BRINELL HARDNESS TEST. AN APPROACH WITH STOCHASTIC PROCESSES

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Abstract : This work presents an evaluation model of the Brinell hardness test, with an approach a Stochastic processes. Hardness evaluation is one of the most important and commonly used methods for material or product testing. For better understand the preparation of samples for testing hardness, we try to describe the steps leading up to training samples test, to evaluate them using stochastic processes. In this case we built a characteristic stochastic process with discreet times and for that one we made some calculation using real data observed in laboratory tests. It may be that these results can improve the financial and economic evaluations to reduce cost expenses.

Keywords: *Stochastic processes, laboratory trials, random phenomena, mathematical modeling.*

1. INTRODUCTION

Stochastic processes are a mathematical modeling of random phenomena, which can be applied in almost all areas. By understanding a mathematical model expressing the mathematical symbols, using mathematical concepts, relationships that are established between variables and their parameters.

Mathematical models suffer in conditions that appear difficult to quantify relationships between factors, that do not have numerical data, or is outside the scope of expertise of the analyst.

We study the stages of preparation of the Brinell hardness test samples within a Mechanical Testing Laboratory, using Stochastic processes.

To better economic management, decided to conduct a preliminary evaluator spending for preparation of samples to testing, in order to budget for the costs of the laboratory. This is a preliminary estimate of the number of samples and the total amount spent.

The role of stochastic processes is to detect mathematically, which rejects occur and how they can be reduced or eliminated following preparation processes of the samples. On the other hand, can evaluate the real costs used to perform preparatory operations.

To decide if a certain product made in a steel enterprise is in accord with quality standards the enterprise has to make some laboratory trials. These tests include the Brinell hardness test. This process for example is composed of three transforming stages: the cutting steel samples, the lathering and the rectification. Standards by the Brinell hardness test is evaluated are: SR EN ISO 6506-1:2006 and ASTM E10-2008. Both test methods covers the determination of the Brinell hardness of metallic materials by the Brinell indentation hardness principle. Both standards provides the requirements for a Brinell testing machine and the procedures for performing Brinell hardness tests. At the time the Brinell hardness test was developed, the force levels were specified in units of kilograms-force (kgf). Brinell hardness test—an indentation hardness test using a verified machine to force an indenter (tungsten carbide ball with diameter D), under specified conditions, into the surface of the material under test. The diameter of the resulting indentation d is measured after removal of the force.

In the next section we design the stochastic process with discreet times suitable for the Brinell hardness of a steel bar. For our calculation we used the pass probabilities computed using real laboratory data.

2. BRINELL HARDNESS TEST STEELS - ACTUAL EXECUTION

Before performing the actual hardness test is necessary to check environmental conditions, according to STAS 6300. The temperature is recorded in the trials register by tester.

The test piece is placed on a rigid support so as to prevent any movement thereof during the testing. During the test will avoid shocks and vibrations. Ball indentor diameter, material nature bile (carbide or steel) and load are chosen so that all diameter is between 0.24 and 0.6 limits * D. Brinell hardness is determined by at least three traces, if the product standard provides otherwise.

Ball mark is measured at least every two diameters perpendicular to each other.

The distance between the centers of two adjacent traces or between center and edge all the play, the recommended maintenance of pregnancy, depending on the hardness of the material examined are listed in Table 4 of EN ISO 6506/1.

Producing a difference between the diameters should be less than 2% of the minimum diameter if not otherwise stated the standard product.

The test is conducted at a temperature between 10ºC - 35ºC and under STAS 6300 and SR EN ISO 6506/1.

Hardness is determined by the average diameter of Table 5 of SR EN ISO 6506/1.

3. APPLICATION OF STOCHASTIC PROCESSES FOR THE PREPARATION OF TEST SAMPLES

We consider a stochastic process with discreet times $\{X(t),\quad t \in T\}$ where $(t) = St_i$ and *St* = stage. We denote the stages space in the following way:

$S = \{St_i\}$ with $i \in \{1,2,\dots,n\}$,where *i* is the number of stages.

In our case, we have 5 in the transforming stage which includes 3-phase. These are:

St_1: The sample of steel bar is at the end of the retailing process;

St_2: The sample of steel bar is at the end of the lathering process;

St_3: The sample of steel bar is at the end of the rectification process;

St_4: The sample of the steel bar is labelled as corresponding;

St_5: The sample of the steel bar is labelled as reject.

We will use real data obtained in laboratory tests - mechanical. In this section we computed the pass probabilities. In Table 1 we build stages machining processes of samples tested in the laboratory.

Table 1. Stages machining processes of samples tested in the laboratory

	Units that must taking again the processing		Units that those which are reject		Units that have passed into the next phase	
Retailing process	3%	$P_{11} = 0{,}003$	3%	$P_{15} = 0{,}003$	99,4%	$P_{12} = 0{,}994$
Lathering process	4%	$P_{22} = 0{,}004$	3%	$P_{25} = 0{,}003$	99,3%	$P_{23} = 0{,}993$
Rectification process	3%	$P_{33} = 0{,}003$	3%	$P_{35} = 0{,}003$	99,4%	$P_{34} = 0{,}994$

These percentages are derived from the annual average of the 12 months of the samples tested in the laboratory (see Table 2).

Table 2. Samples tested in the laboratory, in 12 mounths

Steel	Samples	St_1	St_2	St_3	Samples declared final	Reject samples
42 CrMo4	250	249	248	247	247	3
40H	353	352	351	350	350	3
16MnCrS5	280	279	278	277	277	3
C45	330	329	328	327	327	3
20MnV6	290	289	288	287	287	3

We built the pass probabilities matrix and will be describe the stochastic process evolution. The pass probabilities matrix is the stochastic matrix:

$P = (p_{ij})_{i,j=1,5}$ where the pass probabilities are the conditioned probabilities

$p_{ij} = P\left(X(t+1) = St_j \middle| X(t) = St_i\right)$

The probability is:

$p_{11} = P\left(X(t+1) = St_1 \middle| X(t) = St_1\right) = 0{,}003$

$p_{12} = P\left(X(t+1) = St_2 \middle| X(t) = St_1\right) = 0{,}994$

$p_{13} = P\left(X(t+1) = St_3 \middle| X(t) = St_1\right) = 0$

$p_{14} = P\left(X(t+1) = St_4 \middle| X(t) = St_1\right) = 0$

$p_{15} = P(X(t+1) = St_5 | X(t) = St_1) = 0{,}003$

$p_{21} = P(X(t+1) = St_1 | X(t) = St_2) = 0$

$p_{22} = P(X(t+1) = St_2 | X(t) = St_2) = 0{,}004$

$p_{23} = P(X(t+1) = St_3 | X(t) = St_2) = 0{,}993$

$p_{24} = P(X(t+1) = St_4 | X(t) = St_2) = 0$

$p_{25} = P(X(t+1) = St_5 | X(t) = St_2) = 0{,}003$

$p_{31} = P(X(t+1) = St_1 | X(t) = St_3) = 0$

$p_{32} = P(X(t+1) = St_2 | X(t) = St_3) = 0$

$p_{33} = P(X(t+1) = St_3 | X(t) = St_3) = 0{,}003$

$p_{34} = P(X(t+1) = St_4 | X(t) = St_3) = 0{,}994$

$p_{35} = P(X(t+1) = St_5 | X(t) = St_3) = 0{,}003$

$p_{41} = P(X(t+1) = St_1 | X(t) = St_4) = 0$

$p_{42} = P(X(t+1) = St_2 | X(t) = St_4) = 0$

$p_{43} = P(X(t+1) = St_3 | X(t) = St_4) = 0$

$p_{44} = P(X(t+1) = St_4 | X(t) = St_4) = 1$

$p_{45} = P(X(t+1) = St_5 | X(t) = St_4) = 0$

$p_{51} = P(X(t+1) = St_1 | X(t) = St_5) = 0$

$p_{52} = P(X(t+1) = St_2 | X(t) = St_5) = 0$

$p_{53} = P(X(t+1) = St_3 | X(t) = St_5) = 0$

$p_{54} = P(X(t+1) = St_4 | X(t) = St_5) = 0$

$p_{55} = P(X(t+1) = St_5 | X(t) = St_5) = 1$

St_1 and St_2 are absorbing stages because pass probabilities are value $p_{44} = p_{55} = 1$.

Using our data we obtain following two matrix which gives all pass probabilities.

$$P = \begin{pmatrix} p_{11} & p_{12} & p_{13} & p_{14} & p_{15} \\ p_{21} & p_{22} & p_{23} & p_{24} & p_{25} \\ p_{31} & p_{32} & p_{33} & p_{34} & p_{35} \\ p_{41} & p_{42} & p_{43} & p_{44} & p_{45} \\ p_{51} & p_{52} & p_{53} & p_{54} & p_{55} \end{pmatrix}$$

$$P = \begin{pmatrix} 0.003 & 0.994 & 0 & 0 & 0.003 \\ 0 & 0.004 & 0.993 & 0 & 0.003 \\ 0 & 0 & 0.003 & 0.994 & 0.003 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

With these pass probabilities using test samples rejected. We calculate the percentage of rejected samples using the following formula:

$$T_R = T - T \times 0.997 \times 0.997 \times 0.997 = T - T \times 0.991 = T(1 - 0.991) = T \times 0.009$$

where T_R is the number of units that are labelled as rejected and T is the number of samples.

After these calculations we can say that the previous results conducts to the conclusion that units labelled as reject are in proportion of 0,9% from the total value of the units presented to the samples to using Brinell hardness test.

Next we construct the pass probabilities graph (Fig. 1). This is the oriented graph. The nods are corresponding to the five stages. Three are transforming stages and two are absorbent stages (reject stage and corresponding stage). Orientation transition arcs represent the next stage or transition in a state absorbance.

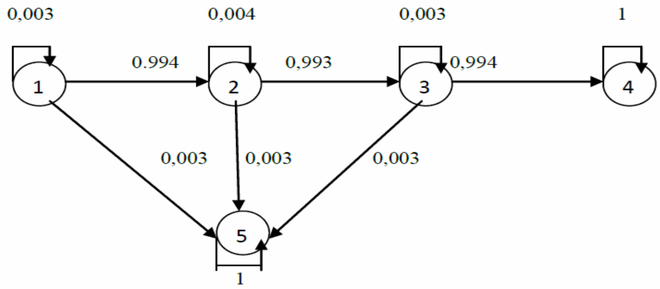

Figure 1. The probabilities graph

4. CONCLUSIONS

Using stochastic processes can make an estimate of costs for processing samples Brinell hardness test. Are rigorous and accurate calculations. These have helped to detect problems and reducing rejections created them (in this case, from 5% to 0.9%). Their application improved laboratory work.

5. REFERENCES

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