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Assessment of Functional Performance of Machinery in a Local Beverage Company in Nigeria

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Abstract: Daily wear and tear of industrial machinery, while performing its intending functions, could not only affect the quality but also affect the output performance. In this study, the functional performance of bottle washing and filling machines in a local beverage industry is assessed. This was done using output data from both machines for the period of two months for limca and goldspot drinks. Analyses of the data were done via the statistical tests such as t-test and F-test. The results of the tests showed that bottle washing machine output performance is satisfactory in washing both limca and goldspot bottles while, in filling machine, there is a gradual shortfall in performance. This calls for immediate attention in term of putting in place a formidable replacement plan.

Key words: Beverage company, functional performance, machinery

INTRODUCTION

Reliability of industrial machinery is usually at its peak when the machine is new. It reduces with age and at a time maintains a constant and durable performance for a reasonable length of time. At old age the machinery could not adequately perform its intending function due to high level of failures. At this stage, replacement of such machinery stands a good option.

The decrease in performance (reliability) of machines as a result of wear and tear could not only affect the quality but also affect the rate at which the outputs are being generated. Through proper monitoring of the quality and output rate of such machine one can acknowledge the time it performs adequately and the time of functional depreciation.

Many research efforts were witnessed on the assessment of the quality of products in industries[1-4]. Fewer efforts at linking product quality and output rate to the performance (reliability) of machinery are available. The related efforts were based on quality and reliability assessment of industrial products[5-7]. In this study, an attempt is made to link the functional performance of machinery to quality based on the rate at which the production outputs are being generated.

MATERIALS AND METHODS

Functional performance of bottle washing and filling machines in a local beverage industry is assessed. This was done using data collected on the outputs of both machines for the period of two months for limca and goldspot drinks. Analyses of the data were done via the statistical tests such as t-test and F-test. These statistical tests revealed the status of machines' output performance-whether satisfactory (accepting null-hypothesis) or unsatisfactory (rejecting null-hypothesis or accepting alternate hypothesis). The hypotheses tested for are:

- The rate at which the filling machine fills the beverage bottles meet its capacity requirements, while the alternative hypothesis is that it does not meet the requirement and
- The rate at which the washing machine washes the beverage bottles meet its capacity requirements, while the alternate hypothesis is that it does not meet the requirement.

These hypotheses were determined by adopting t-test and F-test, respectively based on the procedural steps given in the past works[8-10]. The average bottle filling and washing capacity of the machines were obtained from the manufacturer's manuals[11,12].

Data collection and analysis: Procedures for data collection from a beverage company located at Akure, Ondo State, for both bottle filling and washing machines are stated as follow:

Table 1: The machine bottle filling rate

No of Trials (n)	Filling rate (No of bottle /h) (x)	x = (Σ)/n = 13132.5(x- x)	(x- x)^2
1	13080	-52.5	2756.25
2	13200	67.5	4556.25
3	13320	187.5	35156.25
4	13200	67.5	4556.25
5	13020	-112.5	12656.25
6	12900	-232.5	54056.25
7	13200	67.5	4556.25
8	13140	7.5	56.25
n = 8	Σ = 105060		Σx- x)^2 = 118350

Table 2: Data on washing rate (number/h) of limca and goldspot bottles

	Limca bottles			Goldspot bottles		
No.of trials,n	Washing rate x_i	$x_i = \Sigma x_i/n$ = 14376 $(x_i - x_i)$	$(x_i - x_i)^2$	Washing rate x_j	x_j = 14388 $(x_j - x_j)$	$(x_j - x_j)^2$
1	14400	24	576	14400	12	144
2	14460	84	7056	14340	-48	2304
3	14340	-36	1296	14280	-108	11664
4	14400	24	576	14400	12	144
5	14460	84	7056	14520	132	17424
6	14280	-96	9216	14280	-108	11664
7	14400	24	576	14400	12	144
8	14340	-36	1296	14520	132	17424
9	14280	-96	9216	14340	-48	2304
10	14400	24	576	14400	12	144
n = 10	Σx_i = 143760		$\Sigma(x_i - x_i)^2$ = 37440	Σx_j = 143880		$\Sigma(x_j - x_j)^2$= 63360

Bottle filling machine data and analysis: Data collection on the filling machine was carried out once in a week for the period of two months. The data on bottle filling rate were obtained on hourly basis and are presented in Table 1.

The proposed average filling rate specification for the machine from the manufacturer manuals is 13200 bottles per h (μ_o). It is expected to find out if the machine meets the requirements. Then hypothesis (i) is tested for filling machine based on t-distribution as follows:

Null hypothesis H_o: μ_o = 13200;
For the alternate hypothesis H_i: μ_o Σ 13200

t-test statistics adopted under normal distribution and 5% significant level (α =0.05) is given as[8]:

$$t = (x - \mu_o)/(s/vn) \quad (1)$$

where t is t-distribution with n-1 Degree of Freedom (DF), x is a random variable of the bottle filling rate (in number/h), s is the standard deviation of x, μ_o scheduled mean rate (capacity) of filling of the machine and n is the number of samples taken.

From Table 1 the following statistics are obtained as follow:

$$x = (\Sigma x)/n = 13132.5 \text{ bottles/h.} \quad (2)$$

$$s = \sqrt{\Sigma}\,(x - x)^2/(n-1) \approx 130 \quad (3)$$

Substituting the values of x (13132.5), s (130), μ_o (13200) and n (8) into Eq. 1, the t-test value is obtained as t = -1.468

Then the acceptance region based on standard t-distribution table[8] is found with degree of freedom (n-1), DF (8-1) and significant level, α (0.05) as

$$t_{\alpha/2,n-1} = t_{0.025,7} = 2.365$$

Since t calculated is not greater than or equal to $t_{0.025,7}$ the null Hypothesis (H_o) that filling machine meets requirements is rejected and alternate hypothesis (H_i) that it does not meet the requirements is accepted.

Bottle washing machine data and analysis: Ten batches of limca and goldspots bottles were washed and the rates of washing were collected and analysed as recorded in Table 2. The mean rates of washing the limca and goldspot bottles for ten weeks were compared. It is expected to confirm if the rate of washing these two sets of bottles were the same (null hypothesis, H_o) or not (alternate hypothesis H_i). The data were collected on washing machine on hourly basis. Data analysis was done via F-test and t-test.

From Table 2 the mean x_i standard deviation s_i and variance s_i^2 were obtained for limca batches respectively as

$$x_i = \Sigma x_i/n = 14376 \quad (4)$$

and

$$s_i = \sqrt{\Sigma(x_i - x_i)^2/(n-1)} = 64.4981 \quad (5)$$

$$s_i^2 = \Sigma(x_i - x_i)^2/(n-1)\ 4160 \quad (6)$$

where n is the number of trails taken and x_i is the rate of washing limca bottles.

Similarly for goldspot bottles, the mean x_j standard deviation s_j and variance s_j^2 were obtained respectively as

$$x_j = \Sigma x_j/n = 14388 \quad (7)$$

and

$$s_j = \sqrt{\Sigma(x_j - x_j)^2/(n-1)} = 83.9047 \quad (8)$$

$$s_j^2 = \Sigma(x_j - x_j)^2/(n-1) = 7040 \quad (9)$$

where, n is the number of trails taken and x_j is the rate of washing goldspot bottles.

F-distribution test is used to certify whether variance of the two data are equal (accept null hypothesis) or not (reject null hypothesis or accept alternative hypothesis). Using this test, the data are assumed to be normally distributed under a significant level α of 0.05 and Degree of Freedom (DF) 9.That is, to test: H_o: $s_i^2 = s_j^2$ against: H_i: $s_i^2 \# s_j^2$. The calculated F is obtained from

$$F = (s_i)^2/(s_j)^2 \quad (10)$$

The value in Eq. 10 is compared with what is obtainable in the standard F-distribution table corresponding to $F_{\alpha/2,n^*-1,,n-1}$ (that is $F_{0.025,9,9}$)[8]. The acceptance region of F-test is , therefore given as $F_{0.025,9,9} \le 4.03$ so that $1/4.03 \le F \le 4.03$ or $0.248 \le F \le 4.03$. Then from Eq. 10 the value of F is 4160/7040 or 0.5909 which lies within acceptance region. Based on this result the null hypothesis is accepted based on variance analysis. For difference of means analysis t-test is applied. That is to test: H_o: $\mu_1 = \mu_2$ against: H_i: $\mu_1 \# \mu_2$. t-test statistics used is paired as:

$$t = (x_i - x_j)/ ((((1/n_i+1/n_j)^{1/2}((n_i-1)\, s_i^2 + (n_j-1)\, s_j^2)/ (n_i + n_j-2))^{1/2} \quad (11)$$

Various quantities are as defined above and the assumptions used are similar to that of t-test presented in Eq. 1. Substituting various parameters into Eq. 11, yields a t-test value of -0.3586 while that obtained from the t-distribution table (that is $t_{\alpha/2,ni+nj-2} = t_{0.025,\ 18}$) is given as-2.101 = t = 2.101. Hence, t is within the acceptance region. Based on this, the hypothesis is accepted and the washed limca and goldspot bottles were not differ in mean. The bar chart in Fig. 1 shows the output rate performance trend for washing machine.

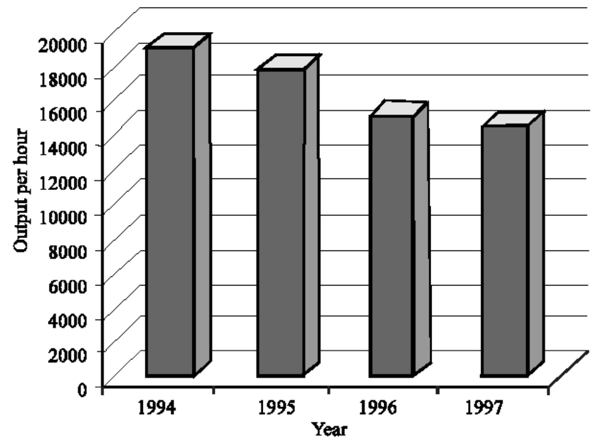

Fig. 1: Yearly output performance of washing machine

RESULTS AND DISCUSSION

The result of the t-test statistical analysis for filling machine Table 1 showed a great disagreement between the calculated value for t-distribution (that is t = -1.468) and the value read off from standard t-distribution table (corresponding to $t_{\alpha/2,\ n-1} = t_{0.025,7} \le 2.365$). This calls for rejection of hypothesis that the filling machine performance is satisfactory and acceptance of alternative hypothesis that the filler machine does not meet the requirement. In study washing machine, the results showed that tests of hypotheses on outputs for both limca and goldspot bottles using F- and paired t-tests, based on equal variance and mean rate of washing, respectively Table 2 and Eq. 11 were accepted since $F \le 0.59$ was within the acceptance region $0.248 \le F \le 4.03$ and $t \le -0.3586$ fell in the feasible region of $-2.101 \le t \le 2.101$. However, the machine's performance rate of washing of bottles was falling annually from its maximum capacity of 19200 (obtainable in 1994) to 14496 bottles per h in 1997. The noticed yearly decrease in performance of machines may be due to its wear during operation, lack of reliable maintenance culture or any other assignable cause.

CONCLUSION

From the results of this study it can be concluded that the performance of both filling and washing machines in the beverage company has suffered a setback over the years. This calls for investigating the assignable causes of this anomaly which include improper maintenance culture, machine wear and/or frequent power outage. The target can only be achieved through corrective maintenance or displacement (replacement) effort, if fund is available. Besides, uninterrupted power supply will also improve the situation. Further conclusion could be drawn, on the outputs variance and mean rates of limca and goldspot bottles being washed respectively by the machine, that there are no significant difference between them because there was insufficient evidence to conclude that the outputs differ in mean or variance. This gives a satisfactory result.

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