ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL,

NAVI MUMBAI – 410206

DEPARTMENT OF MECHANICAL ENGINEERING

A PROJECT REPORT

ON

“Evaluation and Elimination of Errors in Impact Testing Machine”

Submitted by

Group No. 13

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In partial fulfillment for the award of the degree

Of

BACHELOR OF ENGINEERING IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE OF

Prof. Nafe Momin

UNIVERSITY OF MUMBAI

ACADEMIC YEAR 2020 – 2021

ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL

(Approved by AICTE, recg. By Maharashtra Govt. DTE,

Affiliated to Mumbai University)

CERTIFICATE

This is to certify that the project entitled

"Evaluation and Elimination of Errors in Impact Testing Machine"

Submitted by

Khan Asad Gafoor	**17ME27**
Khan Mohammed Adnaan Javed	**17ME36**
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To the Kalsekar Technical Campus, New Panvel is a record bonafide work carried out by them under our guidance and supervision, for partial fulfillment of the requirements for the award of the Degree of Bachelors of Engineering in Mechanical Engineering as prescribed by **University of Mumbai** is approved.

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KALSEKAR TECHNICAL CAMPUS NEW PANVEL

APPROVAL OF DISSERTATION

This is to certify that the thesis entitled

"Evaluation and Elimination of Errors in Impact Testing Machine"

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(Internal Examiner) **(External Examiner)**

__________________ __________________

Date: ____________

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DECLARATION

We declare that this written submission represents our ideas in our words and where others ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

To determine the confidence of the test results, it is necessary to evaluate the main factors contributing to the uncertainty in Charpy impact measurement. These factors are: the uncertainty of reference force and length measuring devices and its long term instability, machine resolution, rated energy error, indicated energy error, losses due to the drag of the pointer, friction losses in the bearing and air resistance and other geometric para-meters. In this study the calibration process is based on the relevant Indian and international standard is explained. Most of the uncertainty elements are identified and directly verified. Other elements not be directly verified are analyzed or assessed using available information.

CASE STUDY

A Proposed Estimation of the Expanded Uncertainty of Charpy Impact Testers

By A. Abu Sinna, Saher R. Hassan

Charpy impact testing is a low-cost and reliable test method which is commonly required by the construction codes for fracture-critical structures such as bridges and pressure vessels. Yet, it took from about 1900 to 1960 for impact-test technology and procedures to reach levels of accuracy and reproducibility such that the procedures could be broadly applied as standard test methods.

Without uniformity of test results from day to day and from laboratory to laboratory, the impact test has little meaning. Over the years, researchers have learned that the results obtained from an impact test can depend strongly upon the specimen size and the geometry of the notch, anvils, and striker: To a lesser degree, impact test results also depend upon other variables such as impact velocity, energy lost to the test machine, and friction. The goal of those who have written and modified ASTM Standard Test companies performing accepta-nce tests are typically required to verify the performance of their impact machine using certified verification specimens.

Since 1998, National Institute of Standards, NIS, has entered the facility of the direct verification of Charpy impact testers according to BS DIN ISO 10045 standard. However, and starting from 2017, NIS has changed the reference standard to BS DIN ISO 148-2. This standard describes two methods:

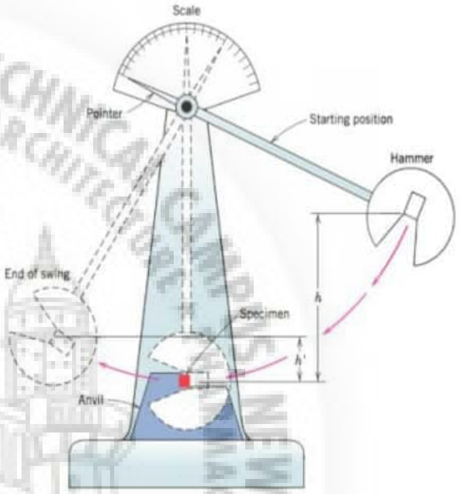
1- The direct method allowing the physical and geometrical properties of the different parts of the testing machine to be verified statically and separateely.
2- The indirect method: global verification method of the pendulum impact testing machine using Charpy V reference test pieces.

The direct method shall be used, initially, when the machine is being installed or repaired, and if the indirect method gives a doubtable result.

This study concerns describing the uncertainty evaluation method of the direct verification of the Charpy impact testers as applied in NIS. Consequently, this study proposes all sources of error that might affect the uncertainty estimation such as reference load, angle and length measuring devices, resolution effect, indicated energy error, drag to of the pointer and bearing friction.

INTRODUCTION

The Charpy impact test, also known as the Charpy V-notch test, is a high strain-rate test that involves striking a standard notched specimen with a controlled weight pendulum swung from a set height. The impact test helps measure the amount of energy absorbed by the specimen during fracture.



Charpy tests show whether a metal can be classified as being either brittle or ductile. This is particularly useful for ferritic steels that show a ductile to brittle transition with decreasing temperature. A brittle metal will absorb a small amount of energy when impact tested, a tough ductile metal absorbs a large amount of energy.

It is good practice in any measurement to evaluate and report the uncertainty associated with the test results. A statement of uncertainty may be required by a customer who wishes to know the limits within which the reported result may be assumed to lie, or the test laboratory itself may wish to develop a better understanding of which particular aspects of the test procedure have the greatest effect on results so that this may be controlled more closely.

In our research project we are going to find the errors and uncertainty of the impact testing machine for Charpy test and will try to reduce the errors as much as we can.

CHARPY IMPACT TEST

HISTORY:

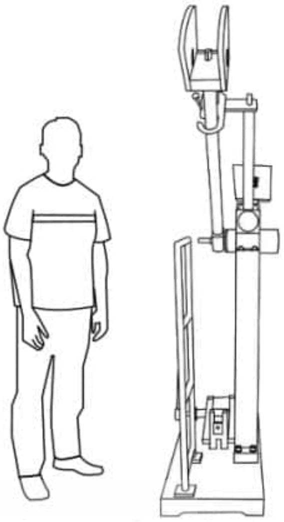
The impact-pendulum test method and associated equipment in nearly its current form was first developed more than a century ago. And while the basic concept behind this testing method is generally credited to two different engineers, S. B. Russell (1898) and G. Charpy in (1901); the test is now known by only the latter's name. The reason for this is due in large part to Georges Augustin Albert Charpy's technical contributions in the first half of the 20th century. These efforts included writing testing procedures in the use of a pendulum to apply an impact force to a specimen and measure the amount of energy absorbed during its fracture.

DEFINITION:

A test of the impact strength of a material, used to determine its relative ductility or brittleness. The test is executed by swinging a large, heavy hammer on a pendulum from a predetermined height. The hammer fractures the material sample, usually a block of a certain size with a notch cut in it. The height to which the pendulum swings is used to calculate the energy necessary to fracture the sample.

THEORY:

Toughness is the ability of the material to withstand crack i.e., to prevent the transfer or propagation of the cracks across its section hence causing failure. Impact testing machine consists of a pendulum suspended from a short shaft that



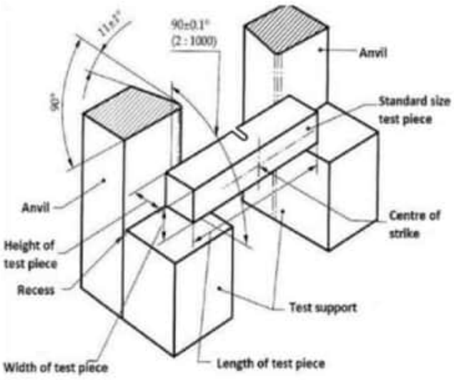
rotates in ball bearing and swings midway between two rigid upright stands supported on a rigid base. According to Indian Standard the speed of pendulum at the instant of striking shall be 4.5 - 7 m/s and the plane of swing of the striker shall be vertical and within 0.5 mm of the plane midway between the supports. The pendulum can be raised to any desired height and rested at that position. It is suported in the starting position by a catch and can be released by a trigger. The mechanism is so designed that the pendulum is not disturbed when the catch is released. The striking energy of the testing machine should be 300±10J for standard testing.

In impact test a specially prepared notched specimen is fractured by a single blow from a hammer and energy required being a measure of resistance to impact. Impact load is produced by a swinging of an hammer weight W from a height h, release of the hammer from the height h swings the hammer through the arc of a circle, which strikes the specimen to fracture at the notch (Kinetic energy of the hammer at the time of impact is mv2/2), which is equal to the relative potential energy of the hammer before its release is mgh,

Where, m is the mass of the hammer and v is its tangential velocity at impact=2gh, g is gravitational acceleration (9.806 m/s2) and h is the height through which hammer falls.

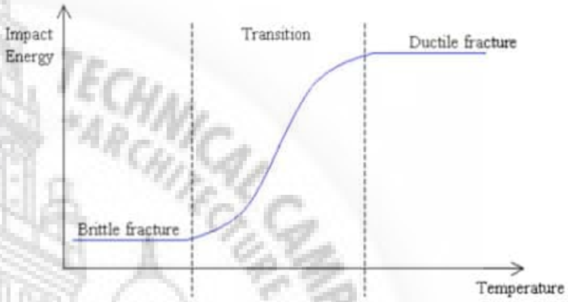
The difference between potential energies is the fracture energy.

Fracture Energy = mgh $(h_0 - h_f)$



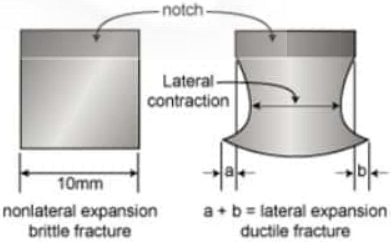
This value is called impact toughness or impact value, which will be measured per unit area at the notch. The test consists of measuring the energy absorbed in breaking a notched specimen supported at each end by one blow from a swinging hammer under prescribed conditions.

Charpy tests show whether a metal can be classified as being either brittle or ductile. This is particularly useful for materials such as ferritic steels that show a ductile to brittle transition with decreasing temperature. A brittle material will absorb a small amount of energy when impact tested, and a tough ductile metal absorbs a large amount of energy. The appearance of a fractured surface also gives information about the type of fracture that has occurred, a brittle fracture will be bright and crystalline, and a ductile fracture will be dull and fibrous. Then the percentage crystallinity is determined by making a judgement of the amount of crystalline or brittle fracture on the surface of the broken specimen, and is a measure of the amount of brittle fracture.



Above curve shows that a ductile fracture absorbs a greater amount of energy than a brittle fracture in the same material. At higher temperatures the impact energy is relatively large since the fracture is ductile. As the temperature is lowered, the fracture becomes more brittle. When a ductile metal is broken, the test-piece deforms before breaking, a pair of 'ears' being squeezed out on the side of the compression face of the specimen. The amount by which the specimen deforms in this way is measured as lateral expansion and expressed as millimeters of lateral expansion.

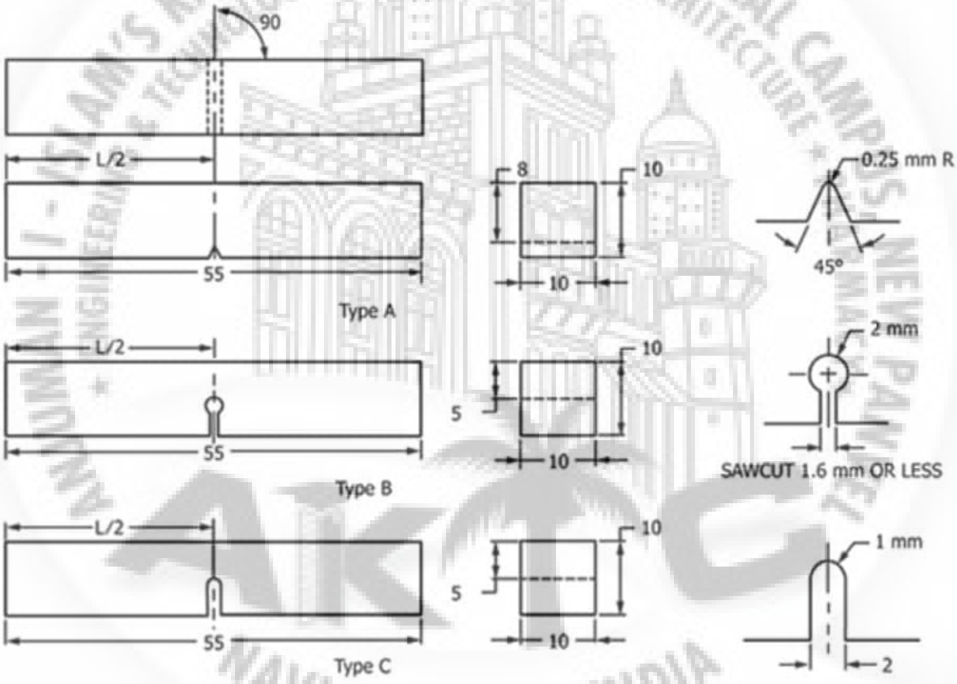
The percent shear area on the fracture surface of a charpy impact specimen typically calculated as the difference between the total fractured area (Fracture Initiation Region, Unstable Fracture region, Shear Lips, and Final Fracture Region) and the unstable fracture area, divided by the total fractured area, times 100.



$$\% \text{ shear area} = \frac{\text{Total fractured area} - \text{Unstable fracture area}}{\text{Total fractured area}} \times 100$$

TEST SPECIMEN:

The standard test piece shall be machined all over and shall have a square cross-section 10 mm x 10 mm sides, 55 mm long and in the centre of the length of one face there shall be a V-notch of specified depth with 1 mm root radius. Where the standard test piece cannot be obtained from the material then one of the subsidiary test pieces having a rectangular cross-section shall be used with the notch cut in one of the narrower faces.



RELEVANT INDIAN STANDARD FOR CHARPY IMPACT TEST:

1. IS:1499-1977; Method for Charpy Impact Test (U-notch) for Metals.
2. IS:3766-1977; Method for calibration of pendulum impact testing machines for testing metals.

SOME RESULTS OF CHARPY IMPACT TEST OF ALLOYS:

Sr. No	Alloy	Impact Energy (J)
1	1040 carbon steel	180
2	8630 low-alloy steel	55
3	410 stainless steel	34
4	L2 tool steel	26
5	Ferrous superalloy (410)	34
6	Ductile iron, quench	9
7	2048 plate aluminum	10.3
8	AZ31B magnesium	4.3
9	AM100A casting magnesium	0.8
10	Ti-5Al-2.5Sn	23
11	Aluminum bronze, 9 % (copper alloy)	48
12	Monel 400 (nickel alloy)	298
13	50:50 solder (lead alloy)	21.67
14	Nb-1 Zr (refractory metal)	174

ERROR AND UNCERTAINTY

ERROR :

In general, a measurement has imperfections that give rise to an error in the measurement result. Traditionally, an error is viewed as having two components, namely, a random component and a systematic component. Error is an idealized concept and errors cannot be known exactly.

Random error presumably arises from unpredictable or stochastic temporal and spatial variations of influence quantities. The effects of such variations, hereafter termed random effects, give rise to variations in repeated observations of the measurand. Although it is not possible to compensate for the random error of a measurement result, it can usually be reduced by increasing the number of observations; its expectation or expected value is zero.

Systematic error, like random error, cannot be eliminated but it too can often be reduced. If a systematic error arises from a recognized effect of an influence quantity on a measurement result, hereafter termed a systematic effect, the effect can be quantified and, if it is significant in size relative to the required accuracy of the measurement, a correction or correction factor can be applied to compensate for the effect. It is assumed that, after correction, the expectation or expected value of the error arising from a systematic effect is zero.

The uncertainty of a correction applied to a measurement result to compensate for a systematic effect is not the systematic error, often termed bias, in the measurement result due to the effect as it is sometimes called. It is instead a measure of the uncertainty of the result due to incomplete knowledge of the required value of the correction. The error arising from imperfect compensation of a systematic effect cannot be exactly known. The terms “error” and “uncertainty” should be used properly and care taken to distinguish between them.

UNCERTAINTY:

Uncertainty of measurement is the doubt that exists about the result of any measurement. You might think that well-made rulers, clocks and thermometers should be trustworthy, and give the right answers. But for every measurement even the most careful - there is always a margin of doubt. In everyday speech, this might be expressed as ‘give or take’ ... e.g. a stick might be two meters long ‘give or take a centimeter’.

The formal definition of the term “uncertainty of measurement is as follows: uncertainty (of measurement) parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand.

ERROR VERSUS UNCERTAINTY:

It is important not to confuse the terms ‘error’ and ‘uncertainty’.

Error is the difference between the measured value and the ‘true value’ of the thing being measured.

Uncertainty is a quantification of the doubt about the measurement result. Whenever possible we try to correct for any known errors: for example, by applying corrections from calibration certificates. But any error whose value we do not know is a source of uncertainty.

PROCEDURE FOR THE ESTIMATION OF UNCERTAINTY

Step 1:Identifying the Parameters for Which Uncertainty is to be Estimated :

The first step is to list the quantities (measurands) for which the uncertainties must be calculated. Table 1 shows the parameters that are usually reported as results from the test procedure. Often intermediate measurands are recorded by the laboratory, but are not necessarily reported to the customer. Both types of measurand are listed in table.

Reported Mesurand	**Unit**	**Symbol**
Energy Absorbed	J	KV or KU
Other Mesurements		
Height of test piece	mm	h
Width of test piece	mm	w
Length of test piece	mm	l
Notch Geometry -Height below notch -Radius of curvature -Angle of notch	 mm mm °	 - - -
Test temperature	°C	T

The energy absorbed is measured directly by the impact testing machine.

Step 2: Identifying all Sources of Uncertainty in the Test:

In Step 2, the user must identify all possible sources of uncertainty which may have an effect (either directly or indirectly) on the test. The list cannot be identified comprehensively before-hand as it is associated uniquely with the individual test procedure and apparatus used. This means that a new list should be prepared each time a particular test parameter changes (e.g. when a plotter is replaced by a computer).

Step 3: Classifying the Uncertainty According to Type A or B:

In this third step the sources of uncertainty are classified as Type A or B, depe-nding on the way their influence is quantified. If the uncertainty is evaluated by statistical means (from a number of repeated observations), it is classified Type A, if it is evaluated by any other means it should be classified as Type B.

The values associated with Type B uncertainties can be obtained from a number of sources including a calibration certificate, manufacturer's information, or an expert's estimation. For Type B uncertainties, it is necessary for the user to estimate the most appropriate probability distribution for each source.

Step 4: Estimating the Standard Uncertainty for each Source of Uncertainty:

In this step the standard uncertainty, u, for each input source identified is estimated. The standard uncertainty is defined as one standard deviation and is derived from the uncertainty of the input quantity divided by the parameter, dv, associated with the assumed probability distribution.

The individual influences of each source of uncertainty on the energy absorbed is very complex and not practical. The simplest way is to use a CRM to calibrate the whole system, and consider the errors, CRM repeatability and test sample repeatability.

Step 5: Computing the Combined Uncertainty u_c:

Assuming that individual uncertainty sources are uncorrelated, the measurand's combined uncertainty of the measurand, $u_c(y)$, can be computed using the root sum squares:

$$u_c(y)=\sqrt{\sum_{i=1}^{N}[c_i.u(x_i)]^2}$$

where c_i is the sensitivity coefficient associated with x_i. This uncertainty corresponds to plus or minus one standard deviation on the normal distribution law representing the studied quantity. The combined uncertainty has an associated confidence level of 68.27%.

Step 6: Computing the Expanded Uncertainty U:

The expanded uncertainty, U, is defined as "the interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand". It is obtained by multiplying the combined uncertainty, u_c, by a coverage factor, k, which is selected on the basis of the level of confidence required. For a normal probability distribution, the most generally used coverage factor is 2, which corresponds to a confidence interval of 95.4% (effectively 95% for most practical purposes). The expanded uncertainty, U, is therefore, broader than the combined uncertainty, u_c. Where a higher confidence level is demanded by the customer (such as for aerospace, electronics, ...), a coverage factor of 3 is often used so that the corresponding confidence level increases to 99.73%.

In cases where the probability distribution of u_c is not normal or where the number of data points used in Type A analysis is small, the value of k should be calculated from the degrees of freedom given by the Welsh-Satterthwaite method.

Step 7: Reporting of Results:

Once the expanded uncertainty has been estimated, the results should be reported in the following way:

$V = y \pm U$

where V is the estimated value of the measurand, y is the test (or measurement) mean result, U is the expanded uncertainty associated with y. An explanatory note, such as that given in the following example should be added (change when appropriate):

“The reported expanded uncertainty is based on a standard uncertainty multiplied by a coverage factor, k = 2, which for a normal distribution corresponds to a coverage probability, p, of approximately 95%. The uncertainty evaluation was carried out in accordance with UNCERT CoP 06:2000.”

1. Uncertainties In The Certified Value Of CRM

The certified values of the CRM, which are given in the certificate belonging to the specimen, are the mean value E_{BCR} and the uncertainty of the certified value of the CRM e_{BCR} . The uncertainty mainly includes the effect of the variation between samples.

The ISO 5725 standard is additional to the GUM. The methods described in it have long been used in test environments. They are based on the principles of a standardized method, reference material, comparison and inter- or intra laboratory variance. These methods, although seemingly very different from that of the GUM, can be considered as a determination of uncertainty by a type A method: experiments carried out by a wide range of laboratories with very similar specialization and statistical processing of the results.

The values generally published are:

- r: repeatability limit: The value less than or equal to which the absolute difference between two test results obtained under repeatable conditions may be expected to be with a probability of 95% (results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment).
- R: reproducibility limit: The value less than or equal to which the absolute difference between two test results obtained under reproducible conditions may be expected to be with a probability of 95% (results are obtained with the same method on identical test items in different laboratories with different operators using different equipment).

If the R of a standardized method is published, then $S = R/2\sqrt{2}$ can be taken as the standard deviation of a measurement carried out scrupulously in accordance with the method,

by approximating $2\sqrt{2} \approx 2.8$. In other cases we use $\sigma = e_{BCR} / 2$.

The following uncertainties have to be considered:

1) Uncertainty from standard deviation of a measurement on a CRM:

$$u_1 = e_{BCR} / 2\sqrt{2}$$

2) The uncertainty due to testing the CRM specimens:

The error of the impact machine eA1 is calculated as $E_{mean} - E_{BCR}$, where:

$E_{mean} = (E1 + E1 + E1 + E1 + E1) / 5$

EBCR = the certified value of the absorbed energy from a single batch of reference

Charpy- V specimens.

BCR did not follow the GUM in the uncertainty calculation until end of 1999.

It is not common practice to correct for the systematic error of the machine, therefore this error is taken into account linearly with the expended uncertainty.

Calibration or correction curves should not be used according to NIST, because the source(s) and magnitude of error for energy values at one energy level may not be the same at different energy levels.

2. Uncertainty In Energy Values Obtained From Test Specimen

The following uncertainties have to be considered:

(1) Uncertainty due to testing n specimens.

(2) Uncertainty due to the error of reading of the energy value, associated with the grade mark on the energy scale:

u= tolerance limit / d_v

The divisor d_v is $\sqrt{3}$ for analogue readouts and $\sqrt{12}$ for digital readouts.

3. Uncertainty Due To Specimen Dimensions

As the measured impact energy is not corrected for the specimen cross-section, the dimensions of the cross-sectional area below the notch directly influences the energy absorbed. The calculated uncertainty due to the uncertainty in cross-sectional area caused by variations in the specimen dimensions, including the depth of the notch, is assumed to vary linearly with the cross-sectional area. Probably this is not a conservative approach. Uncertainty due to specimen dimensions, assuming a linear relationship according to the above formula of u. The tolerance limit is about 1%, with a rectangular probability distribution.

4. Uncertainty Due To Test Temperature

The measured energy depends directly on the specific test temperature at which the test was performed. The stated temperature should be corrected for uncertainty and in that case no uncertainty for temperature should be added. If the impact energy is required for a specified temperature, at which the test is done, then the uncertainty due to temperature should be included. Special attention should be paid to select the right value for the sensitivity coefficient c_i, especially if the temperature is in the transition range of the material being tested. The uncertainty is:

$$u = c_T \, . \, u_T / dv$$

where cT is the sensitivity coefficient, uT is the uncertainty in temperature and dv depends on the distribution of the temperature uncertainty.

5. Uncertainty Due To Specimen Notch Geometry

The influence of the specimen notch geometry is strong, especially outside the allowable tolerances of the standards. This influence is not covered by the use of a CRM as they are always supplied in machined form and therefore any comparison does not include these effects. It can be predicted that a sharper notch will give a lower energy level, and a more blunt notch will give a higher one. The effect of the notch geometry is dependent on material, mean level of energy (temperature), the sharpness of the fabrication tool and probably the roughness of its cutting edge. Using a blunt tool can induce a degree of work hardening at thenotch which can conceivably influence the impact energy, particularly when this energy level is on the lower shelf for steel specimens.

6. Uncertainty Due To Indicated Energy Error

For a machine has a nominal capacity AN Joules, verify the indicator graduations corresponding to 10, 20, 30, 50 or 60-80 % of the initial nominal potential energy A_N, then calculate the absorbed energy A_v for each one. This followed by calculating the indicated energy error percentage u_{ind}. To do this, lift the pendulum driving the indicator in the rise direction until the indicator is on the graduation to be verified. Measure the angle β of rise to within ± 0.065°. The energy absorbed is equal to:

$$A_V = F . L_2 (\cos\beta - \cos\alpha)$$

The difference between the energy indicator A_S and the absorbed energy A_V calculated on the basis of the measured values, shall not exceed ± 1 % of the absorbed energy A_V or ± 0.5% of the potential energy A_P. In each case, the greater value is permitted.

In case that the indicated energy error is within the specified error, the value as taken as the permissible one. If the indicated energy error exceeds the permissible values, it's recommended to make maintenance for the machine.

The value of the standard uncertainty due to indicated energy error (U_{ind}) can be estimated from the following equation (assuming triangular distribution):

$$U_{ind} = \pm u_{ind} / \sqrt{6}$$

$$PE = m \times g \times h$$

$$300 = 21.3 \times 9.81 \times h$$

$$h = 1.435 \text{ m}$$

- For 10%

$30 = 21.3 \times 9.81 \times h$

h = 0.1435 m = 14.35 cm

$\alpha = 34.563°$

Experimental h = 14 cm

$\beta = 34.126°$

- For 20%

$60 = 21.3 \times 9.81 \times h$

$h = 0.2871 = 28.71 \text{ cm}$

$\alpha = 49.6°$

Experimental h = 26.5 cm

$\beta = 47.61°$

- For 30%

$90 = 21.3 \times 9.81 \times h$

$h = 0.4307 \text{ m} = 43.07 \text{ cm}$

$\alpha = 61.95°$

Experimental h = 39 cm

$\beta = 58.64°$

- For 50%

$150 = 21.3 \times 9.81 \times h$

$h = 0.717m = 71.7\ cm$

$\alpha = 83.21°$

Experimental h = 68.5 cm

$\beta = 80.94°$

- For 60%

$180 = 21.3 \times 9.81 \times h$

$h = 0.861\ m = 86.1cm$

$\alpha = 93.38°$

Experimental h = 85 cm

$\beta = 92.12°$

- For 80%

$240 = 21.3 = 9.81 \times h$

$h = 1.148\ m = 114.8\ cm$

$\alpha = 114.33°$

Experimental h = 112 cm

$\beta = 112.18°$

- For 10%

$A_V = F \times L_2 \times (\cos\beta - \cos\alpha)$

$= 216.57 \times 0.813 \times (\cos 34.126 - \cos 34.563)$

$A_V = 0.5761$

u_{ind} = [(A_s - A_V)/ A_V] ×100

$$= \frac{28 - 0.756}{0.756} \times 100$$

$u_{ind} = 3603.21$

- For 20%

  $A_V = F \times L_2 \times (\cos\beta - \cos\alpha)$

  $= 216.57 \times 0.813 \times (\cos 47.61 - \cos 49.6)$

  $A_V = 4.498$

u_{ind} = [(A_s - A_V)/ A_V] ×100

$$= \frac{58 - 4.489}{4.489} \times 100$$

$u_{ind} = 1067$

- For 30%

  $A_V = F \times L_2 \times (\cos\beta - \cos\alpha)$

$= 216.57 \times 0.813 \times (\cos 58.64 - \cos 61.95)$

$A_V = 8.833$

u_{ind} = [(A_s - A_V)/ A_V] ×100

$$= \frac{86 - 8.833}{8.833} \times 100$$

$u_{ind} = 873.6$

- For 50%

$$A_V = F \times L_2 \times (\cos\beta - \cos\alpha)$$

$$= 216.57 \times 0.813 \times (\cos 80.94 - \cos 83.21)$$

$$A_V = 6.90$$

$$u_{ind} = [(A_s - A_V)/A_V] \times 100$$

$$= \frac{145 - 6.90}{6.90} \times 100$$

$$u_{ind} = 2000$$

- For 60%

$$A_V = F \times L_2 \times (\cos\beta - \cos\alpha)$$

$$= 216.57 \times 0.813 \times (\cos 92.12 - \cos 93.38)$$

$$A_V = 3.867$$

$$u_{ind} = [(A_s - A_V)/A_V] \times 100$$

$$= \frac{178 - 3.867}{3.867} \times 100$$

$$u_{ind} = 4500$$

- For 80%

$$A_V = F \times L_2 \times (\cos\beta - \cos\alpha)$$

$$= 216.57 \times 0.813 \times (\cos 112.18 - \cos 114.33)$$

$A_V = 6.0698$

$u_{ind} = [(A_s - A_V)/ A_V] \times 100$

$$= \frac{236 - 6.0698}{6.0698} \times 100$$

$u_{ind} = 3800$

$$\text{Mean } u_{ind} = \frac{3603.21+1067+873.6+2000+4500+3800}{6}$$

$u_{ind} = 2640.63$

$U_{ind} = u_{ind} / \sqrt{6}$

$$= \frac{2640.63}{\sqrt{6}}$$

$\mathbf{U_{ind} = 1078.034}$

7. Uncertainty Due To Drag of Pointer

Calculate the friction losses due to the drag of the pointer p. then, estimate the percentage of the losses u_{drag}. To do this, move the pointer to a position corresponding to a rise angle of zero, let the pendulum fall normally (fall angle a) but without the test piece in position and read off the rise angle β_1, or the energy E_1 directly.

Then, without resetting the pointer, let the pendulum fall a second time from the position corresponding to the fall angle and read off the new rise angle β_2, or the energy E_2 directly. When the scale is graduated in degrees, the friction losses of the pointer are equal to:

$P = F.\, L_2(\cos\beta_1 - \cos\beta_2)$

And when the scale is graduated in energy units, the friction losses of the pointer are equal to:

$P = E_1 - E_2$

In this calculation, use the mean values of β_1 and β_2 (or $E_1 - E_2$) from four determinations at least.

$U_{drag} = (p/A_N).\,100$

The value of the standard uncertainty due to drag of the pointer (U_{drag}) can be estimated from the following

equation(assuming rectangular distribution):

$U_{drag} = u_{drag} / \sqrt{3}$

- E_1 = 32 Joules
- E_1 = 31 Joules
- E_2 = 27 Joules
- E_1 = 27 Joules

Mean E_1 = 29.375 Joules

- $E_2 = 31$ Joules
- $E_2 = 31$ Joules
- $E_2 = 26.5$ Joules
- $E_2 = 26$ Joules

Mean $E_2 = 28.625$ Joules

$$P = E_1 - E_2$$

$$= 29.375 - 28.625$$

$$= 0.75 \text{ Joules}$$

$$u_{drag} = (P / A_N) \times 100$$

$$= \frac{0.75}{300} \times 100$$

$$= 0.25$$

$$U_{drag} = u_{drag} / \sqrt{3}$$

$$= \frac{0.25}{\sqrt{3}}$$

$$= \mathbf{0.1443}$$

8. Uncertainty Due to Bearing Friction

After determining β_2 or the energy E_2, return the Pendulum to its initial position. Then, without re-adjusting the pointer, release the pendulum to allow 10 half-swings. After the pendulum has started its 11th half-swing, move the pointer about 5% from its maximum reach and note the value of β_3. Friction losses, if the scale is graduated in degrees, in the bearings and as a result of air-resistance for a half-swing are:

$\acute{P} = (1/10)\ F.\ L_2(\beta_3 - \beta_2)$

Or friction losses, if the scale is graduated in energy, is equal to:

$\acute{P} = (1/10)\ F.\ L_2(E_3 - E_2)$

Calculate the friction losses due to the bearing and as a result of air resistance $\acute{P}$. then, estimate the percentage of the losses u_{bear}.

$u_{bear} = (\acute{P}/A_N)\ .\ 100$

The value of the standard uncertainty due to drag of the bearing friction (U_{bear}) can be estimated from the following equation (assuming rectangular distribution):

$U_{bear} = u_{bear}/\sqrt{3}$

The total losses $\acute{P}+P$ measured in this way shall not exceed 0.5 % of the rated energy A_N, if the losses exceed that tolerance, the machine may need maintenance.

1st half swing = 172 Joules

10th half swing = 171 Joules

5% of maximum reach (i.e 5% of 172 Joules) = 8.6

$E_3 = 171 + 8.6$

$E_3 = 179.6$

- E_2 to be used the same as in case of drag of pointer

  $P' = 1/10 \times F \times L\ (E_3 - E_2)$

  $$P' = \frac{1}{10} \times 216.157 \times 0.813\ (179.6 - 28.625)$$

  $$P' = 2653.16 \text{ Joules}$$

$u_{bear} = (P' / A_N) \times 100$

$$= \frac{2653.16}{300} \times 100$$

$$= 884.38$$

$U_{bear} = u_{bear} / \sqrt{3}$

$$= \frac{884.38}{\sqrt{3}}$$

$$= \mathbf{510.60}$$

9. Combined Uncertainty Of The Machine

The value of the standard combined uncertainty of the machine, U_{comb}, can be estimated from the following equation:

$$U_{comb} = \sqrt{(Uind)^2 + (Udrag)^2 + (Ubear)^2}$$

$$= \sqrt{(1078.034)^2 + (0.1443)^2 + (510.60)^2}$$

$$U_{comb} = \mathbf{1192.84}$$

10. Expanded Uncertainty Of The Machine

The value of the standard expanded uncertainty of the machine (U_{exp}) can be estimated from the following equation:

$U_{exp} = K \times U_{comb}$ [K =2]

Where K is coverage factor

$= 2 \times 1192.84$

$\mathbf{U_{exp} = 2385.682}$

11. Parallax Error

Parallax error occurs when the measurement of an object's length is more or less than the true length because of your eye being positioned at an angle to the measurement markings.

Parallax error is primarily caused by viewing the object at an oblique angle with respect to the scale, which makes the object appear to be at a different position on the scale.

Parallax error is the shift in apparent position of an object due to different viewing position. When we have to take reading from an instrument(analog) or do some measurements then different viewing position will give different readings leading to an error.

How do we avoid parallax error in measurement?

Parallax in measurement is when the observer's eye does not align at right angles with (for example) a meter needle and the scale. That causes reading error.

In any case, the eye should be properly aligned. In better meters and gauges etc, there is a strip of mirror behind the scale, which greatly assists in accurate alignment.

Ask other people to take measurements. Because parallax error is a type of random error, you can average multiple readings taken by different people to cancel out most of the parallax angle. It is likely that some readings will have positive parallax error and others will have negative error. The average of these readings will be closer to the true measurement.

CONCLUSION

This study dealt with the main sources of uncertainty in the direct verification of the Charpy impact testers. This study gives a numerical example as a guide to show how to estimate the expanded relative uncertainty in the calibration process. Our project has achieved its purpose and drawn a guideline for the users to estimate the uncertainty of Charpy impact testing machine of our institute .It's recommended, in the future work, to establish a similar proposal taking into consideration both indirect verification and instrumented machines.

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PLAGIARISM REPORT

This is to clarify that our project black book that we have written is unique of its own and written from our own ideas. Some definitions and formulas however may have been used from other studies have been put on the reference section. The plagiarism check is done by the group member Mohammed Ali Khatri and the result of the check is our project black book is unique and does not have any similarities. The plagiarism check is done using "turnitin" software.