قسم هندسة الإنتاج والتصميم الميكانيكي

كلية الهندسة

جامعة المنصورة

كتاب تجارب

معمل

الإختبارات الميكانيكية

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مقدمة

تعتبر التجارب المعمليه الركيزة الاساسيه لإستيعاب المفاهيم الهندسيه فهى حلقة الوصل بين الدراسه النظريه والخبرات العملية. وتعتبر الدراسه المعمليه هى جزء أصيل وجوهرى لمختلف المستويات العلميه داخل كلية الهندسه (مرحلة البكالوريوس – مشاريع تخرج – الدراسات العليا).

المحتويات

المحتوى	الصفحه

بيانات المعمل الأساسية

إسم المعمل: معمل الإختبارات الميكانيكية

القسم العلمى: هندسة الإنتاج والتصميم الميكانيكى

المشرفون:

أ.م.د/ توكل أحمد أحمد عنب   د/ منى أبو العز محمد ابو العز   د/ محمد حسين الشافعى

مهندسو المعمل:

م/أحمد سامح عبدالعزيز   م/ هشام أحمد محمد   م/ عبدالله أحمد محمد

أمين المعمل: أ/ أمل محمود

تليفون: 1296

الموقع بالنسبه للكلية: مبنى المعامل الدور الأرضى ومقابل لمبنى البرامج النوعية

مساحة المعمل: 80 متر مربع

رسالة المعمل

يقدم المعمل خدمات عديدة على النطاق الجامعى وفى خدمة البيئه والمجتمع فهو يساهم فى توفير التجارب العمليه اللازمة لإتمام العمليه التعليميه لطلبة الكلية والجامعه على اختلاف مستوياتهم التعليميه. كما يساهم المعمل فى خدمة المجتمع سواء على مستوى المحافظة أو القطاع عن طريق توفير الإختبارات الميكانيكية الدقيقة والمتنوعه بأحدث الأساليب والمساهمه فى توفير التكنولوجيا والكوادر المحليه التى تلائم إحتياجات السوق والمجتمع.

أهداف المعمل

- المساهمة فى تدريس الكثير من المقررات الدراسيه لطلبة كلية الهندسة.
- المساهمه في تقديم تدريب جيد لطلاب البكالوريوس في تعميق فهم بعض المقررات والتدريب العملي عليها.
- توفير بيئة معملية مناسبة لإجراء التجارب والأبحاث الخاصة بمرحلة الماجستير والدكتوراه لطلاب الكلية والجامعه.
- خدمة البيئه والمجتمع الخارجي بتقديم خدمات تخص الصناعه والبحث العلمي مرتبطه باختبارات الأجزاء والمعدات الميكانيكية.

الخدمات المجتمعية التى يؤديها المعمل

يمكن لمعمل الاختبارات الميكانيكيه تقديم الكثير من الخدمات لمجتمع الصناعه تتمثل في اختبار قوة الأجزاء التي يتم تصنيعها مثل التروس والأعمده وعمل اختبارات لها لبيان مدى تحملها تحت الظروف التشغيليه المختلفه مما يمثل توفيرا كبيرا للوقت والتكلفه وضمان صلاحية هذه الأجزاء المصنعه لفترة زمنيه طويله.

الجهات اللتى تتعاون مع المعمل:

شركة شومان لتصنيع ماكينات البلاستيك والمنتجات البلاستيكية بمدينة دمياط الجديدة.

الدخل السنوى للمعمل:

غير متوفر حاليا

الجهات الممولة لأنشطة المعمل:

غير متوفر حاليا

المشاريق النافسية اللتى يشارك فيها المعمل:

غير متوفر حاليا

الخدمات الطلابيه اللتى يؤديها المعمل

الأقسام العلمية المستفيدة من المعمل:

1- قسم هندسة الإنتاج والتصميم الميكانيكى.
2- قسم هندسة القوى الميكانيكية.
3- قسم هندسة الغزل والنسيج.
4- قسم هندسة الميكاترونيات.

الفرق الدراسية المستفيدة من المعمل:

1- التدريب الطلابي الخاص بالفرقتين الأولى والثانيه أثناء التدريب الصيفي أو أثناء الورش العمليه للمقررات.
2- طلاب الفرقتين الثالثه والرابعه حيث يدخل ضمن الكثير من المقررات اهمها تصميم ماكينات الورش ومختبر المواد وأيضا مشاريع التخرج.
3- طلاب الفرق الأولى والثانيه بأقسام الغزل والنسيج والقوى الميكانيكية والميكاترونيات الذي يقومون بدراسة المواد الهندسيه والاختبارات عليها وأيضا المواد التي تدرس تصميم أجزاء الماكينات المختلفه.

المقررار الدراسية المستفيدة من المعمل:

1- اساليب ومعدات تشغيل 1– الفرقه الأولى الفصل الدراسي الأول – كود PDE 121
2- مقاومة مواد وتحليل الإجهادات– الفرقه الأولى الفصل الدراسي الثاني – كود PDE 143
3- مواد هندسية – الفرقه الأولى الفصل الدراسي الثاني – كود PDE 146
4- التدريب الصيفي – الفرقه الثانية الفصل الدراسي الأول – كود ENG 112
5- تصميم ماكينات ورش 1 – الفرقه الثالثه الفصل الدراسي الأول – كود PDE 321
6- تصميم ماكينات ورش 2 – الفرقه الثالثه الفصل الدراسي الثاني – كود PDE 323
7- اساليب ومعدات تشغيل 2– الفرقه الثالثه الفصل الدراسي الأول – كود PDE 322
8- المختبر مقرر اختياري– الفرقه الرابعه الفصل الدراسي الأول – كود PDE 422
9- مشروع التخرج – الفرقه الرابعة الفصل الدراسي الثاني – كود PDE 442

الأنشطة الطلابية داخل المعمل:

يقوم المعمل بتقديم العديد من الخدمات الطلابيه أهمها المساعده في تعميق فهم بعض المقررات مثل مقاومة المواد والاختبارات عليها لطلاب الفرقه الأولى وأيضا دراسة عمليات التشغيل المختلفه وتأثيرها على أسطح الأجزاء الميكانيكية وعمل الاختبارات عليها مثل اختبارات الصلاده وغيرها.كما يقدم أيضا المعمل التدريب لطلاب الفرقتين الأولى والثانيه أثناء التدريب الصيفي لدراسة الإختبارات الميكانيكية لأجزاء الماكينات المختلفه. أيضا يخدم المعمل طلاب الفرقه الرابعه في مشاريع التخرج حيث يساعدهم في اختبار الأجزاء التي يقومون بتصميمها وتصنيعها ايضا لبيان قوة تحملها وملائمتها للتطبيق المراد استخدامها به.

عدد طلاب الدراسات العليا المستفيدين من المعمل:

العدد الكلي لطلاب الدراسات العليا المستفيدين من المعمل هو خمسة طلاب وينقمسون كالآتي:

عدد **1** طالب - قام بانهاء رسالة الماجيستير في ديسمبر عام 2020.

عدد **4** طلاب - رسائل الماجيستير لهم قيد التنفيذ ويقومون باستخدام المعمل في اجراء مختلف التجارب والاختبارات التي تخدم النقطه البحثيه موضع الدراسه.

عدد الرسائل العلمية اللتى تمت فى المعمل:

رسالة ماجيستير واحده تم الانتهاء منها وهناك أربعة رسائل حاليا قيد التنفيذ.

تدريب الطلاب داخل المعمل:

يساهم المعمل بصورة كبيرة في تدريب الطلاب في الفرقتين الأولى والثانيه على اختبارات المواد والاختبارات التي تتم على الأسطح مما يساعد بصورة كبيرة في ترسيخ المعلومات المستفاده من المقررات الدراسيه مثل مقاومة المواد وأساليب التشغيل وايضا تصميم ماكينات الورش.

المسابقات العلمية اللتى شارك فيها طلاب من المستفيدين من المعمل:

لا يوجد

المقررار الدراسية المستفيدة من المعمل:

1- اساليب ومعدات تشغيل 1– الفرقه الأولى الفصل الدراسي الأول – كود PDE 121
2- مقاومة مواد وتحليل الإجهادات– الفرقه الأولى الفصل الدراسي الثاني – كود PDE 143
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قائمة بالأجهزه والمعدات داخل المعمل

	إسم الجهاز	العدد
1	Light Microscope	1
2	Friction and Wear testing machine	1
3	Dynamometer	1
4	Friction and Wear Test machine	1
5	The laboratory balance	1

التجارب التى يتم تنفيذها داخل المعمل

	التجربة	الغرض منها
1	Impact test	تستخدم لبيان سلوك الماده عند تعرضها لقوى وأحمال بسرعات عاليه. وهناك نوعين منها وهما اختبار التصادم باستخدام البندول واختبار التصادم بالحمل الساقط.
2	Micro-hardness test	يتم في هذا الاختبار حساب الصلاده للمادة ومقاومتها للإختراق ويتم ذلك على عينات صغيرة أو قليلة السمك ويتم تجهيز الأسطح للعينات قبل عملية الاختبار.
3	Measuring forces and Moments	يتم في هذا الاختبار قياس مقدار القوى والعزوم الذي يؤثر على جزء معين ويتم ذلك باستخدام جهاز الدينامومتر ويتم قياس القوى والعزوم في المحاور الفراغيه الثلاثة.
4	Friction and Wear Test	يتم في هذا الاختبار قياس مقدار مقاومة المادة للتأكل ويتم ذلك على جزء معين عن طريق الحركة النسبية.
5	The laboratory balance	يستخدم لتعيين كتلة الأجسام بصورة دقيقه جدا.

وفيما يلي شرح لكل تجربة من التجارب التي يتم تنفيذها داخل المعمل وجوانب الاستفاده منها وتطبيقها.

1- Impact test

Why impact testing is important?

Impact test determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent brittle-ductile transition. It is to determine whether the material is brittle or ductile in nature.

Why impact test is done?

Purpose of the test. Impact testing is used to determine material behavior at higher deformation speeds. Classical pendulum impact testers determine the impact energy absorbed by a standardized specimen up to break by measuring the height of rise of the pendulum hammer after impact.

What are the types of impact tests?

There are basically two types of impact tests: pendulum and drop weight.

Izod, Charpy, and tensile impact are the most common of the pendulum type tests.

What is impact testing machine?

Impact testing machines evaluate an object's capacity to withstand high-rate loading and it is commonly used to determine the service life of a part or material. Impact resistance can be among the most challenging qualities to measure. ... There are two standard kinds of impact test: Charpy and IZOD [1].

Why do we use notch in impact test?

Impact energy is a measure of the work done to fracture a test specimen. When the striker impacts the specimen, the specimen will absorb energy until it yields. The test specimen continues to absorb energy and work hardens at the plastic zone at the notch. When the specimen can absorb no more energy, fracture occurs [2].

CHARPY IMPACT TESTING

A Charpy V-notch impact test is a dynamic test in which a notched specimen is struck and broken by a single blow in a specially designed testing machine. The measured test values may be the energy absorbed, the percentage shear fracture, the lateral expansion opposite the notch.

Testing temperatures other than room (ambient) temperature often are specified in product or general requirement specifications (hereinafter referred to as the specification). Although the testing temperature is sometimes related to the expected service temperature, the two temperatures need not be identical.

Charpy machines used for testing steel generally have capacities in the 220 to 300 ft·lbf (300 to 400 J) energy range. Sometimes machines of lesser capacity are used; however, the capacity of the machine should be substantially in excess of the absorbed energy of the specimens (see Test Methods E23). The linear velocity at the point of impact should be in the range of 16 to 19 ft/s (4.9 to 5.8 m/s)

For testing at other than room temperature, it is necessary to condition the Charpy specimens in media at controlled temperatures. Low temperature media usually are chilled fluids (such as water, ice plus water, dry ice plus organic solvents, or liquid nitrogen) or chilled gases. Elevated temperature media are usually heated liquids such as mineral or silicone oils. Circulating air ovens may be used.

Handling Equipment—Tongs, especially adapted to fit the notch in the impact specimen, normally are used for removing the specimens from the medium and placing them on the anvil.

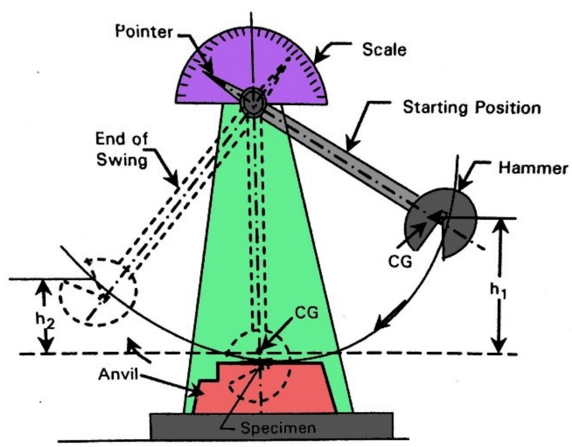


Fig1. Charpy impact test configuration [3].

In cases where the machine fixture does not provide for automatic centering of the test specimen, the tongs may be precision machined to provide centering.

TEST PROCEDURE

A Charpy V-notch specimen is placed across parallel jaws in the impact-testing machine. The pointer is set up to its maximum value (300 J). The hammer is released from the initial height downward towards the sample. Observations and the energy absorbed are recorded and tabulated. Steps 1-3 are repeated for another specimen [4].

FACTORS THAT AFFECT THE CHARPY IMPACT ENERGY OF A SPECIMEN

- Yield strength and ductility.
- Notches.
- Temperature and strain rate.
- Fracture mechanism.

NOTCH IMPACT ENERGY

$KV = mgH - mgh$

m The mass of pendulum

g Gravity

H Height of pendulum starting point

H Height of the pendulum from first

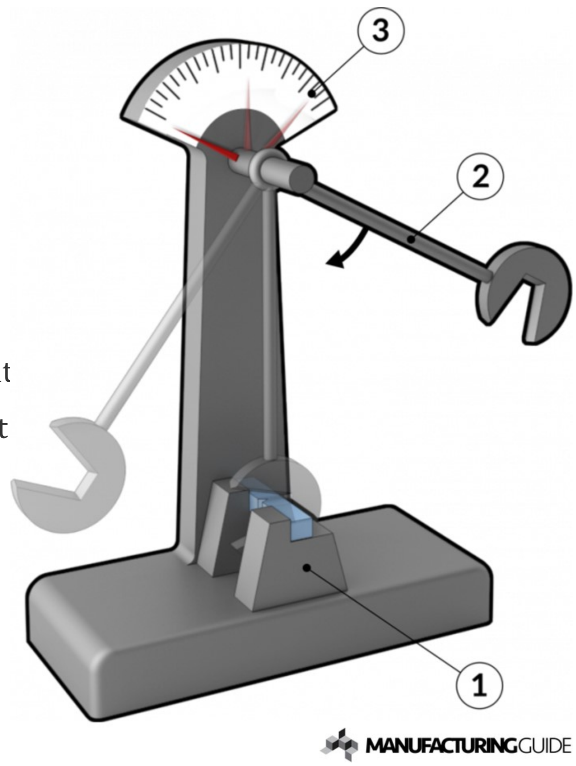


Fig2. Charpy impact test machine's components as follows (1) machine's base (2) Pendulum arm (3) Scale.[4]

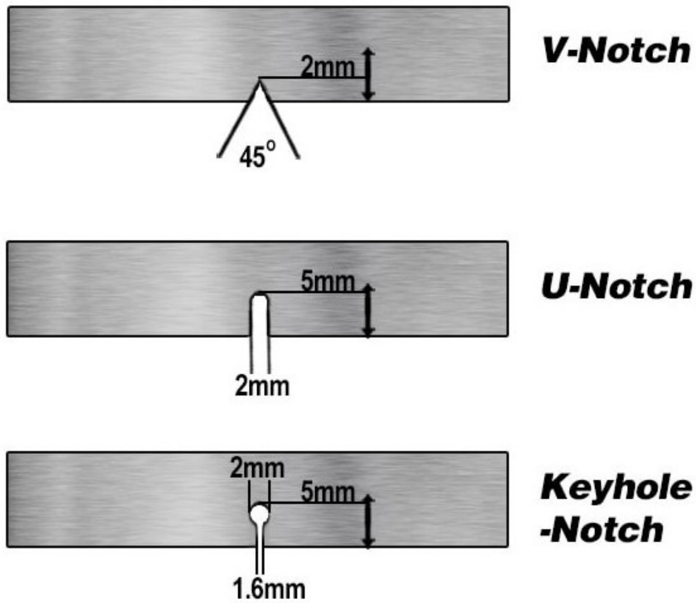


Fig3. Types of Impact test [5].

DROP-WEIGHT TESTING

Drop-Weight testing is preformed to **ASTM E208** [6]. This test is conducted to determine the nil ductility transition temperature (NDT) of materials. Impact testing can also be conducted to your temperature requirements from elevated temperature down to 320°F [7].

STANDARD SPECIMEN SIZE

According to ASTM A370,[8] the standard specimen size for Charpy impact testing is 10 mm × 10 mm × 55 mm. Sub size specimen sizes are: 10 mm × 7.5 mm × 55 mm, 10 mm × 6.7 mm × 55 mm, 10 mm × 5 mm × 55 mm, 10 mm × 3.3 mm × 55 mm, 10 mm × 2.5 mm × 55 mm. Details of specimens as per ASTM A370 (Standard Test Method and Definitions for Mechanical Testing of Steel Products).

According to EN 10045-1 (retired and replaced with ISO 148) [9], standard specimen sizes are 10 mm × 10 mm × 55 mm. Sub size specimens are: 10 mm × 7.5 mm × 55 mm and 10 mm × 5 mm × 55 mm.

According to ISO 148, standard specimen sizes are 10 mm × 10 mm × 55 mm. Sub size specimens are: 10 mm × 7.5 mm × 55 mm, 10 mm × 5 mm × 55 mm and 10 mm × 2.5 mm × 55 mm.

2- Micro hardness test

Microhardness Testing is a method of determining a material's hardness or resistance to penetration when test samples are very small or thin, or when small regions in a composite sample or plating are to be measured. It can provide precise and detailed information about surface features of materials that have a fine microstructure, are multi-phase, non-homogeneous or prone to cracking.

The microhardness test can measure surface to core hardness on carburized or case-hardened parts (case depths), as well as surface conditions such as grinding burns, carburization or decarburization [10-12].

Fig4. Microhardness test device.

Selecting Samples

The first step for selecting the representative sample is determining the sections where the measurements are performed either traverse or longitudinal sections, for example the traverse section is required to measure the grain size and general microstructure evaluations needs longitudinal sections. The cutting according to ASTM E3-95 [13] standard. It is very significant to keep the sample cool with a suitable lubricant or coolant so the microstructure will not be alternated or destroyed, and any deformation comes from abrasive sawing or machining should be removed.

Mounting Step

The samples are compressed inside transparent epoxy or plastic materials to facilitate the handling of samples during polishing and grinding steps. The mounting material must be adaptable and compatible with respect to abrasion resistance. Most material which are used are thermoplastic material and Bakelite. The sample and epoxy are heated and pressurized in a mold at the correct levels. The hot compression mounting machine are used to mount the specimens to facilitate the handling operation.

Grinding

To get a free surface damage, grinding operation is performed after mounting the samples, also to provide a flat surface. The operation involves cooling using the water for abrasive wheel this will produce a free surface of deformed metal. A silicon carbide papers of grades "220","500","800", and "1000" were used for grinding operations. The rotary disc operates at 250 rpm.

Polishing and Etching

The last thin layer of the deformed material will be removed using the polishing operation in which 1 μm was removed after that 0.3 μm was removed. The polishing disc was rotating by 200 rpm. The polishing used was aluminum oxide (Al_2O_3) in a liquid state. The last step is etching, that will be performed to reveal feature such as the boundaries of grain and without etching, the grain boundaries will not be seen. The etching was 2.5% concentrated nitric acid, 1.5% hydrofluoric acid, 1% concentrated hydrochloric acid and 95% water. There is another etching technique using potassium permanganate ($KMno_4$) in water.

Fig5.Grinding and polishing equipment

The Microstructural examination is done using a light microscopy which was used to give topographic information about the welding joint. The light microscope with a digital camera (PAX-Cam) and (PAXIT) software to examine the microstructure of materials. The microscope could be used to evaluate the material thickness also. Many operations had been implemented on the sample including pre-grinding, grinding and polishing.

Fig6.Light microscope used for specimen inspection.

3- Measuring forces and Moments using Dynamometer

Friction occurs between moving parts, and is commonly analyzed in parts that come into contact with one another during operation, such as power trains in automobiles. The friction causes heat generation and wear in these parts. Heat generation and wear derived from friction account for most mechanical system failures, and economic losses due to such failures are not small. To reduce such losses, tribological tests are conducted to evaluate parts and properties of the parts materials.

Calculating forces and moments Kistler's DynoWare software [14] calculates the three forces (Fx, Fy and Fz) and the three moments (Mx, My and Mz); the 6-component summing processor in the charge amplifier can also perform the calculation in the same way. The distance from the sensors must be included when calculating the moments.

TEST PROCEDURE

The dynamometer is mounted on the machine tool table and the workpiece is positioned on top of it in both of milling and drilling operations.

To reduce the mass on the dynamometer and thus minimize the negative influence on its dynamics, the workpiece is bolted directly onto the dynamometer; this eliminates the need for heavy (and often non-rigid) vises. In a few simple steps, the active force acting in the working plane can be calculated from the feed force and the normal feed force [15].

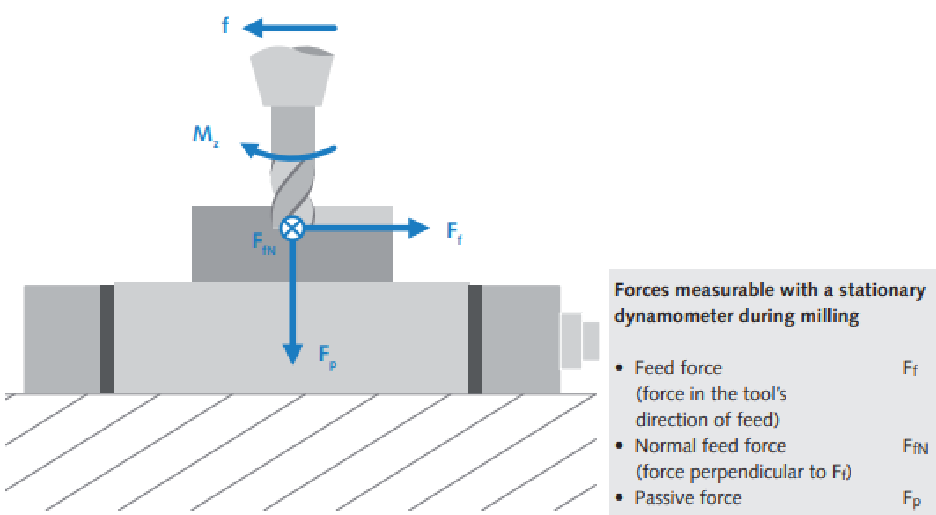


Fig7.forces and moments measured using dynamometer[16].

In turning and longitudinal turning, the dynamometer is mounted on under the tool.

It is used to determine and characterize specific forces (kc, kp, kf) for certain materials subject to different boundary conditions. Cutting forces are often measured during the turning operation in order to examine plastic-mechanical processes within the actual cutting process, to analyze chip formation and its influence on the process, or to substantiate wear processes with force progressions.

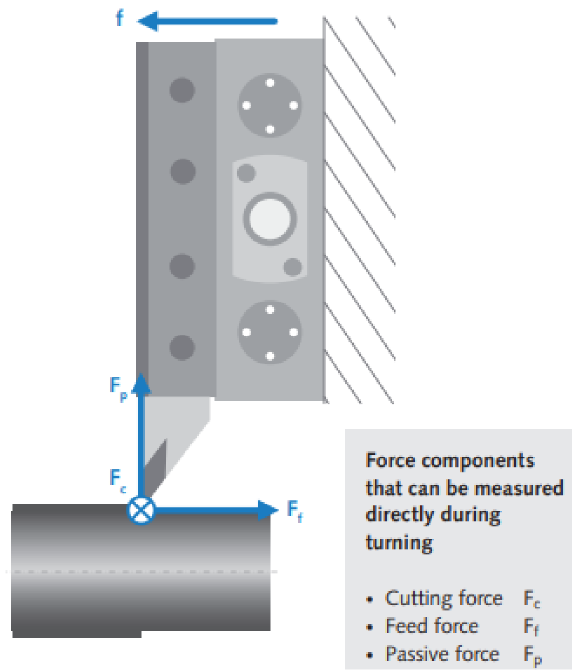


Fig8.forces measured using dynamometer during turning operations [16].

4- Friction and Wear Test

Friction occurs between moving parts, and is commonly analyzed in parts that come into contact with one another during operation, such as power trains in automobiles. The friction causes heat generation and wear in these parts. Heat generation and wear derived from friction account for most mechanical system failures, and economic losses due to such failures are not small. To reduce such losses, tribological tests are conducted to evaluate parts and properties of the parts materials. [17]

Why Friction and Wear Testing is important?

Almost all mechanical systems, artificial or natural, involve the relative motion of solid components. Wherever two surfaces slide or roll against each other, there will be frictional resistance, and wear will occur. The response of materials to this kind of interaction, often termed tribological, depends not only on the precise nature of the materials, but also on the detailed conditions of the contact between them and of the motion. Friction and wear are system responses, rather than material properties. The measurement of tribological behavior therefore poses particular challenges, and a keen awareness of the factors that influence friction and wear is essential.

Why Friction and Wear Test is done?

Purpose of the test: Impact testing is used to determine material response of wear to the interaction of two surfaces slide or roll against each other.

What are the methods of impact tests?

A friction test measures the frictional characteristics together with an abrasion resistance test, and the result is generally calculated using the coefficient of friction. On the other hand, a wear test measures the changes in conditions caused by friction, and the result is obtained from deformation, scratches, and indentations on the interacting surfaces.

There are several ways to measure the coefficient of friction: by measuring the frictional force with a gauge, by measuring and converting the load power of the driving motor, by calculating from the behavior of vibration damping by friction, and by calculating the maximum static frictional force based on the angle at which an object placed on a slanted surface starts sliding. These tests check not only for wear and friction but also for the effectiveness and deterioration of lubricants.

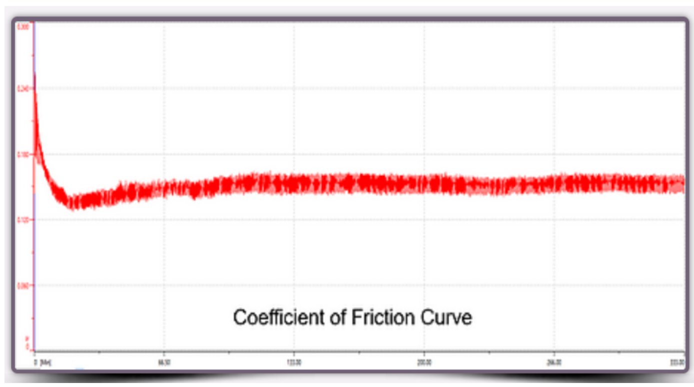
What is friction and wear testing machine?

Friction and wear testing machines evaluates the friction and wear test where a test piece and an interfacing surface are subject to interaction in relative motion to measure the coefficient of friction and the wear volume.

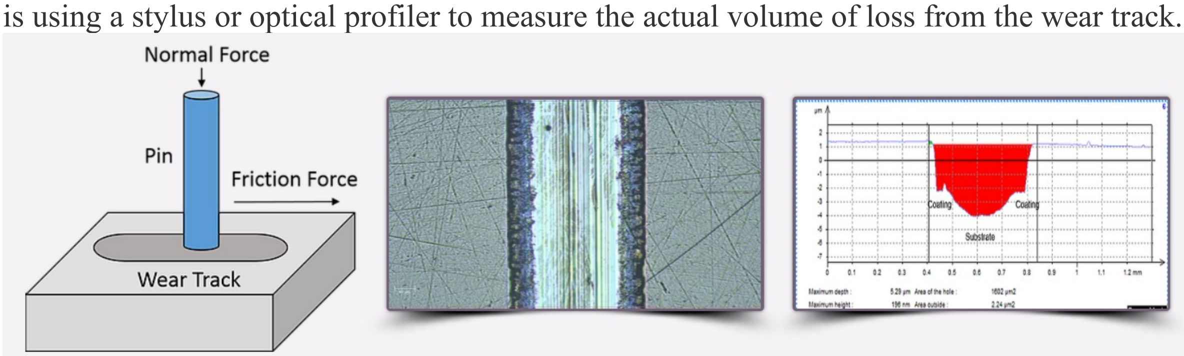
Theory

During a pin-on-disc friction/wear study, a sharp pin, ball, or cone tip is employed to wear against the disc surface. Usually, a constant normal load is applied from the pin towards the contact interface. The round shape of the tip is to ensure symmetrical contact and reduce any unnecessary stress concentration during friction test. The pin will move back and forth on the disc surface with certain stroke length and speed. A lateral force sensor is usually installed to measure the friction force. The coefficient of friction (μ) is calculated as friction force divided by normal load. The coefficient of friction is a constant and material property. Based on Amonton's law, friction coefficient is independent of normal load applied and the apparent contract area. Also, the Coulomb's Law dictates that μ is also independent of sliding velocity. However, the friction coefficient can be influenced by temperature and humidity. [18]

$$\mu = \frac{Friction\ Force}{Normal\ Force}$$



During the friction test, a wear track is gradually made on the sample surface due to the materials loss from friction/wear. The pin/ball tip is usually connected with a high precision depth sensor, so the wear track depth can be measured. Through an optical microscope, the wear track width and length can be accurately measured as well. As the geometry of the wear tip/pin is known, the wear track volume can be estimated. However, a more accurate method is using a stylus or optical profiler to measure the actual volume of loss from the wear track.



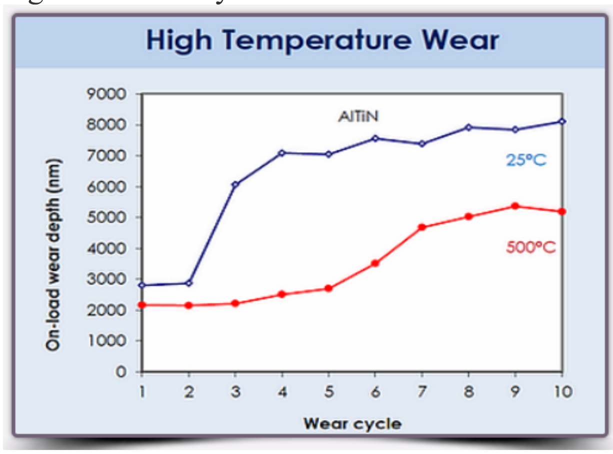
With the volume of loss (V), travel distance (L), normal load (P), disc material Brinell hardness (H) measured, the wear coefficient (K) can be derived from the equation below. However, the hardness of sample surface is difficult to measure accurately without the influence from sub-layers and substrate, thus the ratio K/H is more practical to represent material wear resistance; K/H ratio is known as the dimensional wear coefficient or the specific wear rate. This is usually quoted in units of (mm3 N−1 m−1). A simplified calculation of wear volume loss is from averaged cross-section area of the wear track (A) and the wear track stroke length (S).

Wear Coefficient(K) $= \frac{3HV}{PL}$ Specific Wear Rate (K/H)=3V/PL Wear Volume Loss (V)=A*S

High Temp Friction/Wear

In addition to hardness, Young's modulus and creep behavior, tribological properties (friction and wear) may alter significantly at elevated temperature. The ability to directly assess this behavior at relevant temperatures is an important tool in determining a materials' suitability for its final application.

The figure below shows how sample tribological behavior changes as temperature increases when the hot stage was used in conjunction with the friction/wear function in testing the sliding wear of a PVD AlTiN coating at high load. The coating fails totally during the third scan at 25 ºC but shows greater ductility at 500 ºC and the final wear depth is lower.



Advantages

Instrumented friction/wear testing is ideal for small coupons or coating specimens' surface tribological study, where conventional high load ball-on-disc tests might be an overkill for ultra-thin film structures. The high precision depth and load sensors employed by the friction/wear instruments will accurately determine the critical moment of coating wear as well as capture the small and gradual change of friction evolution through sliding test. Also, instead of having a static loading by weight, the instrumented friction/wear function features the automatic control of load applied, which enables some advanced friction/wear (such as step wear) test methods.

Measurements

1. Friction (Lateral) Force
2. Coefficient of Friction (Static and Dynamic)

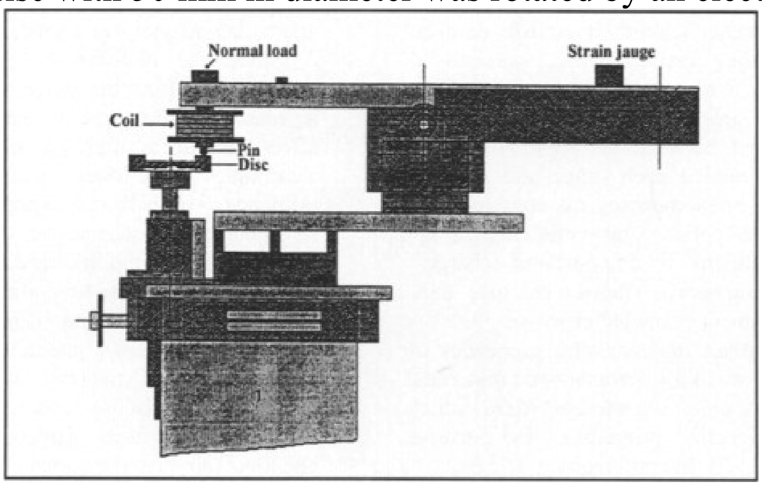
3. Wear track depth
4. Wear track width
5. Wear track volume (Volume of loss material)
6. Wear rate and wear coefficient
7. Wear resistance
8. Effectiveness of lubricants

Standards

1. ASTM G133 Standard Test Method for Linearly Reciprocating Ball-on-Flat Sliding Wear
2. ASTM G171 Standard Test Method for Scratch Hardness of Materials Using a Diamond Stylus

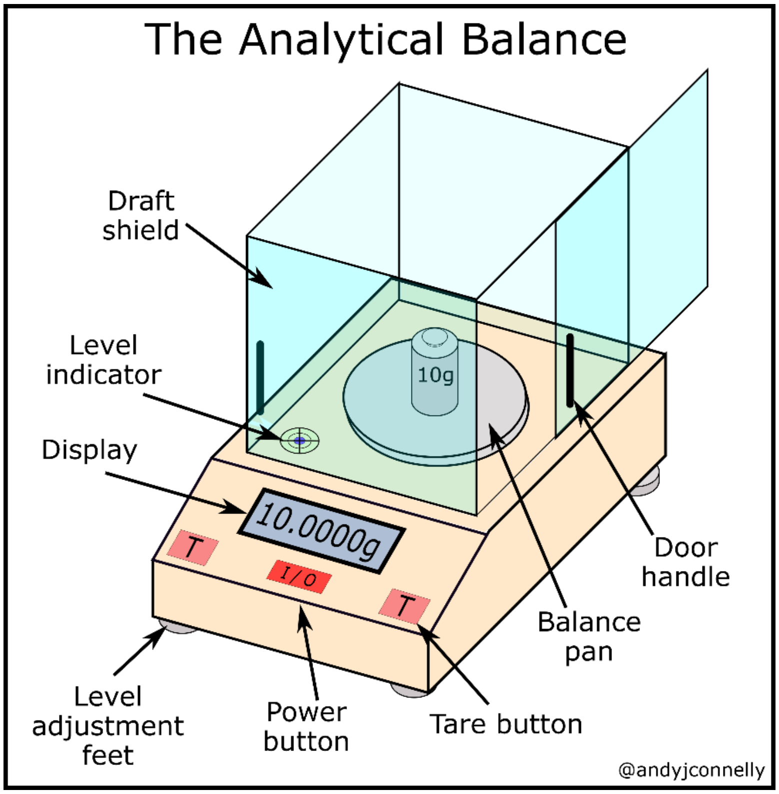
Test procedure and test specimen

The wear tests were carried out on a pin-on-disc tribometer, placed in a magnetic field applied perpendicularly to the sliding surface, in an ambient environment (Fig. 1). The disc with 50 mm in diameter was rotated by an electrical motor.



The pin was a cylinder with 10 mm in diameter and 20 mm in length. The sliding surface of the pin is hemispherical. Disc and pin were both polished before each experiment with ultrathin emery paper (grade 1200) and then cleaned with alcohol. The surface pin specimen was Nickel (ferromagnetic metal; purity 99.95%) and the disc was stainless steel [0.08-0.15) % C, (12-14) % Cr]. The initial Vickers hardness of the pin and disc were respectively 60 Hv and 473 Hv. The test duration was 1 h. The wear loss of the pin or disc was obtained gravimetrically by using a microbalance.

5- The laboratory balance



Introduction

The laboratory balance is so often the forgotten object that sits in the corner of the laboratory. Forgotten, that is, until it is called on to give an accurate measurement. Then all hell breaks loose as it is found to be dirty and the mass just will not settle, it just keeps wondering. Eventually it is given up as a bad job and forgotten about again. There are few things more frustrating than a balance that is not behaving itself and usually this is due to neglect [19].

Types of balance

Analytical balances are designed to measure small masses from around 320g to sub-milligram. They are very sensitive pieces of equipment so need to be treated with care. The main types of laboratory balance are (masses stated are general values only):

- Top-pan balance (200g – 0.001g)
- Analytical balance (320g – 0.0001g)
- Microbalance (6g – 0.000001g)
- Ultra-microbalance (6g – 0.0000001g)

Here we will mainly look at analytical balances as see in Figure 1. These are sensitive enough that they normally require a transparent enclosure which blocks air currents and prevents dust collecting (see Figure 1). To perform well they have to be level and so are fitted with level indicators (usually a spirit level). Apart from these two important factors the basic operation is very similar to your electronic kitchen balances at home.

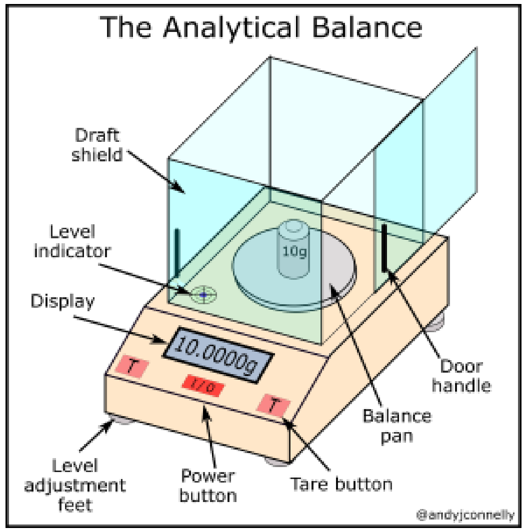


Figure 1: The analytical balance.

Operating principal

Balances do not directly measure mass; they measure the force (weight) that acts downward on the balance pan. Most analytical balances are electromagnetic balances and so measure this weight using an electromagnet. Figure 2 shows the electromagnetic servomotor which generates a force counter the weight of the mass being measured. The electrical current required to generate this force is proportional to the weight and so can be used, with appropriate calibration, to calculate the mass. This mass is then displayed on the screen. To signal when the weight and electromagnetic forces are equal many balances have a "null detector" that uses a light source and detector.

The use of the electromagnetic means that balances that have been turned off (at the wall) should not be used straight away after turning back on. You should wait at least thirty minutes for the electromagnetic field to stabilise (times may vary depending on manufacturer and model). It also means that placing any magnetic materials or magnets near the balance could cause problems for the balance.

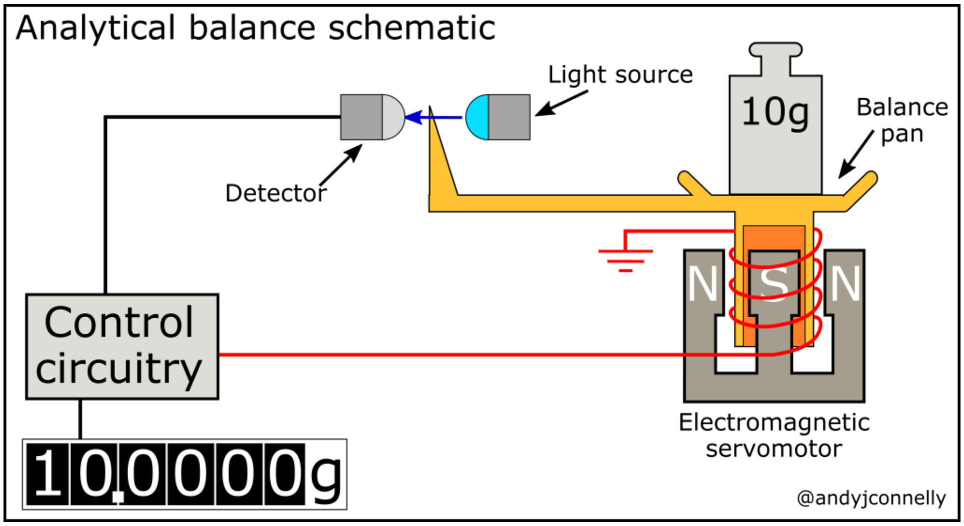


Figure 2. The operation of a modern analytical balance.

Operating an analytical balance

The following is a basic procedure for using an analytical balance. Before using a balance, it is a good idea to check the calibration with a check weight (see below).

- Check the balance is level using the level indicator (see Figure 1). If the bubble is not in the centre adjust the level, normally by twisting the feet, until the bubble is in the centre of the inner circle.
- Check that the balance is on and that the door is closed. Press the "Tare" button and wait 5-10 secs for a '*' or similar symbol to appear in the upper left/right hand corner of the display, and the mass to read 0.0000 g.
- Open the door and place a weigh boat, weight paper, or other container on the centre of the balance pan (ideally with tweezers or similar).
- Close the door and wait for the digital readout to stabilize ('*').
- If you do not wish to include container mass in your measurement then press "TARE" to reset the mass to zero (see Step 2 above),
- Remove the container from the balance and add the substance to be weighed. Avoid adding substances on the balance pan as this can result in contaminating the balance.
- Return container to balance and wait 5-10 secs (may take up to a minute) for the mass reading to settle.
- If the mass reading is unstable it may be due to static electricity build up or other issues– see trouble shooting section.

Trouble shooting

The accuracy and precision of an analytical balance must be guarded and checked at regular intervals. There are many factors that govern whether an analytical balance behaves itself:

- **Gravitational acceleration** differences across the globe mean that the balances calibration may require local adjustment.

- **Temperature**: Balances take time to equilibrate to laboratory temperature changes. Also, hot or cold objects can create convection currents in the air which can cause variation in mass measured. For these reasons it is important to let the balance and objects equilibrate to the same temperature.
- **Moisture**: Objects or materials that absorb moisture can appear to gain weight. This may particularly be an issue for objects that have recently been removed from a desiccator. Other materials may evaporate or sublime during measurement.
- **Air flows**: Air movement in the laboratory across the pan will cause variations in the measurement. A draft shield reduces this but it will take time for the air within the draft shield to stabilize once the door is closed. Changes in air temperature within the draft shield will also cause air movement. These changes can be due to the temperature of the mass, hands, etc. Reducing air flow incident on the balance in the laboratory is key to reducing this issue and ensuring all items entering the draft shield are equilibrated to ambient temperature – using tweezers, not your warm hands, to move items can help.
- **Static electricity**: This can be one of the biggest causes of frustration when using a balance. If the mass you are measuring wonders up or down and will not stabilise then there is a good chance that you have a static issue. The static-electrical field interferes with the electromagnetic field of the balance. To prevent this you can use an anti-static device which will "fire" positive and negative ions at the weight boat, powder, etc. to neutralize the static charge. The good anti-static system are incredibly effective and can save hours of pain and frustration. Anti-static plastic weigh boats or metal weigh weight boats can also help.

To help diagnose any issues you are having with a balance the check weight is a vital tool. A check weight (or calibration weight) is simply an object that has been certified to have certain mass. They are simple to use but must be handled very carefully as they are expensive and sensitive to touch and rough handling so should only be handled with tweezers and must not be dropped as this may change the mass.

There are different grades of check weights. The main accuracy classes for weights are:

- **Class E1** the highest accuracy class used as primary laboratory reference standard (1 kg is ±0.5 mg).
- **Class E2** Used as a high precision standard for calibration of weights and special precision analytical instruments such as Ultra Micro, Micro, Semi–Micro Balances and analytical balances. (1 kg is ±1.6 mg).
- **Class F1** For the calibration of some analytical balance and high accuracy top-pan balances. (1 kg is ±5 mg).
- **Class F2, M1, M2, and M3** are of lower standard and not suitable for analytical balances.

It is worth checking each section of a balance pan to ensure you do not have any eccentricity error as well (see Figure 3). This type of error is the reason why it is good practice to always place items in the middle of a balance pan.

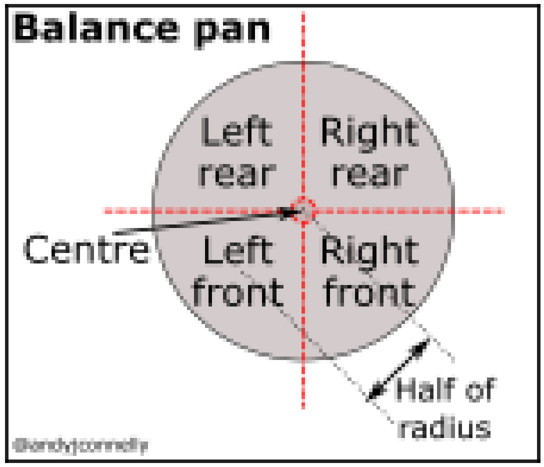


Figure 3: Areas of a balance pan.

Maintenance

For most laboratories an annual service and calibration is sufficient. However, accredited laboratories will often check that calibration every day to ensure no error has occurred.

In between calibrations the key maintenance is to keep the balance clean. Any material that works its way inside a balance can cause major problems; especially if it is a corrosive material. Clean the balance by dusting off the stage and surrounding area with a paint brush or similar and then gently wipe down the balance, glass panels, and counter top around the balance with a lint free tissue. Ethanol can sometimes also be used depending on manufacturer and model – always check manufacturer's instructions.

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نموذج اجراء التجارب

- **بيانات عامه:**

إسم التجربة:

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الفرقة المقرر عليها التجربة:

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الفصل الدراسى:

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الأدوات المطلوبة للتجرية:

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- **الأساس النظرى للتجربة:**

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- **خطوات تنفيذ التجربة:**

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- **النتائج:**

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- **مناقشة النتائج:**

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- **أسئلة عامة:**

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