Portable Digital Instruments for On-site Testing of Lignocellulosic Fibres

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Over the past decade, the demand for natural fibre-based products has surged, driven by their environmental sustainability and economic benefits. This trend is reflected in a projected compound annual growth rate (CAGR) of 7.6% from 2024 to 2031, with the market expected to reach a value of $102,712.91 million by 2031. Among natural fibres, long lignocellulosic fibres such as jute, mesta, ramie, hemp, flax, sisal, and banana are in particularly high demand for the production of value-added goods including upholstery, furnishings, decorative items, and secondary apparel.

The two most important physical characteristics of lignocellulosic fibres that have a major impact on their market value, quality, and applications are bundle strength and colour. Understanding the importance of these two factors is becoming more and more crucial for producers and end users as natural fibres continue to replace synthetic alternatives in a variety of industries due to their eco-friendliness and biodegradability. The tensile strength of the fibres within the bundle is indicated by the bundle strength. For applications where mechanical durability is crucial, like in the production of technical textiles, automotive composites, geotextiles, and building materials, high bundle strength is especially important. The stress and friction that come with carding, spinning, weaving, or mat formation are better tolerated by strong fibres. Similarly, in industries where surface appearance and aesthetics are important, colour is crucial in determining the lignocellulosic fibres' visual and commercial appeal. The plant source, harvest age, post-harvest handling, and environmental factors all affect the colour of natural fibre. Lighter and more consistent fibre colours are generally favoured because they provide a cleaner foundation for dyeing and finishing procedures. Furthermore, fibre quality can be inferred indirectly from colour. For example, discolouration or uneven shades could indicate a fungal infestation, impurities, or poor retting conditions, all of which could weaken the fiber's mechanical integrity. The sustainability goal is further supported by the fact that lighter-colored fibres frequently require less bleaching and chemical treatment, which lowers processing costs and has a smaller environmental impact.

Due to the non-availability of portable testing instruments, key fibre parameters such as bundle strength and colour are often assessed using traditional hand-and-eye methods in field conditions. In this manual approach, bundle strength is evaluated by gripping a small bundle of fibres between the thumbs and applying pressure until the fibres break, providing a subjective estimate of their strength. Similarly, colour is assessed visually based on appearance, brightness, and uniformity, relying on the experience and perception of the observer. While these methods are quick and convenient, they lack precision and repeatability, highlighting the need for reliable, portable digital tools for onsite testing. To make it objective evaluation, ICAR-National Institute of Natural Fibre Engineering and Technology, Kolkata has developed portable instruments.

Portable Bundle strength Tester

The portable bundle strength instrument developed to measure the tenacity of fibres and comprises of mechanical fibre breaking unit and embedded system. The fibre breaking unit consists of base frame, jaws, clamping unit, feed screw and gear drive. Embedded system consists of Arduino Mega 2560, limit switch, load cell with HX711 interface, motor driver, buck converter and potentiometer.

One of these jaw bases, S-type load cell is attached and another one is moved forward and backward by dc motor (12 V 16A) using feed screw and nylon gear drive. The sample holder consists of a fixed lower clamp and an upper clamp that is adjustable using a T-shaped handle screw. The fibre should be manually cleaned to remove dust and short fibres, and then cut to the recommended length of 125 mm and placed between the clamping units. It should then be securely tightened using a T-shaped screw, and the sample weight adjusted using the potentiometer knob. Once the “start” command is pressed, the fibres are broken and readings are displayed on thin-film-transistor liquid-crystal touch display.

Advantages of portable bundle strength tester

- Portable, low cost, lightweight and compact design
- It can be operated by battery of 24V, 16A battery, providing up to 6 hours of continuous testing operation
- It can be used for other natural fibres

Portable colour meter

Portable colour meter developed to measure the whiteness value of fibres. Instrument operates based on the principle of photo reflectance and includes components such as a light-emitting diodes, photodiodes, capacitor, and microcontroller, battery, and battery booster. To ensure uniform sample illumination, four 5 mm light-emitting diodes (LEDs) are provided. To measure the light reflectance, four BPW34 silicon PIN photodiode sensors are incorporated. A 4800 mAh battery powers various components of the developed instrument, including the light-emitting diode, photodiode, microcontroller, and other circuitry. To provide a stable 5V supply for the light-emitting diode, an XL6009 boost converter integrated circuit (IC) is used.

Advantages of portable colour meter

- Portable and battery operated instrument
- Total weight of 800 grams
- Data storage – up to 2 GB

Conclusion

These portable instruments, such as the bundle strength tester and colour meter, are designed to be user-friendly, accurate, and cost-effective. Their adoption at purchase centers and procurement agencies will not only streamline the selection process but also ensure the acquisition of high-quality products that meet specific standards.