Co-efficient of friction, definition and measurement of sheet materials

Co-efficient of Friction (COF) defines the sliding interaction between two surfaces. Static Friction and Dynamic Friction (or Kinetic Friction) are defined in many standards including ASTM D1894, ASTM D4918, ASTM G219, ISO8295, TAPPI T549, TAPPI T815, TAPPI T503, TAPPI T548, and NFQ 03083.

The co-efficient defines the sliding resistance of two surfaces, such as a ski on snow (A), or feet on grass (B). In the absence of friction, the effort needed to slide an object would be significantly reduced, as would the effort needed to stop or change direction.

Newton's first law of motion states that a body remains at rest or in uniform motion unless acted upon by a force. Gravity causes a mass to press down with a force equal to its mass multiplied by acceleration. It follows that friction is the force needed to start sliding an object (Static Friction), or the force needed to keep it sliding (Kinetic Friction), expressed as a ratio by dividing into the downward force of the mass.

In industrial applications it can be important to understand how two surfaces interact with one another, e.g. flexible plastic film sliding over pouch formers in a high-speed packaging machine, or paperboard cartons being drawn into an erector then later stacked on top of one another. Things can go wrong when the interaction is not constant. In automated processing, adjustments made to dynamic machinery only work when the material reacts the same way each time. When replenishing a roll of flexible plastic film on a high-speed packaging line, film that exhibits different friction may not run smoothly, potentially causing alignment, snagging and running problems.

DURING MANUFACTURING

All materials have co-efficient of friction values, during manufacturing of processed sheet materials this property can be varied to suit the application using lamination of different materials, coatings and varnishes, or slip agent in the material formulation. Typically, values are recorded to three decimal places, in the range 0.000 to 1.000.

It makes sense to employ a reliable and accurate method of measurement with enough sensitivity to detect small changes. Methods of measurement include Inclined Plane, Flatbed and Tensile Machine fitted with friction attachment.

The inclined plane method relies on measuring the angle of a slope upon which an object starts to slide and reporting the tangent of that angle as the Co-efficient of Static Friction. Dynamic Friction cannot be measured. Such instruments employ a flat smooth bed fixed to a pivot, upon which a sled, of defined dimensions and mass, is placed with the test materials loaded. The bed starts in a horizontal position and is then moved by hand or powered, whilst an angle-measuring device is observed.

Whilst modern motor and logic controls incorporated with optical movement sensors and angle measurement can automate much of this method, there remains much room for error. With hand lifted bed versions, it's difficult to achieve reproduceable results, and inexpensive motorised units are little better due to bumpy movement, vibrations and inconsistent speed.

RDM's Model CF-200i uses a fine pitch motor driven by PLC logic control to provide a smooth vibration free movement. An optical sensor reacts in milliseconds, capturing the precise angle when the sled starts to move, and an HMI touchscreen displays both the angle and tangent representing Static Friction. The bed is manufactured to a precise roughness and incorporates a clamp for holding the base sample. The sled is supplied with dimensions, mass and surface finish to meet the appropriate test standard.

In contrast, the Flatbed method measures both Static and Dynamic Co-efficient of Friction values, based on the initial movement and ongoing sliding interactions in a horizontal plane. In many applications, both Static and Dynamic Friction are key to understanding how consistently a material will run through an automated handling process, often termed 'run-ability'.

Test instruments are constructed using a fixed horizontal smooth flatbed surface and a moveable sled attached to a force measuring sensor. Either or both surfaces are loaded with test material, and the sled is placed onto the flatbed then dragged along to measure the sliding interactions. Static Friction is measured from the force needed to start the movement (e.g. 45 grams) divided by the weight of the sled (e.g. 200 grams) to provide a unitless ratio value, in this case 0.225.

Factors affecting the static value include the mechanical link between the sled and sensor, if this is too elastic or too long it can store tensile energy rather than directly pulling on the sled which can lead to false high values. Some materials (esp. paper or fibrous materials) can be sensitive to the placement of the sled, any sliding adjustment made by the operator, and the time elapsed between sled placement and the start of test. Test Standards don't define the flatbed material or surface finish, yet experience shows differences in this causes variance in results from instrument to instrument.

DYNAMIC FRICTION

The average force needed to continue moving the sled at a defined fixed speed is also measured (e.g. 35 grams) and divided by the weight of the sled to provide a ratio for Dynamic Friction, in this case 0.175. RDM's model CF-800XS is considered by many as a 'gold standard' machine due to the low variance from machine to machine. The flatbed is precision manufactured to a specific roughness, and the robust construction ensures repeatability. The instrument combines modern motor drive, load cell sensing, a PLC logic controller and HMI touchscreen to guide the user in performing the test and reporting the results.

Friction is a unitless property, but is sometimes referred to as Mu, the 12th letter of the Greek alphabet. Measurements may be made on a specimen when sliding over itself or over another material. The CF-800XS is designed with replaceable insert beds to allow for different materials. Correlation of test results with actual material performance can usually be established.

Another testing method combines a tensile testing machine with a Friction Test bed accessory. This can be an inexpensive option if a tensile machine with 20N load cell is already available, otherwise it would be the most expensive to purchase. However, the impracticality and downtime needed for changing the load cell and fitting the flatbed makes this option mostly unfavoured. The flatbed must be fitted then levelled to ensure the sled is not pulling uphill, and the flexible cord link between load cell and sled passes through a pulley, the friction of which can skew results.

For all methods, extreme care must be taken in sample preparation. The test surface must be kept free of dust, lint, fingerprints or any debris that might change the surface characteristics. The sled should be placed gently and without excessive movement to prevent smoothing of the surface. RDM's CF-800XS includes a standard operating procedure and special test routine that helps standardise these issues to increase the reliability of results.

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