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RESEARCH ARTICLE

CONVENTIONAL ANALYSIS OF EQUIPMENT FAILURE IN OLEFIN PLANT

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ABSTRACT

In this paper conventional data collection exercise was carried out to investigate the causes of equipment failure in Olefin plant using a series of interviews about the plants life for the past six years. The two variables used are the maintenance hour (X) and the loss in production during maintenance (Y). Mathematical approach of regression analysis was used to analyze the failure. The developed model was simulated to determine the intercept and the slop, which is the change in production loss that accompanies a unit change in maintenance hour. The correlation coefficient of maintenance hour and production loss and the standard error of the slope were computed. The simulated model reveals that the intercept is zero, the slope is 24, and the correlation coefficient is 1 and 95% prediction interval for the slope. Human error, depreciation and lack of maintenance after startup were considered as the contributing factors to the failure of industrial equipment.

INTRODUCTION

A process plant is designed to work with optimization at the background; anything short of optimization is working at loss. There are some basic equipment constituting the plant example reactor, compressor, furnaces, boiler, UPS electronic card, cooling system and power plant. When any of this equipment is faulty the plant is short down and their will be no production till that equipment is rectified. In the first study, the approach was used for the conventional assessment of the availability of a new refinery plan. Maintenance data was available for a comparable plant which had been in operation for 24 years and this permitted good calibration curves to be derived for the simulation model. The data also provided mean time to failure and, mean time to repair for some of the main types of equipment under local condition (Robert *et al*., 1977 and Stevens, 1992).

In a second study a simplified model to assess different scheme to improve the available of a integration Olefin plant. The model was built containing failure modes for all the main items of equipment which could contribute to loss of production and included minimum cut set as for common mode failure such as loss of utilizes. The model was calibrated by comparing the simulated loss of production and number of outage incidents with the historical record. The model was used to evaluate two possible areas of improvement dealing with these historical problems such as replacement of the existing single instrument for compressor condition monitoring and improved operator training and supervision during steam system line out (Peters *et al*.,1968 and Stevens *et al.,* 2000). Several literature (Peter *et al.,*1968, Levenspiel, 1972; Norman, 1985; Alexander, 1990; Lorenzo, 1990; Richardson and Coulson, 1993; Frank, 1996; Odigure, 1998; and Eghuna, 1998) revealed that in the conservation of resources and product, there is optimum utilization of resources which results in maximum production at minimum cost that will yield the projected profit. The facture of equipment could be attributed to the following such as depreciation, human error, corrosively and lack of maintenance after start up. An analysis of costs for any business operation requires recognition of the fact that physical assets decrease in value with age. This decrease in value may be due to physical deterioration, technological factors which ultimately will cause retirement of the property. The reduction in values due to any of these causes is a measure of the depreciation (Peters, 1968). Investigation conducted by various researches revealed that human error is the major contributor to abnormal plant operation also the characteristics of human errors contributions, necessitating abnormal situation are as follows: Poor understanding of process, frequently product change resulting in contamination training of personnel (Odiqure, 1998).

The Model

From least square formula a number of different equations were used to analyze the failure. The following parameters were determined, estimated or predicted value of production loss, the intercept, the slope which is the change in production loss that accompanies a unit change in maintenance hour, the relationship between maintenance hour and loss in production, the standard error of the slope, the 95% confidence interval for the slope and 95% prediction interval for Y_o at level X_o.

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To derive the equation of a straight line we take its slope to be (b) and any one point on the line. If the one point we know is the Y intercept the point where the line crosses the Y axis, at height (a). Considering Figure 1 as shown below, in terms of moving from point X to point Y the following mathematical equations are developed using regression analysis to predict the failure rate of equipment.

$$slope\ \frac{\Delta Y}{\Delta X} = \frac{Y-a}{X-o} \qquad (1)$$

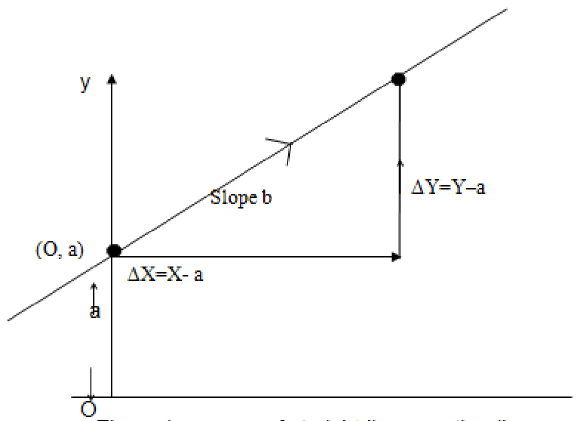

Figure 1. a curve of straight line equation line

For the line to be straight, the slope must be equal the constant (b)

$$\frac{Y-a}{X-0} \qquad (2)$$

Rearranging equation (2) yields

$$Y = a + bx \qquad (3)$$

Intercept

From fitted line equation

$$Y = a + bx$$

From estimated regression

$$\hat{Y} = (a + b\ \bar{x}) + b\ (x - \bar{x}) \qquad (4)$$

that is $\hat{Y} = a + bx$ (5)

where:

$$\hat{a} = a + b\bar{x} \qquad (6)$$

$$X = X + \bar{X} \quad \text{(deviation form)} \qquad (7)$$

$$Y = Y + \bar{Y} \quad \text{(deviation form)} \qquad (8)$$

from equation (7) we have

$$\hat{a} = Y \qquad (9)$$

and

$$\bar{Y} = \sum Y/_{n} \quad (average) \qquad (10)$$

solving equation (6) yields

$$\hat{a} = a + b\bar{x} \qquad (11)$$

$$a = \hat{a} - b\bar{x} \qquad (11a)$$

Slope

Considering a case in which E(Y) = $M_{(x)}$ is a linear function. The data points are $(X_1,Y_1)(S_2Y_2)$ (S_nY_n). Assuming that the mean of (Y) is a linear function, we can say that (Y) is normally distributed with unknown variance σ^2. For convenience, rather than the taking the mean line to be equal to a + bx, thus, let.

$$M(x) = a + b\ (x - \bar{x}) \qquad (12)$$

Where $\bar{X} = \sum_{i=1}^{n} \frac{xi}{n}$ (13)

Hence Y_1, Y_2 ---Y_n are mutually independent normal variable with respective, means a + b $(x_i - \bar{x})$, I =1,2-----n, and unknown variance σ. Their joint (partial differential function (p.d.f) is therefore the product of the individual probability.

$$L(a,b,\sigma^2) = \frac{n}{11}\ \frac{1}{\sqrt{2\pi\sigma^2}}\ \exp.\left[\frac{-[Y_i - a - b\ (x - \bar{x})]^2}{2\sigma^2}\right] \qquad (14)$$

Multiplying through equation (14) by n yields

$$n - \left(\frac{1}{2\pi\sigma^2}\right)^{1/2}\ \exp.\left\{\frac{-\sum_{i=1}^{n}[Y_i - a - b\ (x_i - \bar{x})]^2}{2\sigma^2}\right\} \qquad (15)$$

To minimize L (a,b, σ^2) taking log of both sides of equation (15) yields

- In L (a,b, σ^2) =

$$\frac{n}{2}\ In\ (2\pi\sigma^2) + \left\{\frac{-\sum_{i=1}^{n}[Y_i - a - b\ (X_i - \bar{X})]^2}{2\sigma^2}\right\} \qquad (16)$$

To minimize we select a and b, selecting a and b so that the sum of the square is minimized means that we are flitting the straight line to the data by the method of least squares. To minimize H (ab), we find the two first partial derivatives. We differentiate with respect to (a,b)

$$\frac{\delta H(a,b)}{\delta} = 2\sum[Y_i - a - b\ (x_i - x)\ (-(x_i - x)] \qquad (17)$$

Setting $\delta H\ (ab) / \delta a = 0$ (18)

We obtain

$$\sum_{1}^{n} Y_i - na - b \sum_{1}^{n} (x_i - \bar{x}) = 0 \qquad (19)$$

Since

$$\sum_{1}^{n} (x_i - \bar{x}) = 0 \qquad (20)$$

we have that

$$\sum_{1}^{n} Y_i - na = 0 \qquad (21)$$

and thus recall equation (9) we have

$$\hat{a} = \hat{Y} \qquad (21a)$$

Therefore, equation (17) can be written as:

$$\delta H(a,b) / \delta b = 0 \qquad (21b)$$

Solving equation (19) and (21b) mathematically yields the given expression

$$\sum_{1}^{n}(Y_i - \overline{Y})(X - \overline{X}) - b\sum_{1}^{n}(X_i - \overline{X})^2 = 0 \quad (22)$$

$$b = \sum_{i}^{n} \frac{\sum_{1}^{n}(Y_i - \overline{Y})(X_i - \overline{X})}{\sum_{i}^{n}(X_i - \overline{X})^2} \quad (23)$$

Estimating the Standard Error B

With the expected value, standard error, and normality of b established, statistical inference about b are now in order from equation.

$$\text{Standard error of b} = \sqrt{\frac{\sigma^2}{\sum x^2}} \quad (24)$$

Where σ^2 is the variance of the Y observations, but σ^2 is generally unknown and must be estimated. A natural to estimate σ^2 is to use the deviation of Y about the fitted line specifically, considering the mean squared deviation about the fitted line.

$$1/n\sum d^2 = \frac{1}{n}\sum(y - \overline{y})^2 \quad (25)$$

Equation (250 was modified by considering n = n-2, thus equation (250 can be written as shown in equation (26). Two degrees of freedom (d.f) have already been used up in calculation a and b in order to get the fitted line. This then leaves (n-2) d.f to estimate the variance as well as estimate σ^2 with the residual variance S^2 given as.

$$S^2 = \frac{1}{n-2}\sum(Y - \overline{Y})^2 \quad (26)$$

When S is substituted for σ in equation (24), we obtain the estimated standard error, which is denoted with SE

$$SE = \frac{S}{\sum x^2} \quad (27)$$

Correlation of X and Y

Correlation analysis shows us the degree to which variable is linearly related. We recall how the regression coefficient of Y against X was calculated; we first t expressed X and Y in deviation form (X and Y) and the calculated.

$$b = \sum_{1}^{n} \frac{\sum_{1}^{n}(Y_i - \overline{Y})\,(X_i - \overline{X})}{\sum_{i}^{n}(X_i - \overline{X})^2} \quad (28)$$

The correlation coefficient (γ) uses the same quantities $\sum xy$ *and* $\sum x^2$ *and* $\sum y^2$ *as well*

$$\gamma = \frac{\sum xy}{\sqrt{\sum x^2}\sqrt{\sum y^2}} \quad (29)$$

In the above formula, y appears symmetrically in exactly the same way as x. Thus the correlation (γ) does not make a distribution between the response Y and the repressor X, the way the regression coefficient (b) does. To illustrate, how maintenance in the plant and the quantity of product loss during the maintenance hour are related, observation of γ for six years running are made and given in the first two columns as discussed in the result. In the next two columns the deviation were calculated and then sums Σxy, Σx^2 and Σy^2. The correlation (γ) measures how much X and Y are related and X = X - $\overline{X}$. The deviation (x) tells us how far an x value is from its means $\overline{X}$. Similarly, the deviation Y tells us how far a (Y) value is from its mean ($\overline{Y}$). Multiplying the X and Y values for each observation and sum them to get Σxy, this gives us a good measure of how maintenance hour and loss in quantity during maintenance hour tend to move together for correlation coefficient (γ) to be zero there is no relation at in X and Y but for + 1 or –1 there is a perfectly positive or negative relation.

Confidence interval for the mean M_o

In the theoretical approach that follows, it is convenient as in equation (7) to use the form X = X- $\overline{X}$, then fitted line has the following expression:

$$\hat{Y} = \hat{a} + bx \quad (30)$$

in particular, when X is set at a specific level X_0

$$\hat{Y}_o = \hat{a} + bx \quad (31)$$

For the time regression line, there is a corresponding form denoted with Greek symbols.

$$E(Y) = \hat{\alpha} + \beta x \quad (32)$$

Then

$$M_o\ E\ (Y_o) = \hat{\alpha} + \beta x \quad (33)$$

In this paper we have already showed that b fluctuates around β with variance $\sigma^2 / \sum x^2$. Similarly, we could show that $\hat{\alpha}$ fluctuates around $\hat{\alpha}$ with variance $\sigma\, 2/n$. According to equation (21) $\hat{a} = \hat{Y}$, so this variance is just the formula $\overline{x} = \sigma / n$ for sample means. Furthermore b and a are uncorrelated (Coulson and Richardson, 1993). This zero correlation is an important reason for using the deviation form X. the prediction $\hat{Y}_o$ in equation (31) fortunately is a linear combination of these two variable (estimates) b and $\hat{a}$ (with coefficient 1 and X_o). Thus the theory if linear combinations can be applied from the equation.

$$E\ (aX + bY) = aE(x) + bE\ (Y) \quad (34)$$
$$= E\ (\hat{Y}_o) = E\ (\hat{a} + B\ X_o)$$
$$= E\ (\hat{a}) + X_o\ E\ (b)$$

$= \hat{a} + X_o B$
$= M_o$

Thus, $\hat{Y}_0$ is indeed an unbiased estimator of M_o, with the mean of $\hat{Y}_0$ determined. Considering the expression from the mathematical correlation of the variance

$$\text{var } \hat{Y}_0 = \text{var}(\hat{a} + b x_o) \quad (35)$$

$$= \text{var } \hat{a} + X^2_o \text{ var b} \quad (36)$$

$$= \frac{\sigma^2}{n} + x^2{}_o \frac{\sigma^2}{\sum x^2} \quad (37)$$

$$= \sigma^2 \left[\frac{1}{n} + \frac{X_o{}^2}{\sum x^2} \right] \quad (38)$$

$$\text{SE of } \hat{Y}_0 = \sigma \sqrt{\frac{1}{n} + \frac{X^2{}_o}{\sum x^2}} \quad (39)$$

To achieve 95% confidence interval, for the mean of M_o, the mathematical expression can be written as.

$$Mo = \hat{Y}_0 \pm t_{0.025} \text{ SE} \quad (40)$$

That is

$$Mo = (\hat{a} + b x_o) \pm t_{.025} S \sqrt{\frac{1}{n} + \frac{X^2{}_o}{\sum x^2}} \quad (41)$$

While this is the formula for the deviation form x, it can be easily seen that it translates back into the original x values as follows:

$$Mo = (\hat{a} + b x_o) \pm t_{.025} S \sqrt{\frac{1}{n} + \frac{(x_o - \bar{x})^2}{\sum (x_o - \bar{x})^2}} \quad (42)$$

Prediction Interval for Single Observation Y_o

we consider a question of how widely would we hedge our estimate if we are making a single application of Xo = 900 hours for maintenance and wish to predict the product loss which will result. This is the sort of interval that a process engineer might want to know in order to plan his budget for the coming year. In predicting this single Y_o, we estimate the means Mo, namely, we will have to recognize the sampling error involved in the estimates (a) and (b). in this case we are trying to estimate only one observed Y. (with its inherent fluctuation) rather than the stable average of all the possible Y_s. Considering when the individual Y values are along the regression line, with X expressed in deviation form, the best prediction of a single observed Y_o is again the point on the estimated regression line above X_o as already noted an interval estimated for Yo requires firstly the variance equation (39) reflecting the errors in estimating the fitted regression secondly the variance σ^2 reflecting the fluctuation in an individual Y observation. Adding these both together we obtain.

$$\sigma^2 \left(\frac{1}{n} + \frac{X_o^2}{\sum X^2} \right) + \sigma^2 = \sigma^2 \left(\frac{1}{n} + \frac{X_o^2}{\sum x^2} + 1 \right) \quad (43)$$

except for larger variance, the prediction interval for Y_o is the same as the confidence interval for M_o given earlier

$$Y_o = (a + bX_o) \pm t_{.025} S \sqrt{\frac{1}{n} + \frac{X^2{}_o}{\sum x^2} + 1} \quad (44)$$

RESULTS AND DISCUSSIONS

Table 1 present a situation where there is no equipment failure for six year running. In a normal process plant operation, the plant is expected to run for 8000 hours per annum. Then for the Olefin plant used here two products obtained are ethylene and propylene; ethylene is produced at 32.5 tons/hours that gives 260000 tons per annum, while propylene is produced at 15.75 tons/ hours giving 5600tons per annum all based on 8000 hours operation per annum.

Table 1. Normal production process (no equipment failure)

Year	Production	Ethylene production in tons/ hour	Propylene production tons/hour
1997	8000	260,000	126,000
1998	8000	260,000	126,000
1999	8000	260,000	126,000
2000	8000	260,000	126,000
2001	8000	260,000	126,000
2002	8000	260,000	126,000

Table 2, display the major equipment in the plant of which when they are faulty the plant is shut down and repair work is done. The first is the reactor, the basic failure of a reactor is over spent catalyst, and agitator failure and reactors seal failure. When it takes place in the plant it takes 20 days or 480 hours to bring it back to life and normal operation. The next is the compressor the basic failure of compressor are: fouling effects, silica deposits, failure of turbine due to high bearing temperature, when this occur to the compressor it takes 23days to 52 hours to bring it back to normal. For the furnace the basic problem it encounter are transfer line and tube failure it takes 17days or 408 hours to bring it back to normal. The next is the boilers the basic problem with the boiler include fouling factors corrosion auxiliary unit failure. It takes 12days or 288 hours to bring it back to normal. For cooling system the problems are failure from pumping, leaks and others, it takes 15 days or 360 hours to bring it back to normal. The next is the power plant the common problem is the failure of fuel gas. It takes about 16days or 384 hours to bring it back to normal.

Table 2. Major equipment failure that lead to plant shutdown and their maintenance hour

Equipment	Maintenance	Maintenance
Reactor	20	552
Compressor	23	480
UPS elect card	12	288
Furnaces	17	408
Boilers	12	288
Cooling system	15	360
Power failure	16	384
Air converter	13	312

Table 3 shows the equipment that was involved during plant shutdown from the year 1997 to 2002. In the year 1997 the equipment problem is seal failure which lasted for 480 hours, a total quantity of 15600 tons of ethylene and 7560 tons of propylene was loss. In 1998 the compressor was involved, silica deposit is the cause, 552 hours was spent for rectification and 17940 tons of ethylene, 8694 tons of propylene was loss. In 1999 the failure is compressor and demineralized H_2O, for the compressor the fault is fouling effect while there was shortage in demineralized H_2O, it took a total number of 720 hours to rectify both cases while 23400 tons of ethylene and 11340 tons of propylene were lost. In the year 2000, the equipment involved is the compressor which fault of turbine due to high bearing temperature. The furnaces also had problem of tube failure. It took 888 hours to bring the plant back to and 13986 tons of propylene was loss. In the year 2001, the equipment involved are compressor, boilers and UPS electronic card, 1176 hours was spent for rectification, while 36220 tons of ethylene and 18522 tons of propylene was loss. In the year 2002, there was lack of feed supply. Boilers failure, cooling system and power plant failure. This took a total number of 1200 hours to rectify 39000 tons of ethylene and 18900 tons of propylene was loss.

Table 3. Equipment failures from 1997 to 2002

Year	Maintenance days	Maintenance hours	Ethylene Loss in tons	Propylene loss in tons
1997	Reactor	480	15600	7560
1998	Compressor	552	17940	8694
1999	Compressor and demin. H_2O	720	23400	11340
2000	Compressor and furnaces	888	28860	13986
2001	Compressor, boiler and UPS electronic card	1176	28220	18522
2002	Cooling system and power plant, lack of feed, and boiler	1200	39000	18900

Table 4 shows the two variables used for this analysis X and Y which represent maintenance hour and quantity loss during maintenance hour respectively. Y is the quantity of ethylene and propylene lost put together. In the year 1997, 36 hours was used for maintenance and a quantity of 864 tons was loss. In the year 1998, 72 hours was loss and 1724 tons of product loss. In 1999,240 hours was used for maintenance and 5760 tons of product loss. In the year 2000, 408 hours was used for maintenance and 9792 tons of products were loss. In 2001, 696 hours was used for maintenance and 16704 tons of products were loss. Lastly in the year 2002, 1200 hours was spent for maintenance and a total of total of 28800 tons of product was loss. There was no means of regression analysis in 1997 as shown in tables because we have just one observation of maintenance hour 36 and 864 tons loss. There was no result for deviation form X and Y; thus, let

$x = X - \overline{X}$ and $y = Y - \overline{Y}$)

In 1998 no room for analysis there was just one observation maintenance hour 72 and quantity loss 1728 tons, no deviation and no product. For 1999 there is analysis but incomplete because the error of b (SE_b) cannot be calculated. Analysis for 1999 shows two observation of 72 and 168 maintenance hours while quantity loss 1728 and 4032 tons. The average of the maintenance hour $\overline{X}$ is 120 while the average of the quantity loss $\overline{Y}$ is 2880. The deviation $X = X - \overline{X}$ and $Y = \overline{Y}$ was found to be zero. The value of Σxy is 110592, ΣX^2 =4608 and Σy^2 = 2654208. for 2000 there is analysis but incomplete because we have just two observation of 72 and 36 maintenance hours while 1728 and 8064 tons for quantity loss.

Table 4: The values of the two variable X and Y

Maintenance hours	Quantity loss during maintenance
36	864
72	1724
240	5760
408	5760
696	16704
1200	28800

The means maintenance hour ($\overline{X}$) is 4896 deviation x $= X - \overline{X}$ and $y = Y - \overline{Y}$ are zero. The sum of product Σxy is 836352, the sum Σx^2=34848 and the sum Σx^2= 20072448. For 2001 shows three observation there us complete analysis because the observation are more than two, 72 288 and 8064 for quantity loss. The mean for maintenance hour is ($\overline{X}$) 232 while the mean for quantity loss ($\overline{Y}$) is 5568. the deviation for $X = X - \overline{X}$ and $Y = Y - \overline{Y}$ are zero, while the sum of product Ay $\Sigma\pi y$ is 949248, the sum X^2 Σx^2 is 39442 and the sum y^2 Σy^2 is 22781952. For 2002, shows from observation which are 168,285,360 and 384 maintenance hours and 4032,6912,8640 and 9216 quantity loss. The mean for maintenance hour ($\overline{X}$) is 300 while the mean for quantity loss ($\overline{X}$) is 7200 tons. The deviation for $X = X - \overline{X}$ and $Y = Y - \overline{Y}$ are zero, while the sum of product xy (Σxy) is 677376, the sum X^2 (Σx^2) is 28094 and the sum y^2 (Σy^2) is 16257024. for 1997 through out 2002, shows six observation s for the six years running, which are 36, 72, 240, 408, 696 and 12000 maintenance hour all in the first column, while 864, 1724, 57601, 9792, 16704 and 28800 are quantity loss in tons all in the second column, the third column is all about the deviation of X and ΣX is zero while the fourth column is deviation of Y and Σy is zero. The sum of πy is 23586624, the sum of (x^2) is 982776 and the sum of (Y^2) is 566078976. The standard error of b (slope) for six years, from the equation (27) was found to be SE_b =zero. From the analysis made (a) and (b) are the constants. The value of (a) is zero showing that the line passed through the origin, while (b) is twenty four. To check if there is any error in (b) equation (27) was applied this gave zero showing that (b) the slope value is accurate. The two variables here used are X and Y which are maintenance hour and quantity loss respectively. A correlation test was carried out for X and Y to see if there is any relationship between them, the value got is one showing that there is a relationship between X and Y. Since A is equal to zero equation (4) becomes $\overline{Y} = 0 + bx$ and $\overline{Y} = bx$. From the investigation to determine a change in (Y) that accompanies a unit change (X) b is taken to be 24 for any forecast made b is

Table 5. Analysis for 1997,1998, 1999, 2000, 2001 and 2002

Year	Data		Deviation form		products		
	Maintenance hour X	Maintenance hour Y	X= X- $\overline{X}$	Y=Y- $\overline{Y}$	XY	X^2	Y^2
1997	36	864	-	-	-	-	-
1998	72	1728	-	-	-	-	-
1999	72	1728	-48	-1152	55296	2304	1327104
	168	4032	48	1152	55296	2304	1327104
	$\overline{X}$ =120	$\overline{Y}$ =2880	Σχ +0√	Σχ +0√	Σχy=11	$\Sigma\chi^2$ =46	$\Sigma\chi^2$ =26
2000	72	1728	-132	-3168	417176	17424	10036214
	336	8064	132	3168	417176	17424	10036224
	$\overline{X}$ =204	$\overline{Y}$ =4896	Σx =0√	Σx =0√	Σχy=836352	$\Sigma\chi^2$ =34848	$\Sigma\chi^2$=20072448
2001	72	1728	-160	-3840	614400	25600	14745600
	288	6912	56	1344	75264	3136	1806336
	336	8064	104	2496	259584	1816	6230016
	$\overline{X}$ =232	Y =5568	Σχ +0√	Σχ +0√	Σχy =949248	$\Sigma\chi^2$=39552	Σy^2=22781952
2002	168	4032	-132	-3168	418176	17428	10036224
	288	6912	-12	-285	3456	144	82944
	360	8640	60	1440	86400	3600	2073600
	384	9216	84	2016	169344	7056	4064256
	$\overline{X}$ =300	$\overline{Y}$ =7200	Σχ+0√	Σχ+√	Σχy=67736	$\Sigma\chi^2$=28094	Σy^2=16257024
1997 through 2002	36	864	-406	-9744	3956064	164836	94945536
	72	1728	-370	-8880	3285600	136900	78854400
	240	5760	-202	-4848	979296	40804	23503104
	408	9792	-34	-816	279296	1156	66.5856
	696	16704	254	6096	1548384	64516	37161216
	1200	28800	758	18192	137895436	574564	330948864
	$\overline{X}$ =440	$\overline{Y}$ =10608	Σχ +0√	Σχ +0√	Σχy=23586624	$\Sigma\chi^2$=982776	Σy^2=5660789

Table 6. Estimate standard error of b

Years	X	Y	Y=a+bx	Y- $\overline{Y}$	$(Y-Y)^2$
2001	72	1728	1728	0	0
	288	6912	6912	0	0
	336	8064	8064	0	0
					$S^2 = \frac{\sum(Y-\overline{Y})^2}{3-2} = \frac{0}{1}$
2002	168	4032	4032	0	0
	288	6912	6912	0	0
	360	8064	8064	0	0
	384	9216	9216	0	0
					$S^2 = \frac{0}{4-2} = \frac{0}{1}$
1997-2002	36	864	864	0	0
	37	1728	1728	0	0
	240	5760	5760	0	0
	408	9792	9792	0	0
	696	16704	16704	0	0
	1200	28800	28800	0	0
					$s^2 = \frac{0}{6-2}$

Table 7. Computational analysis for the determination of necessary parameters on yearly basis (using data obtained in Table 5 for the mathematical computation)

Year	$b = \sum \frac{(x-\bar{x})(y-\bar{y})}{\sum (x-\bar{x})^2}$	$a = \bar{y} - b.$	$\bar{y} = a + bx$	$r = \frac{\sum xy}{\sqrt{\sum x^2}\sqrt{\sum y^2}}.$	Standard error of b SEb= $\frac{S}{\sqrt{\sum x^2}}$	95% prediction interval for Y_0 at level of X_o
1999	From table 5 $\frac{110592}{4608} = \underline{\underline{24}}$	2880 - 24 (120) = $\underline{0}$	Assumed 500 hrs 0+24 (500) =$\underline{12000}$n tons X_{500}hours	$\frac{110592}{(67882)(1629.174)} = \underline{1}$	n>2	-
2000	From table 5 $\frac{836352}{34848} = \underline{\underline{24}}$	4896-24 (204) = $\underline{0}$	0 + 24 (400) = $\frac{96000 tons}{X_{400} hours}$	$\frac{836352}{(186.676)(4480.23)} = \underline{1}$	$\frac{0}{982776} = 0$	Using equation (44), Y_o= 9600 1 0 using equation (42), M_o =9600 $\pm$ 0
2001	From table 5 $\frac{949248}{39552} = \underline{\underline{24}}$	5568 –24 (232) = $\underline{0}$	0 +24 (300) = =$\underline{7200}$n tons x X_{7200}hours	$\frac{949248}{(198.87)(4773.044)} = \underline{1}$	$\frac{0}{198.877} = 0$	Using equation (44), Yo =7200 $\pm$ 0 using equation (42), Mo =7200$\pm$ 0
2002	From table 5 $\frac{677376}{28094} = \underline{\underline{24}}$	7199 – 24(300) = 0	0 + 24(200) 4800tons at x X_{200}, homs	$\frac{677376}{(167.61)(403.2)} = 1$	$\frac{0}{167.613} = 0$	Using equation (44), $Y_o = 4800 \pm 0$ Using equation (42), $M_o = 4800 \pm 0$
For 1997 through 2002	From table 5 $\frac{23586624}{982776} = \underline{\underline{24}}$	10608 –24 (442) =$\underline{0}$	0+24 (72) =1728tons at X_{72}hours	$\frac{2358664}{(991.350)(23792.4125)} = \underline{1}$	$\frac{0}{991.35} = 0$	Using equation (44), Y_0 =1728 $\pm$ 0 using equation (42) ,M_0 =1728 $\pm$ 0

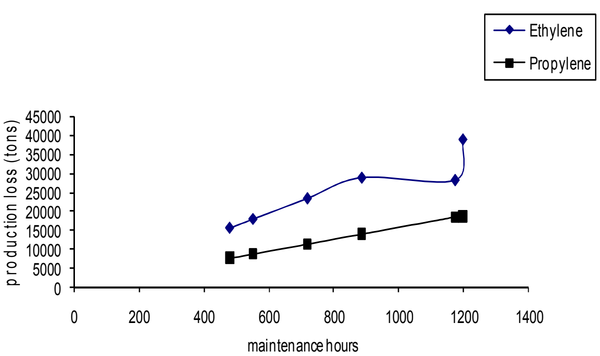

Figure 2: production loss versus maintenance hours from 1997 to 2002 for the various equipment failure in the plant

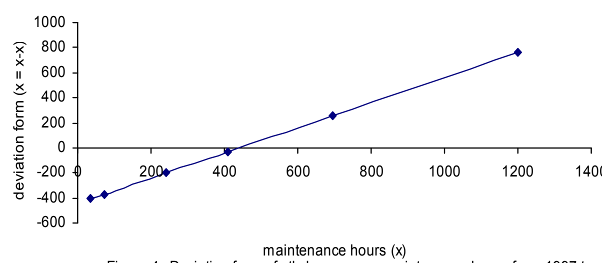

Figure 4: Deviation form of ethylene versus maintenance hours from 1997 to 2002

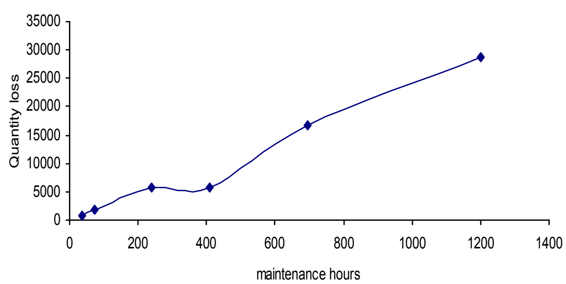

Figure 3: Quantity loss versus maintenance hour from 1997 to 2002

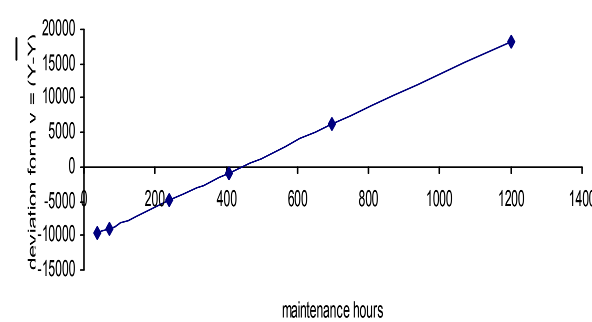

Figure 5: Deviation form of propylene versus maintenance hours from 1997 to 2002

taken to be 24. Assuming X to be 700, 500,400,300,200 and 72 all in hours the predicted values if Y is 16800, 12000,9600,7200,4800 and 1728 tons respectively. Figure 2 shows comparison of product loss of the ethylene and propylene (Olefin) plant in the petrochemical industry with maintenance hour. Maintenance hour increases with increase in production loss for both ethylene and propylene products. Similarly, figure 4 show that increase in maintenance hour will result to quantity loss. Figure 4 and 5 shows the deviation form of ethylene and propylene (Olefin product) with maintenance hour. The deviation form increases with increase in maintenance hour. From Figure 2 the production loss on ethylene is higher than the propylene with increase in maintenance hours. The variation in the production loss can be attributed to variation in maintenance hours for the various years of investigation. The quality loss value was observed for both ethylene and propylene due to increase in maintenance hours as presented in Figure 3. The variation in the quality loss can be attributed to the variation in maintenance hours for the various years of investigation. Figure 4 illustrates the deviation form of ethylene with increase in maintenance hours for the various years of investigation. Increase in deviation form was observed with increase in maintenance hours. The variation in the deviation form can be attributed to the variation in maintenance hours as presented in figure 4.The result presented in Figure 5 illustrates the deviation form of propylene with increase in maintenance hours for the various years of sampling. The variation in deviation form of propylene can be attributed to the variation in maintenance hour. Increase in deviation form was observed with increase in maintenance hours.

Conclusion

In this paper the regression analysis of equipment failure is presented. The correlation coefficient of maintenance hour and production loss is was discussed in detail as presented in this research work. The estimated value of production loss, the standard error of slope (is zero), the predication interval and obtained from the plant were well examined as presented in this paper. The least square formula was used and incorporated into a quick basic computation. As the number of maintenance hour increases the loss in production also increases. A sensitive analysis depicts that firstly human error-misuse or abuse of equipment, design error and assembly error, secondly maintenance-improper heat treatment; unforeseen operating conditions corrosively, lack of maintenance after start up. Finally depreciation-long term use are contribute to equipment failure.

The following conclusions were drawn from the results obtained from the investigation

1. Constant maintenance of the plant will result in poor quality of products obtained at the end of the process.
2. Less profit with increase in maintenance cost
3. Increase in personnel will be required to achieve a meaningful production per annual.
4. More waste will be produced, that is more of undesired product will be achieved.
5. Lag response will be experienced by the equipment due to constant maintenance in the plant.
6. The mathematical tools used in evaluating the equipment failure in olefin plant indicate a good investigation approach which leaded in the computation of the functional parameters as presented in this paper.

Nomenclature

$\hat{Y}$	=	the estimated values of production loss
a	=	intercept
b	=	the slope which is a change in Y that accompanies a unit change in X
x	=	maintenance hour
y	=	product loss in maintenance hour
χ	=	regression deviation form of y
S^2	=	variance of sample
$\overline{X}$	=	average (mean) of x
$\overline{Y}$	=	average (mean) of y
$\overline{Y}_o$	=	prediction interval
SE_b	=	standard error of b
S	=	standard deviation
n	=	no of observations
$t_{.025}$	=	critical point

Greeks Symbols

α	=	population regression intercept
β	=	population regression slope
Σ	=	sumation of
σ	=	variance
γ	=	regression mean at X_o

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