been successful in reducing weight, the main obstacle now is making them affordable. To address this, creative manufacturing methods are being employed, but it is clear that technological progress alone is not enough to overcome the cost challenge. A comprehensive approach that includes design, material processing, tooling, quality assurance, manufacturing, and program management is necessary for composites to compete with metals in terms of cost-effectiveness. Therefore, other strategies that prioritise evaluating the mechanical characteristics of composites immediately prior to performing tensile, compressive and shear testing are typically used. As such, a detailed analysis is necessary to assess the properties of anisotropic and heterogeneous composites[6,7]. Many tests, models, and experiments from various disciplines are required for the study of composite data. This paper offers a critical overview of how various testing behaviour impact the design, durability, and performance of excavator engine hoods. By examining testing protocols, procedural variations, and their direct and indirect effects on engine hood performance, this study aims to provide insights into optimizing testing practices to enhance the overall effectiveness and resilience of excavator engine hoods. Through a detailed analysis, the paper seeks to highlight key areas where testing methodologies can be refined to ensure that engine hoods meet rigorous performance standards and adapt to evolving industry demands.

1.1 Tribological and Mechanical Tests Needed for Hood Preparation

Accurate excavator engine canopy measurements promote lightweight component manufacture visually. To determine whether the material is acceptable for the engine bonnet, samples must be made after processing.

Table 1. Results by various researchers related to hood[8-13]

Reference	Investigation on	Comparison with	Fiber Used	Weight Reduction (%)	Result
8	Pedestrian head injury in a collision	Aluminum and steel	Carbon fibre and glass fibre	42.6 and 46.8	Growth within the hood thickness has greater effects on middle locations compared to adjacent locations.
9	Front hood of small electric vehicle	Steel	Carbon fibre	22	Enhancement up to 62% in the transversal and torsional stiffness when compare with steel hood.
10	Automobile hood	Conventional steel	Long carbon fibre non-woven	37	Better lateral and torsional stiffness compared to conventional steel with reduced bending stiffness.
11	Inner and outer hood panel	Steel	Carbon fibre	33	Good stiffness with excellent energy absorption properties.
12	Marine engine hood	Aluminium	Glass fibre	30	Improvement in the mechanical properties with the addition of fire retardant material.
13	Car engine hood	Steel	Carbon fibre	24.4	Excellent dynamic stiffness performance

Tensile, flexural, density, wear, water absorption, flammability, heat distortion, thermal gravimetric analysis, charpy impact, izod impact, environmental, and hardness tests must be performed on the manufactured material. During assessments, samples should be made according to ASTM standards. The tests, sample size, and standards are outlined below. Table 1 presents results from many publications.

2.0 Test Details and Sample Dimensions

2.1 Tensile Test

A fundamental material science and design test, tensile testing, also referred to as tension testing, applies controlled strain till failure. A straight forward method for determining breaking strength, stiffness, extension, and region decreasing is the malleable test, this calculates Young's modulus, strain hardness, yield strength, and Poisson's percentage. Universal testing equipment is typically used for tensile testing. The power and expansion of the sample were monitored until the measure length breaches, where it entirely collapsed. Composite strength and modulus were determined using a quality technique. Each composite type had seven evaluations, and standard discourse criteria were applied[14,15].

The specimen size and crosshead speed were obtained using ASTM D3039[16]. Figure 1 shows specimen dimensions. This test determines the in-plane tensile properties of high-modulus fiber-reinforced polymer matrix composites. Continuous filament or staple fiber reinforced composites are the only allowed composites when the laminate is symmetrical and stable in the test direction[17]. The machine elongates the test sample till it breaks. The equations below show that this approach records elongation and tension[18]. Table 2 lists the tensile strengths of several materials. Many specialists are looking for new combinations to improve the material's tensile strength.

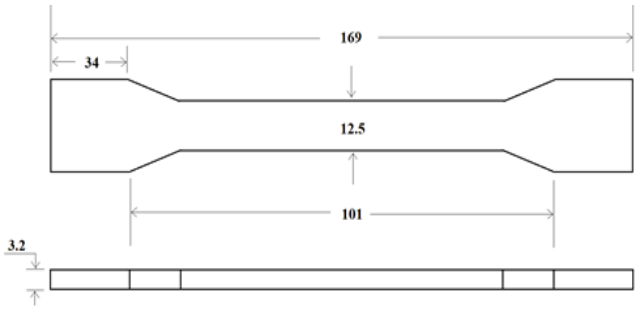


Figure 1. Tensile test specimen drawing with ASTM approved dimensions[16].

Table 2. Tensile strength of various types of material[21]

Material	Tensile strength (GPa)
Whisker	27
Graphite	20
Silicon nitride	5-7
Aluminium oxide	10-20
Silicon carbide	20
Aluminium oxide	1.38
Aramid	3.6-4.1
Carbon	1.5-4.8
E-glass	3.45
Boron	3.6
Cotton	0.4-0.7
Kapok	0.0932
Bamboo	0.571
Flax	0.5-0.91
Hemp	0.3-0.76
Jute	0.2-0.46
Kenaf	0.3-1.2
Ramie	0.915
Abaca	0.014
Banana	0.53
Pine apple	0.414
Sisal	0.1- 0.8
Coir	0.1-0.2

Analyst Kartikeya *et al.*, established a simple and reliable ductile test for UHMWPE fiber-supported composites. This approach requires little sample

preparation. The installation for UTM's using just composite material may be made effectively. Testing revealed elasticity closer to the theoretical value for the tried-and-true texturing material. The sub-overlay display approach is widely used to numerically simulate composite material high-speed instability. Thus, the single-employ test strategy may directly influence sub-laminated composite material models[19]. Tan *et al*., also developed a new technique for collecting modified electro spun filaments and organizing single strand samples for ductility testing. The mechanical properties were affected by fiber measurement. Due to the increased draw percentage, smaller strands were stronger but less flexible[20].

2.2 Flexural Test

Flexural testing determines laminated fiber reinforced composite material and resin mechanical characteristics. This test simply determines a laminate's tensile, compressive, flexural, interaminar, shear, and shear moduli. Materials compressive, shear, and tensile strengths make up its flexural strength[22]. Flexural stacking uses all three induced material properties. The direction of material disappointment depends on which of the three essential burdens solidarity is needed to reach its limitation value[23]. Flexural testing is simple, requires little equipment, and is a calm procedure. This should improve the sample's stress state by reducing shear stress.

The sample is flat throughout testing, putting compressive pressure on the top cross section and malleable pressure on the bottom. When a specimen exhibits symmetrical characteristics around the mid-plane, its maximum tensile and compressive stresses may coincide, leading to failure influenced by the material with the lower strength. Given the reduced compressive strength, the specimen is more likely to fail on the compression side rather than on the composite side, often due to local fiber fractures. Flexural testing employs three- and four-point bend tests, with the three-point test involving a central stress point and supports located at the beams ends[24].

In a four-point bend test, two stress points are evenly distanced from the support. There are slight differences between various exams, but choosing one depends on personal preferences. Chitchumong *et al*., found that the polymers modulus values were not significantly different

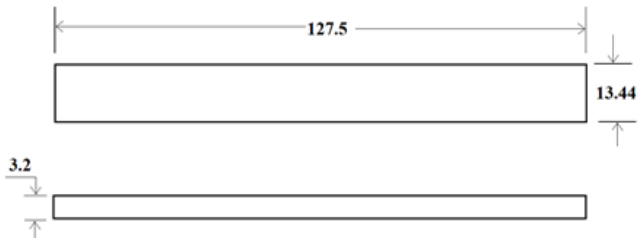


Figure 2. Flexural test specimen dimensions[27].

when the 3 and 4 point bend tests were correlated. The material has considerably greater flexural strength in three-point bending than four-point bending[25]. Other tests by Hamza *et al*., added fibers to the resin to increase its flexural strength. Fiber and resin combinations also increased mean flexural strength[26]. Figure 2 shows a UTM used for this test with ASTM standard D7264 a sample dimensions[27]. The following three situations may readily identify the samples maximum shear stress during testing[28].

2.3 Density

Density is meaningless, but its concentration in a well-defined region sometimes signifies mass density and matter per unit volume. Thus, density-weight misunderstandings abound. Many scholars can explain and reconcile these inconsistencies. Composite material density must be considered while making any composite. Combining synthetic or natural fibers determines

Table 3. Densities of matrix and the reinforcement[33]

Reinforcement	**Density(g/cm^3)**
Carbon	1.75-1.95
E-glass	2.56
Aramid (Kevlar 49)	1.45
Matrix	**Density(g/cm^3)**
Polyester	1.2-1.5
Epoxy	1.1-1.4
Polyamide	1.14
Polypropylene	0.9
PEEK	1.26-1.32

reinforced material density. If the density of each material is known during composite manufacturing, the overall density may be calculated[29,30]. High-precession weight balancing apparatus measures composite density. The preparation sample is measured to ASTM D792[31,32]. Programming all parameters of a high precession weight balancing machine allows it to accommodate for tiny subassembly variances and create balances. This technique entails cleaning the beaker, filling it with water to zero weight, and then adding the sample to determine density. Table 3 lists matrix and reinforcement densities.

2.4 Wear Test

Composite materials reliability in applications where they interact with surfaces and the environment depends on wear. Speed, environment, and workload affect material, making wear the most prevalent issue in modern life. Continuous scouring causes wear because to reformist and slow loss. When worn parts require replacement or repair, significant consumption occurs. Metal grid composite wear resistance depends on micro structural features such molecule size, volume %, support material distribution, and shape. Glass fiber reinforced epoxy pitch composites improve mechanical properties[34,35].

Carbon Nanotubes (CNTs) improve the wear characteristics of glass fiber built-up polymer, making them suitable filler materials for mechanical and polymer properties. The supported segments and their interface determine these materials tribological properties under similar interactions. Reacting contacts rely on the two frameworks trademarks and support component interfaces. These epoxies using CNTs and high-strength glass filaments are lightweight and strong. Fibers enhance epoxy framework sliding wear[36-37]. Support greatly affects composite material wear and grinding coefficient. Many studies choose pin-on-disc tribometers to quantify composite wear rate. Its simplicity of usage and quantity of tribological cooperation make the procedure straightforward. A basic pin on plate connects latch screw dry contacts to rail wheels to rail contact and lubricates rare supplement connections[38]. Figure 3 shows ASTM standard G99 wear testing dimensions[39].

2.5 Water Absorption

Water is a polymers maximum environmental moisture absorption. As a plasticizer, the polymers moisture absorption reduces glass temperature variation and reversibly affects plastic strength. Only a few polymers absorb moisture. Excellent absorbent polymers are becoming more popular in cutting-edge clinical research, development, and other fields. However, thermoplastic absorption limits need preparation and quality changes. The extraction of water-absorbing components, electrical and mechanical alterations, and size and mass changes produced by water absorption are prominent impacts[40,41]. Understanding water retention during polymeric material preparation is crucial to avoid moisture-related failure. Plastic items usually suffer from absorption. Due to moisture content, material design affects dielectric and heat protection qualities.

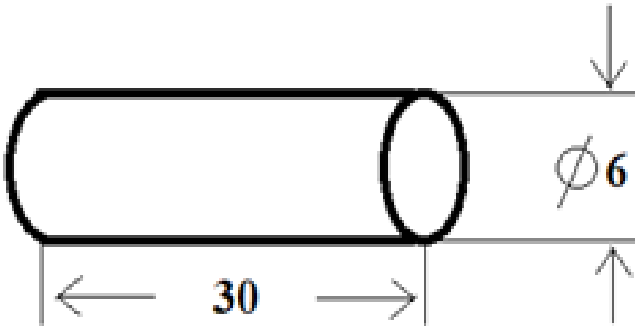


Figure 3. Wear test specimen dimensions[39].

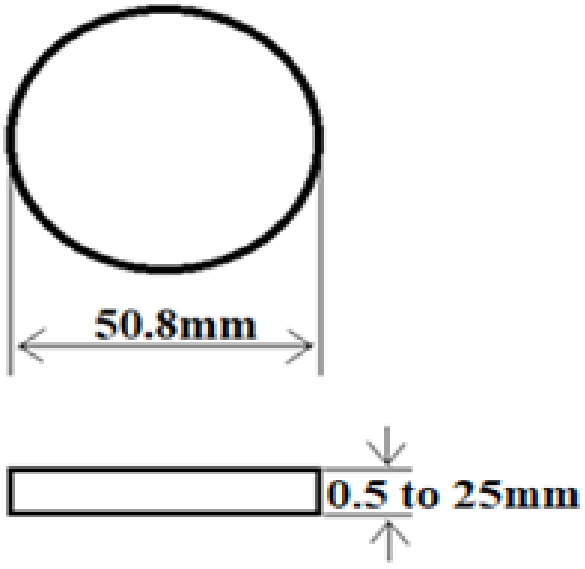


Figure 4. Water absorption test sample dimension[42].

Table 4. Some polymer water absorption properties[44]

Polymer	Minimum Value (% weight)	Maximum Value (% weight)
20% Glass fiber with ABS/PC blend	0.20	0.30
Amorphous TPI blend	0.39	0.39
Cellulose Diacetate	2.15	2.15
Cellulose Proprionate	1.20	3.00
Ethylene Chlorotrifluoroethylene	0.10	0.10
Carbon Fiber-reinforced (LPC)	0.03	0.03
Glass Fiber-reinforced (LPC)	0.02	0.02
Fiber-reinforced (PA 12)	0.50	1.40
Glass filled (PA 12)	0.30	0.40
30% Glass fiber (PA 46)	9.50	9.50
30% Glass fiber (PA 66)	0.80	1.10
30% Glass Fiber (PBT)	0.05	0.10
20-40% Glass fiber (Polycarbonate)	0.10	0.20
Glass filled (PC/PBT)	0.06	0.30

Hydration retention and polymer structure affect maturation. Material moisture affects the parts existence. Figure 4 shows the specimens dimensions[42]. Polymer water absorption is assessed using ASTM D570 and ISO 62. After drying in an oven for a set time and temperature, water absorption test models are chilled in a desiccator. The models should cool quickly. The material is then elevated in water at 23^{0}C for 24 hours or until equilibrium is reached. Samples are removed, cleaned with a buildup-free towel, and weighed. Table 4 shows the materials water absorption[43].

2.6 Flammability Test

A flammability test determines how much heat an object absorbs when heated. Flammability testing violations endanger public safety, limit market access, and may compel administrative experts to take action. The flammability test tracks self-supporting polymer consumption. This test is often used for quality, fabrication, and material analysis. Generally, fire hazards are exempt. This testing uses many methods to evaluate a materials fire resistance, failure to ignite when touched, and burn rate. Flame tests assess a substances ability to ignite burn quickly, and react to intake. Depending on the result, materials are placed over a burner in an equal or upward orientation Figures 5(a) and (b). The amount of sample consumed, flame particles, and extinguishing time determine a substances upward flammability. It's interesting that flammability tests also measure sample consumption and if it continues after the test fire is extinguished[45-49].

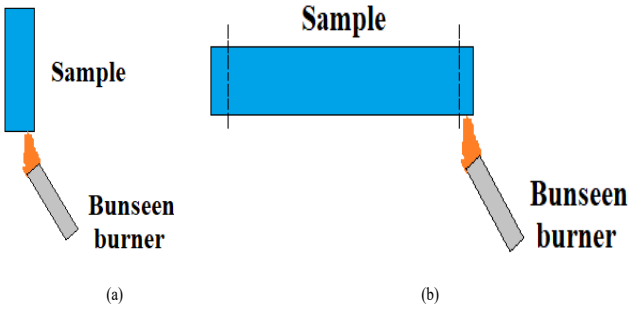


Figure 5. **(a)** Vertical **(b)** Horizontal burning[50].

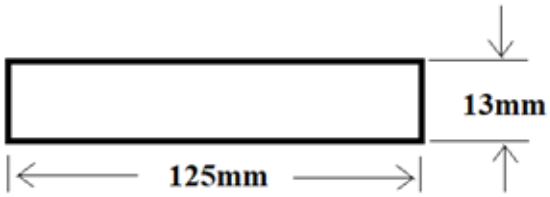


Figure 6. Flammability test sample dimension[52].

Flammability may also be assessed using the limiting oxygen index. It measures the oxygen needed to ignite plastic; it rises as combustibility falls. Since oxygen makes up 21% of the environment, any chemical with an oxygen limitation index below 21 is dangerous to eat outside. A candle-like sample is supported by an upright glass section for the limiting oxygen test. Oxygen and nitrogen are introduced into the glass part continuously. Fire decomposes samples. The measurement determines the basic oxygen aggregation that can only maintain burning[50,51]. The oxygen/nitrogen ratio may vary. Figure 6 shows ASTM D623 dimensions, which prepare samples for testing[52,53]. The polymer limiting oxygen index is shown in Table 5.

Table 5. Limiting oxygen index of some polymer[54]

Polymer	Limiting Oxygen Index
Polypropylene	18
Nylon-6	20
Cotton	16
Polyaramid	38
Polycarbonate	26
Epoxy resin	25
Polystyrene	18
Polyethylene	17
Polysulfone	30

2.7 Heat Distortion Test

Polymers capacity to withstand a certain load at a specific temperature is often tested using the thermal distortion test. Value of a polymer grade depends on availability of auxiliary expertise and main resin. Polymers using glass fiber or carbon fiber may have distortion temperatures around the resin yielding point. The polymers relative assistance temperature may be determined by the twisting temperature test on load-bearing components. However, the temperature contortion test is temporary and should not be used alone for item design. The component math, temperature rise rate, and exposure hour affect the presentation. Like other materials, polymers have temperature-dependent characteristics.

This is important for precisely targeted, high-temperature components. Warmth twisting temperature testing of plastics is crucial because polymer warmth mutilation temperature has become a vital tool for product configuration, design, and production. The thermal distortion temperature testing of a polymer sample with required measurements is done by placing it in the mechanical assembly, three-point rotating it, adjusting the level insightful, or using an edgewise bearing[55-57]. The sample heading, which depends on ASTM D648 or ISO 75, has a significant influence on the test result, as shown in Figure 7[58]. The sample must be carefully organized to match the significant norm. Table 6 lists the polymers melting and heat distortion temperatures.

Table 6. Distortion temperature of some of the polymers[59]

Polymer Category	Distortion Temperature at	
	0.46 MPa (°C)	1.8 MPa (°C)
Polystrene	95	85
Polypropylene	100	70
Polypropylene + 30% glass fibre	250	230
Polycarbonate	140	130
Nylon 6 + 30% glass fibre	220	200
Acrylic	95	85
Acetal copolymer + 30% glass fibre	200	190
ABS + 30 % glass fibre	150	145

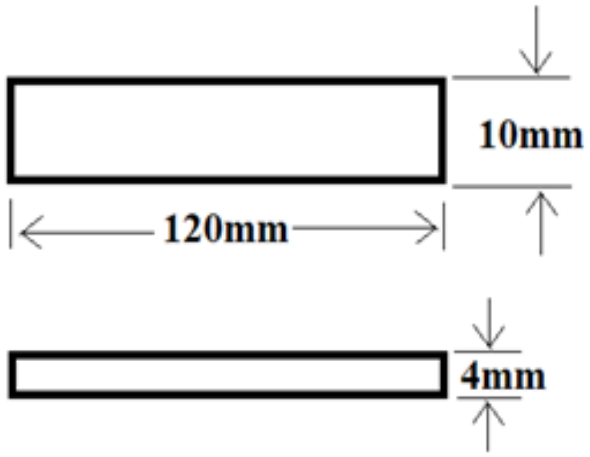


Figure 7. Heat distortion test sample dimension[57].

2.8 Thermal Gravimetric Analysis

The mass of a sample can be ascertained using thermo gravimetric analysis as a temperature-dependent characteristic. Mass changes as a function of temperature in many materials as they deteriorate and lose unanticipated components. This outstanding performance could indicate a thorough comprehension of the materials under study. By deliberately heating a sample under strict air conditions and monitoring weight changes, thermal gravimetric analysis may assist in achieving a number of materials presentations objectives[60,61]. Thermal gravimetric analysis measures mass as a function of temperature and time. In a specified setting, the sample is heated to exact equilibrium. Research categories may need unique peak temperature, inclination rate, and stay lengths. To construct a thermo gravimetric bend, the sample mass is determined at normal stretches along the temperature profile and shown as a function of temperature or time.

The sample often separates due to thermal breakdown with this characteristic curve. Thermogravimetric analysis is used for content assurance because it provides accurate and meaningful test design ideas. It constantly measures carbon and inorganic matter. Scientists can show test materials reactive or destructive properties *via* thermogravimetric analysis. This benefits metal alloys, composites, and catalysts[62,63]. Zhu *et al.* consolidated stearic acid into high-thickness polymers and carbon fibers to boost heat conductivity by 2.2 over composite phase transition material[64]. The sample dimensions in

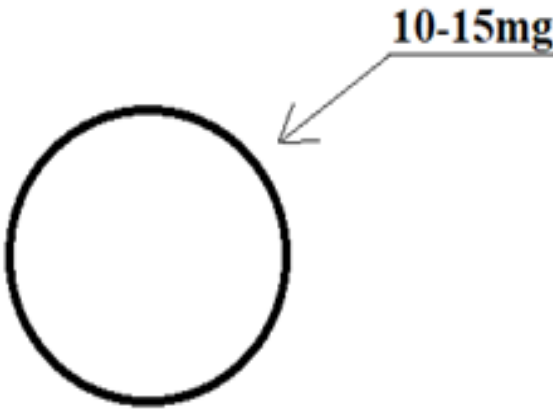


Figure 8. TGA test sample dimensions in milligram[65].

Figure 8 for the TGA need ASTM standards E1131 and ISO 11358[65]. Researchers using thermal gravimetric analysis must meet two requirements: Heat treatment must separate all organic material and no inorganic material to compute the following[66]. Table 7 shows the thermal conductivity of several fibers.

Table 7. Thermal conductivity of some materials[67]

Material	Thermal Conductivity (W/m-K)
Glass	0.8
Concrete	1
Fiber glass	0.042
Aluminium	237
Polystyrene foam	0.029
Steel	46
Urethane foam	0.022
Carbon fiber	0.23
Aramid fiber	0.040

2.9 Charpy Impact Test

High-strain rate Charpy tests determine how much energy a material can take under severe motivation. This test calculates the effect load energy needed to shatter a

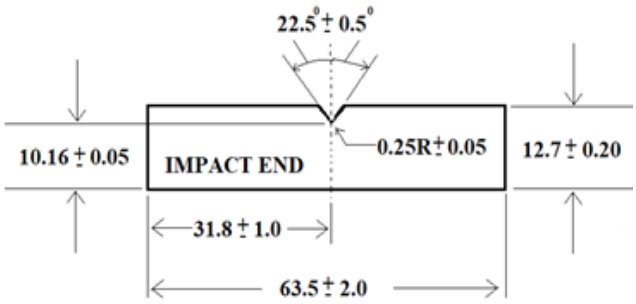


Figure 9. Specimen dimension of the Charpy impact test[74].

typical indented sample. Charpy impact testing requires striking an unindented sample with a pendulum arm to measure its effect intensity. This test remains a reliable quality control approach for evaluating the impact durability and indent affectability of new materials. Holding the sample at both ends while striking an appropriate sample with a hammer on a pendulum arm is required. Implement strikes imprint inversely. Pendulum arm decrease is carefully calculated to manage sample energy consumption. In a Charpy test, the effect of energy maintained in influencing a composite sample is likely the difference between the pendulum's potential energy and its energy after striking the composite sample[68-70].

Composite material opposition on indented composite sample cover testing is measured using normal Charpy test methods. This test calculates the effect load energy needed to shatter a typical indented sample. For evaluating the impact durability and indent affectability of new materials, the Charpy test is still useful. In the impact test, a real example is hit with a bludgeon on a pendulum limb while fastened at both ends. Implement strikes imprint inversely. The pendulum arms decreasing movement is accurately monitored to control sample energy consumption. To verify material quality, compare normalized Charpy test findings[71-73]. Figure 9 shows the sample's ASTM D6110 and ISO 179-compliant dimensions[74]. The formula gives the pendulum mallet's energy to break the specimen[75].

2.10 Environmental Test

Environmental testing simulates the mechanical stresses and climates things experience throughout time. This testing will discover product plan or execution flaws, especially at higher levels. Environmental testing generally ensures that your product works in any setting. Testing may reveal issues and improve items within the early phase. Some item flaws may occur under special conditions. Environmental testing shows that items that meet international rules are easier to sell worldwide[76,77]. Figure 10 shows the ASTM standards utilized for testing: G154, D4799, D 4587, and ISO 11507[78]. Sunlight, a dangerous force, is used to test items like hoods. Additionally, it emits undetectable particles in an electromagnetic spectrum and produces visible light and warmth. UV emissions damage materials over time. Porch furniture and car interiors may show UV radiation damage whether overtly or implicitly exposed. Shade distortion, fracture, and strength loss result. Sunlight testing may detect product damage without the natural environment.

The standard G154 technique for fluorescence UV exposure of non-metallic materials is chosen. Tests under this standard evaluate the products overall protection against weather, which may involve cyclic UV exposure and precipitation. This standard helps experts evaluate UV damage to plastics, printing inks, glues, sealants, and coatings. This standard covers open-air family items and roofing materials. For changes, specialists compare elasticity, coloring, damaged area, and shine to pre-opening[79,80].

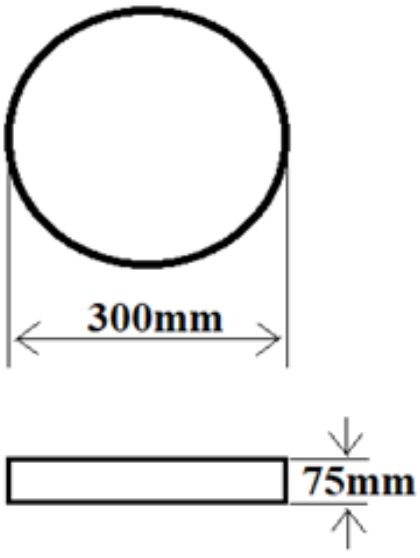


Figure 10. Environmental test specimen dimensions[78]

2.11 Hardness Test

This testing procedure assures the hardness of reinforced or unreinforced inflexible polymers. Material hardness, not physical trait. Space protection uses long-term space depth calculations. There are several ways to measure material hardness. Metallurgy and design workers evaluate indentation durability. Indentation hardness measures compressive resistance. To test indentation firmness, workers crush material using hardware. They determine the materials unused space at this point. In tight places, stiff materials are typical. Assessing indentation firmness best depends on the testing scale. Indentation firmness may be estimated using four criteria. The equipment used depends on Brinell, Rockwell, Vickers, or Shore scales. Plastic and rubber hardness is often estimated using Rockwell or Shore hardness techniques. Both methods give observational hardness esteem, which is unrelated to other properties[81,82].

The Rockwell hardness is used for robust materials like steel, polycarbonate, polymethacrylates, polystyrene, and acetal, where polymer creep is less important. The Shore durometer measures rubbers, elastomers, and flexible polymers. Strong steel balls imprint 6.35 mm samples due to Rockwell hardness. A small preload focuses the mechanical assembly. Next, an extra load is added and removed. Hardness of the plastic or elastic material after uttermost depth determines needle depth. Indenter condition, test length, viscoelasticity, and stiffness affect space profundity. Many Shore hardness indices assess material hardness. Defective plastic Rockwell scale connections cause catastrophic changes. Indenter capacity and calculation affect estimations[83,84]. ASTM D2583 was used to make the hardness sample in Figure 11[85].

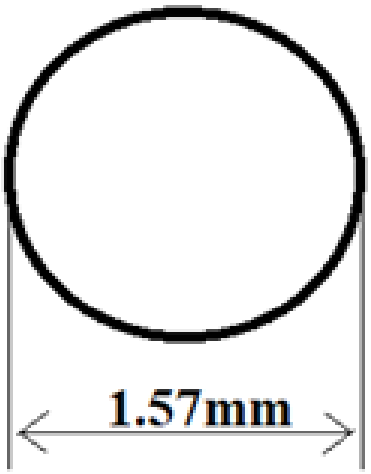


Figure 11. Specimen dimension for the hardness test of polymer composite.

3.0 Conclusion

ASTM-compliant composite excavator engine canopy characteristics and testing are the main subject of the entire review study. The testing procedure and sample dimensions are thoroughly explained in this work. Thorough assessments of the literature rarely assess everything. Therefore, more research is required to ascertain the mechanical and tribological properties of excavator engine canopy composite materials. It may be an excavator superstructure because of its solidity, energy retention, and ease of production using innovative reinforced materials in sandwich composites. Composite sandwich canopies for vehicles and excavators have a smaller environmental impact. New automobile materials may be developed and explored with the use of composite materials.

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