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Mechanical Behaviour of Carbon Steel-Aluminium Laminated Composites under Impact Tests

Mohan Kumar G[1], Lakshmana H K[2], Ravichandran S C[3]
[1]Senior Scale Lecturer, Department of Mechanical Engineering, GPT Nagamangala, Karnataka, India[1]
[2]Senior Scale Lecturer, Department of Mechanical Engineering, GPT Holenarasipura, Karnataka, India[2]
[3]Senior Scale Lecturer, Department of Mechanical Engineering, GPT Channapatna, Karnataka, India[3]

Abstract: Composite materials are engineered by combining two or more distinct constituent materials to create a new material with properties superior to those of its individual components. These materials exhibit exceptional attributes such as high stiffness and strength, low density, excellent thermal stability, high electrical and thermal conductivity, adjustable thermal expansion coefficients, corrosion resistance, and enhanced wear resistance. In this study, Izod and Charpy impact tests were conducted on laminated composites and their parent materials, including Carbon Steel (SAE 1042) and various aluminium alloys: 6061-T6, 6082-T651, and 5083-H112. The investigation focused on comparing the mechanical properties of these composites with one another, identify the most suitable composite with superior mechanical performance. The Izod and Charpy tests were conducted, and the results indicated that the Aluminium 6082-T651 combination exhibited the highest impact resistance and superior fracture resistance among the materials tested.
Keywords: MMC, Reinforcement, Impact Test, Layered Composites, Carbon Steel-Aluminium

I. INTRODUCTION

Composite materials are formed by combining two or more distinct materials that differ in form and chemical composition. These materials are increasingly gaining prominence as structural materials in modern engineering design and development due to their exceptional mechanical properties. Composites offer advantages such as a high strength-to-weight ratio, enhanced thermal resistance, and superior corrosion resistance, making them highly desirable for various applications.

Examples of composites include cemented carbides, plastic moulding compounds with fillers, rubber reinforced with carbon black, and wood. Typically, composite materials are composed of two phases: a primary phase (matrix), which serves as the binding material, and a secondary phase (reinforcement), which provides strength and enhances specific properties.

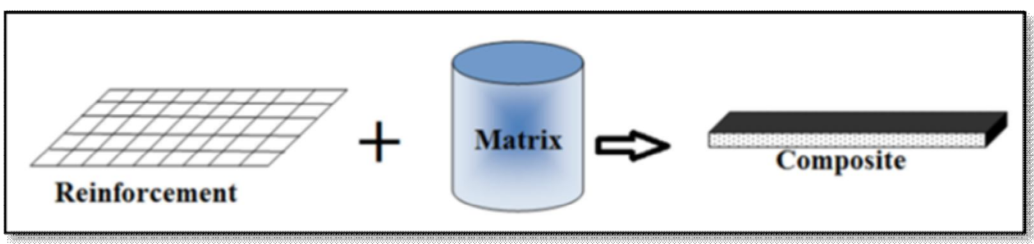

Fig. 1 Composite material

The emergence of advanced reinforced composite materials has been hailed as one of the most significant technological revolutions since the invention of the jet engine. This comparison is particularly compelling, given the profound impact the jet engine had on military aircraft performance. Its influence on commercial aviation was even more transformative, as airlines transitioned from propeller-driven planes to fully jet-powered fleets within just a few years.

Advanced composites offer two primary advantages, among many others: enhanced strength and stiffness, particularly when evaluated on a per-unit weight basis compared to traditional materials. For instance, composites can achieve the same strength and stiffness as steel while being 70% lighter. Similarly, some composites are up to three times stronger than aluminium, a commonly used structural material in aircraft, yet weigh only 60% as much.

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Another notable feature of composites is their ability to be tailored to meet specific design requirements, such as strength, stiffness, and other mechanical properties, in multiple directions. These compelling advantages have driven extensive research and development efforts across diverse fields. Instead of focusing solely on conventional applications, entire organizations have been established to analyse, design, and manufacture components made from composite materials, reflecting their transformative potential in modern engineering and technology.

An impact test is a critical mechanical test used to evaluate the toughness and ability of a material to withstand sudden forces or impacts. It measures the energy absorbed by a material when subjected to a high-speed collision or a rapidly applied load. The primary purpose of this test is to determine a material's resistance to fracture under dynamic conditions, which helps predict its behaviour in real-world applications such as accidents, collisions, or high-stress environments.

Common types of impact tests include the Izod Impact Test and the Charpy Impact Test, which involve striking a notched specimen with a pendulum hammer to measure the absorbed energy. The results of these tests provide valuable insights into the material's brittleness, ductility, and overall toughness. Impact testing is widely used in industries like aerospace, automotive, and construction to ensure material reliability and safety under extreme conditions.

II. EXPERIMENTATION

Laminate composites of Carbon Steel plate (SAE-1042) and Aluminium plates (6016-T6, 6082-T651, or 5083-H112) are formed using epoxy resin as an adhesive. The process involves surface preparation of the plates through cleaning and roughening to enhance adhesion. Epoxy resin, mixed with a curing agent, is applied evenly between the plates. The layers are aligned, stacked, and pressed under controlled pressure to remove air bubbles and ensure proper bonding. The assembly is cured at room or elevated temperatures to achieve a strong bond. After curing, the composite is trimmed or machined to the desired dimensions, resulting in a lightweight and durable laminate with enhanced mechanical properties.

Fig. 2 Carbon Steel/Epoxy/Aluminium Laminated Metal Composite (LMC)

For the impact testing of laminated, Carbon Steel plate (SAE-1042) and Aluminium plates (6016-T6, 6082-T651, and 5083-H112) were selected. The specimens were prepared with dimensions of 75x10x10 mm for the Izod test and 55x10x10 mm for the Charpy test. One surface of each plate was knurled to a depth of 1 mm to enhance bonding and then sandwiched using epoxy adhesive. The epoxy resin used was Resin X (M544), a clear, yellow-coloured uniform paste, paired with Hardener Y (H-209), a clear, beige-coloured uniform paste [6]. The resin and hardener were mixed in a 60:40 ratio and allowed to set at room temperature for 20–25 minutes. To fabricate the laminated metal composites, the sandwiched plates were pressed in a 400-ton upsetting press at 90°C for 150 seconds. After pressing, the composite laminated plates were cooled to room temperature before further processing [9]. This method ensured strong adhesion and uniformity in the composite structure.

A. Izod Test

Impact testing of metals is primarily conducted to measure the energy absorbed during fracture, providing a determination of the material's impact resistance or toughness. In this test, a specimen is machined into a square section. Izod test samples typically measure 75 × 10 × 10 mm, with a notch machined across the 10 mm face to a depth of 2 mm.

The test uses a pendulum applying a load of approximately 1000 N at the end of its arm as it swings downward. The pendulum strikes the specimen, which is securely held in a vertical position at 90°. Upon impact, the energy absorbed by the specimen is recorded as the result.

After the test, a brake is applied to stop the pendulum, and a safety lock is engaged to prevent accidental operation. This ensures safety and proper setup for subsequent tests.

Fig. 3 SAE 1042 Carbon Steel Izod Test Specimen

Fig. 4 Aluminium 6061-T6 Izod Test Specimen

Fig. 5 Izod Specimen Comprising Carbon Steel SAE 1042, Epoxy, and Aluminium 6061-T6

Fig. 6 SAE 1042 Carbon Steel Specimen After Testing

B. Charpy Test

Charpy V-notch test specimens are used for the standard Charpy impact test. The standard specimen dimensions are 55 mm × 10 mm × 10 mm, with a notch machined across one of the larger faces.

In the Charpy impact test, the specimen is positioned horizontally. The pendulum is released, striking the specimen and fracturing it. The energy absorbed during the fracture is recorded as the test result.

After the test, a brake is applied to stop the pendulum, and a safety lock is engaged to prevent accidental movement, ensuring safety during setup for the next test.

Fig. 7 SAE 1042 Carbon Steel Charpy Test Specimen

Fig. 8 Aluminium 6061-T6 Charpy Test Specimen

Fig. 9 Charpy Test Specimen of Carbon Steel + Epoxy + Aluminium 5083-H112

Fig. 10 Charpy Test Specimen of SAE 1042 Carbon Steel + Epoxy + Aluminium 6061-T6

III. RESULT AND ANALYSIS

All The Izod test was conducted to measure the impact resistance of materials. on various material combinations, including Carbon Steel SAE 1042 + Epoxy + Aluminium 6061-T6, Carbon Steel SAE 1042 + Epoxy + Aluminium 6082-T651, and Carbon Steel SAE 1042 + Epoxy + Aluminium 5083-H112. The testing was performed following the IS: 1598:1977 (RA 2015) standard method, and the results are summarized in the Table 1.

TABLE I
THE RESULT SUMMARY OF IZOD TEST

Sl. No.	Composite Material	Trial Number	Test Result In Joule	Average In Joule
1	C.S SAE 1042 + Epoxy + Aluminium 6061-T6	1	24	26.33
		2	32	
		3	23	
2	C.S SAE 1042 + Epoxy + Aluminium 6082-T651	1	46	51
		2	40	
		3	67	
3	C.S SAE 1042 + Epoxy + Aluminium 5083-H112	1	18	20.33
		2	23	
		3	20	

The Charpy test was conducted to measure the energy absorbed by different material combinations during fracture. The materials tested included Carbon Steel SAE 1042 + Epoxy + Aluminium 6061-T6, Carbon Steel SAE 1042 + Epoxy + Aluminium 6082-T651, and Carbon Steel SAE 1042 + Epoxy + Aluminium 5083-H112. The tests were performed in accordance with the IS 1757 (Part 1): 2014 standard, and the results are presented in Table 2.

TABLE III
THE RESULT SUMMARY OF CHARPY TEST

Sl. No.	Composite Material	Trial Number	Test Result In Joule	Average In Joule
1	C.S SAE 1042 + Epoxy + Aluminium 6061-T6	1	34	30
		2	28	
		3	28	
2	C.S SAE 1042 + Epoxy + Aluminium 6082-T651	1	54	58
		2	68	
		3	52	
3	C.S SAE 1042 + Epoxy + Aluminium 5083-H112	1	60	42.67
		2	30	
		3	38	

IV. CONCLUSIONS

The Izod test results indicate that the Aluminium 6082-T651 combination is the most effective in withstanding impacts among the materials tested. Similarly, the Charpy test results confirm that the Aluminium 6082-T651 composite offers the best fracture resistance compared to the other combinations. Delamination in laminated composites can occur due to the irregular chemical or mechanical properties of the materials, as each component has distinct characteristics. When subjected to impact, such as a pendulum strike, one component may separate from the composite, causing delamination. Preparing the composite by moulding the materials together to form a new, unified structure, rather than laminating them with epoxy, could potentially yield more effective results. Despite this limitation, laminated composites remain a cost-effective and lightweight option, particularly suitable for applications in machines where low impact resistance is acceptable.

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