Development of 3-Point Flexural Test Fixtures

Imoisili Patrick Ehi (Corresponding author)
Engineering Materials Development Institute,
P.M.B.611, KM4 Ondo Road. Akure Nigeria.
Tel: +2348032079383 E-mail: patrickehis2002@yahoo.com

Ukoba O. K., Ogunkoya A. K., AttahDaniel, B. E., Olusunle, S.O.O.
Engineering Materials Development Institute,
P.M.B.611, KM4 Ondo Road. Akure Nigeria.

Abstract

In developing economies, the cost of acquiring laboratory testing equipment and accessories is huge, thereby depriving most of the supposedly advanced laboratories of most of this necessary research equipment. In this study, a 3-point flexural test accessory has been designed and developed for a universal mechanical testing equipment. The 3-piont flexural accessory is an important accessory in mechanical examination for the flexural strength of engineering materials. The computer aided design and modelling as well as the materials selection was done using Pro/engineer and Granta software. The material selected for the development of the components is austenitic stainless steel which is readily available and accessible in Nigerian market The developed flexural test accessory was used on the test equipment to conduct flexural tests on composite samples and the results were found to conform to international standard.

Keywords: Mechanical, Flexural Test, accessory, Equipment, Design and Development

1. Introduction

The mechanical behaviour of a material reflects the relationship between its response to an applied load or force(s). Some of the required important mechanical properties are strength (yield and ultimate), hardness, ductility, and stiffness [1]. The mechanical properties of materials are ascertained by performing carefully designed laboratory experiments that replicate as nearly as possible the service conditions. Factors to be considered include the nature of the applied load and its duration, as well as the environmental conditions. It is possible for the load to be tensile, compressive, or shear, and its magnitude may be constant with time, or it may fluctuate continuously [2].

1.1 Basic Theory of Flexural Test

The flexural test measures the force required to bend a beam under three point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end user environment.[3]

1.1.1 Important and Types of Flexural Test

A flexure test produces tensile stress in the convex side of the specimen and compression stress in the concave side. This creates an area of shear stress along the midline. To ensure the primary failure comes from tensile or compression stress the shear stress must be minimized. This is done by controlling the span to depth ratio; the length of the outer span divided by the height (depth) of the specimen. For most materials S/d=16 is acceptable. Some materials require S/d=32 to 64 to keep the shear stress low enough [3]. Flexure testing is often done on relatively flexible materials such as polymers, wood and composites. There are two test types; 3-point flex and 4-point flex. In a 3-point test the area of uniform stress is quite small and concentrated under the center loading point.

Most commonly, the specimen lies on a support span and the load is applied to the center by the loading nose producing three points bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM international standard and International Organization of Standardization (ISO). According to ASTM D790, the test is stopped when the specimen reaches 5% deflection or the specimen breaks before 5%, while for ISO 178, the test is stopped when the specimen breaks but for the specimen that does not break, the test is continued as far as possible and the stress at 3.5% (conventional deflection) is reported [3]

1.1.2 Typical Materials for Flexural Test

Polymers: The 3-point flexure test is the most common for polymers. Specimen deflection is usually measured by the crosshead position. Test results include flexural strength and flexural modulus [3].

Wood and Composites: The 4-point flexure test is common for wood and composites. The 4-point test requires a deflectometer to accurately measure specimen deflection at the center of the support span. Test results include flexural strength and flexural modulus[3]

Brittle Materials: When a 3-point flexure test is done on a brittle material like ceramic or concrete it is often called modulus of rupture (MOR). This test provides flex strength data only, not stiffness (modulus). The 4-point test can also be used on brittle materials. Alignment of the support and loading anvils is critical with brittle materials. The test fixture for these materials usually has self-aligning anvils [3].

2. Methodology

The 3-point flexural test fixture components were developed using computer aided design software and manufacturing techniques. Each component was virtually manufactured by modelling and simulating it using parametric Computer-Aided Design and Manufacturing software. The modelled components are shown in Figures 1 & 2. After the virtual manufacture, the various components were manufactured in mechanical workshop floor where they were fabricated and assembled using bottom–top approach as shown in figure 3. The recommended material for the development is austenitic stainless steel which ready available in the Nigerian market

1.1.4 Performance Evaluation

Flexural testing is conducted on simply supported beams with a constant cross- sectional area, with a flat rectangular specimen being supported close to its ends and loaded centrally [5] In this case three point flexural testing has been selected as the bending moment increases linearly from zero at the supports to a maximum under the central loading point [5]. Using the three point flexural test machine, the test samples will be tested until failure therefore obtaining results for modulus of elasticity in bending [6]. Test performance evaluation result for polymer composite samples are shown in table 1.

3. CONCLUSION

The 3-point flexural test fixture was successfully designed and developed using Computer Aided Design and Computer Aided Manufacturing, at the lowest cost possible. The success recorded in developing it coupled with the relatively low cost of production is expected to make the accessory available and affordable in materials testing laboratories across tertiary institutions in Nigeria. The product was subsequently used to conduct flexural test on polymer composite sample and the results were found to conform to an international standard. The developed fixture will also enhance the quality of teaching and learning of materials science and engineering in developing country like Nigeria.

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Table 1: Results of flexural test performed by the developed flexural test

Flexural Test Results		Flexural Strength (MPa)	Flexural Modulus (GPa)
Obtainable (International Standard)		40-150	1.2-10
Obtained	Epoxy composite	81	2.7
	Polyester composite	51	1.3

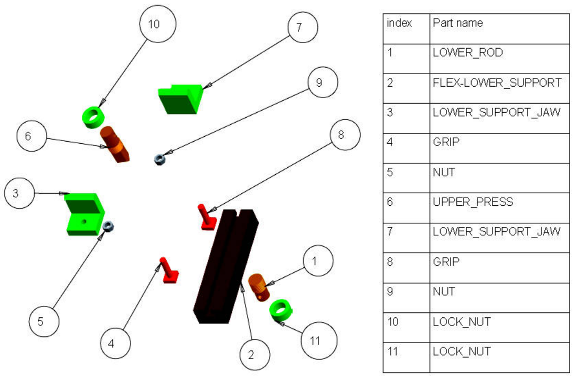

Figure 1: Exploded view showing various modelled components of the 3-point flexural test fixture

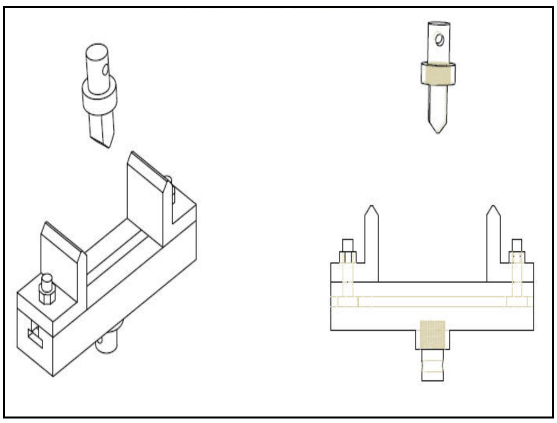

Figure 2: Different views of the assembled flexural test fixture

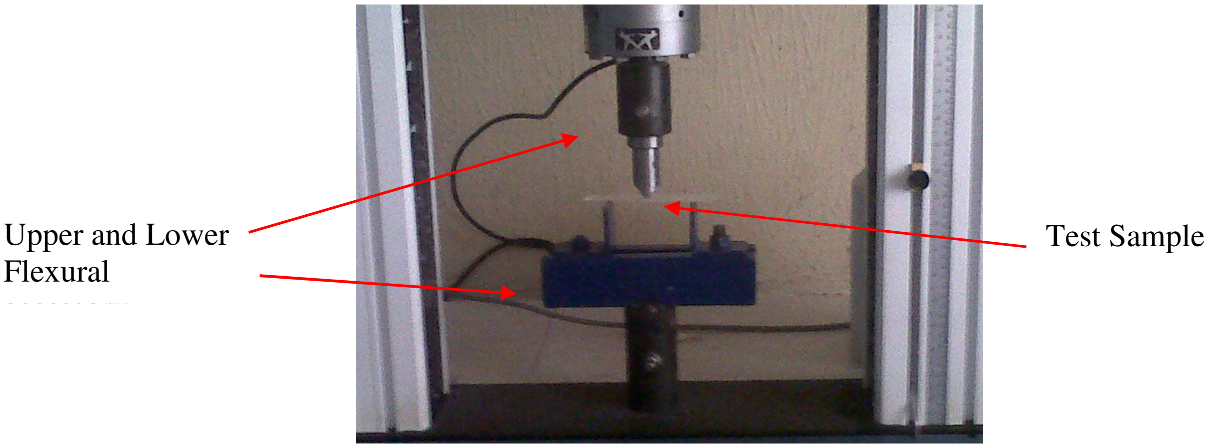

Figure 3: Developed flexural test fixture mounted on
Instron Universal Tester (Model 6369)