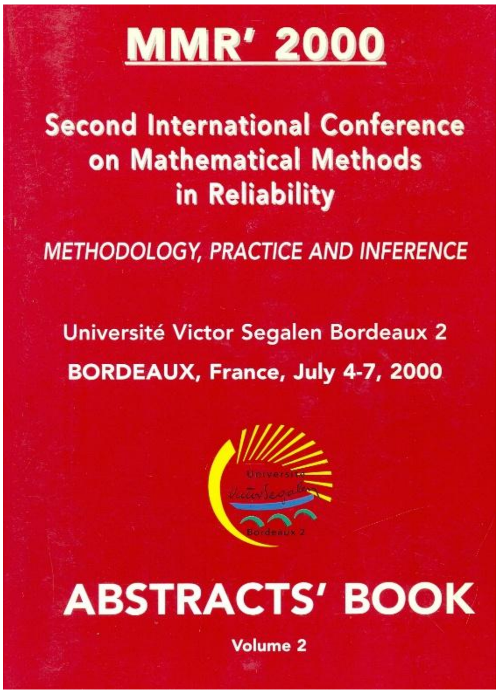

Repeat Failure Analysis for Oil Refinery Maintenance Optimization
Case Study of Skikda Refinery Compressing Magnaforming

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Abstract

This work demonstrate a methodology analyzing and processing repeat failure related to breakdowns in order to improve the oil equipments management (using primary data gathered at manufacture site). In order to deal with diversity and multiplicity of oil equipments located at oil refinery sites, a trivial analysis (Pareto analysis) was conducted to select the most important equipments, then selecting the components with significant contribution in decreasing equipment availability. A more detailed analysis (reliability distribution fitting) establishes the components operational behavior. Applying non parametric reliability distributions yield the evolving trend of failure rate. This information defines the reliability evolution of the components and detect those sensitive or critical related with operational safety and those behavior may deteriorate the equipments reliability. It also help to choose the appropriate maintenance strategy.

The illustration of this methodology was achieved in the Skikda refinery unit. This unit was designed for : feeding the east part of the country with refined products, drawing up some intermediate petrochemicals, especially refining crude oil to obtain exportable products.

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ABSTRACTS' BOOK

Volume 2

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Introduction

At present time, oil management activity (hydrocarbon transformation) is evolving steadily around the south part of the Mediterranean sea. Algeria has recently erected a new set of economic directions (transition into economic market, the Algerian company Sonatrach has undergone restructing,...), these actions may allow our country to keep a strategic position inside the oil market.

The repeat failure related to the material management within the Algerian oil refineries is worth to study, but it remains somewhat ambiguous and partial. The analysis of repeated failures is hardly done. Therefore, some unwanted situations occur frequently (high maintenance cost, frequent equipment breakdowns, low rate running, ...). In the other hand, reliability is at its embryonic phase [3].

1. Pareto Analysis

The Pareto analysis allowed us to situate the most important Magnaforming equipments, corresponding the intervening cost, expressed in Men-Hours, to the number of failures.The same analysis allowed us to select the components with significant contribution in decreasing equipment availability, corresponding the number of days of breakdowns to the number of failures.

The reliability analysis was achieved in two stages, a classic analysis based on the utilization of the Weibull model attended with the application of the non parametric reliability distributions in order to consolidate the obtained results.

2. Reliability Classic Analysis

Weibull model was chosen because it adjusts better to the mechanical equipments, it allows to describe alternately the three phases of the components life (early-life, mid-life, wear-out) and its utilization is simple because it is easy to transform it to linear model.

The reliability expression is : $R(t)=\exp\left[-\left(\frac{t-\gamma}{\eta}\right)^{\beta}\right]$, where t is the time between failures of individual components, η is the scale parameter, β is the Weibull index and γ is the location parameter . For components that do not have a shelf life (there is no deterioration before the components goes into service), $\gamma = 0$ and the expression simplifies to $R(t)=\exp\left[-\left(\frac{t}{\eta}\right)\right]$. The most important parameter is β, it takes different values depending on the temporal distribution of the failures. Indeed:

$\beta < 1$: Decreasing failure rate (infantile mortality)

$\beta = 1$: Constant failure rate (random failure)

$\beta > 1$: Increasing failure rate ($\beta > 3.4$: wear-out)

The necessary data for this survey were gathered at manufacture site (Skikda refinery, Algeria). The parameters identification was done by the least squares method. The Kaplan-Meier estimator allowed us to take into account the censorships generated by the intervening of preventive maintenance. The expression of Kaplan-Meier estimator is: $R(t_i)=\prod_{j=1}^{i}\left(1-\frac{d_j}{r_j}\right)$, where d_j is the number of failures at the time t_j and r_j is the number of components submitted to risk at t_j, (neither deaths nor censured). The application was achieved on the Magnaforming hydrogen centrifugal compressor (TK103), it is driven by a steam turbine.

The table 1 shows that $\beta > 1$ for all the studied components, this allows us to conclude that these components accuse some deteriorations and their failure rates are increasing. Indeed, the figure 1 shows that the components accuse a very fast deterioration for the compressor tightness ring HP 275, thus that the turbine carrying bearing 419 , to a least degree for the stub bearing 230, and relatively nit for the sheathings 285 and 286, thus that the stub bearing 401, the tightness ring 460 and the labyrinth support 780.

Note finally the heterogeneous behavior of components, some of them degrade more quickly than others, so they must be checked and/ or replaced at different dates.

3. Applying non Parametric Reliability Distributions

The classes of non parametric reliability distributions expresse a qualitative property of equipment, according to its life phase, we can find some distributions as IFR (Increasing Failure Rate), DFR (Decreasing Failure Rate), NBU (New Better than Used), NWU (New Worse than Used), ...[1]. The non parametric tests [2], [5] are based on these distributions. The principle consists to test the hypothesis H0 that F is exponential against H1 that F is IFR, DFR...

3.1. Proshan-Pyke Test (for IFR or DFR)

This test is based on the statistic $V_r=\sum_{i<j}V_{ij}$. It suggests rejecting the hypothesis H_0 if $V_r > V_{r,1-\alpha}$.

The critical values of $V_{r,1-\alpha}$, for $r < 10$, were tbulated in [4]. For the large values of the sample, we use the asymptotic normality $V_r \sim N(\mu_r, \sigma_r^2)$, where $\mu_r = n(n-1)/4$ and $\sigma_r^2 = n(n-1)(2n+5)/72$

$$V_{ij}=\begin{cases}1 \text{ if } & S_i > S_j\\ 0 \text{ if not;} & i,j=1,\dots n\end{cases}$$

$$S(t_r)=\sum_{i=1}^{r}S_i$$

$$S_i=(n-i+1)(t_i-t_{i-1})$$

The table 1 shows that, except the labyrinth support 780, all the components belong to the IFR distribution (Increasig Failure Rate), this confirms the results obtained by the Weibull model ($\beta > 1$).

3.2. Graphic Test Based the TTT- Statistical

Basing on the Glivenko-Cantelli theorem, we reports the points (i/r , $S(t_i)/S(t_r)$) on a graph. If the obtained curve is concave (convex) then F is IFR (DFR).

The table 1 summarizes the application of this test for all the studied components. The figure 2 shows that all the curves are concave, this confirms again that these components present an increasing failure rate.

4. Applications

The obtained results above can be exploited for the maintenance optimization. Indeed, we are in presence of increasing failure rate , this allows us to conclude that the preventive maintenance is registered. The intervening time will be optimized by using economical criteria (maintenance cost) which is expressed by: $G_c = \frac{C_p + C_d}{MTBF}$, where Gc is the corrective maintenance cost brought back to the time unit, Cp is the new piece cost, Cd is the failing cost and MTBF is the Mean Time Between Failures. $G(T) = \frac{C_p + [1 - R(T)]C_d}{\int_0^T R(t)dt}$, where G(t) is preventive maintenance cost. The optimal time of replacement is the time wich would minimize G (t), it is the solution of : dG(t)/dt = 0.

Table 1: Reliability analysis results

Component	Weibull model			Proshan -Pyke Test			Graphic Test	
	n	η	β	Observed value Z	Crucial values (5%)	IFR or DFR	Curve	IFR or DFR
Sheathing 286	14	523	1.28	2.24	± 1.96	IFR	concave	IFR
Sheathing 285	15	521	1.39	3.41	± 1.96	IFR	concave	IFR
Tightness ring 275	15	271	1.99	3.71	± 1.96	IFR	concave	IFR
Stub bearing 230	8	889	2.08	2.23	± 1.96	IFR	concave	IFR
Tightness ring 460	14	953	1.96	4.32	± 1.96	IFR	concave	IFR
Carrying bearing 419	8	713	2.90	1.98	± 1.96	IFR	concave	IFR
Stub bearing 401	8	998	1.77	3.46	± 1.96	IFR	concave	IFR
Labyrinth support 780	7	1164	1.54	1.65	± 1.96	-	concave	IFR

Conclusion

The reliability classic analysis made to come out again that the Weibull parameter β is greater than 1 for all the studied components. It allows to conclude that these components degrade in time (Increasing failure rate), the non parametric tests (Proshan-Pyke and the graphic test) allowed to confirm that the failure rate increases. So the preventive maintenance is recommanded. The maintenance optimization was obtained by the taking into account economical criteria (maintenance cost). The application of the suggested politicies would beget some gains where could go until 83% of maintenance cost.

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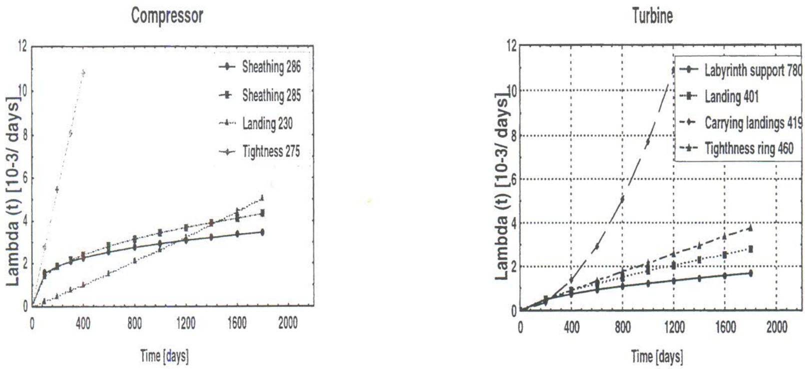

Figure 1. Failure rate (Weibull model with two parameters)

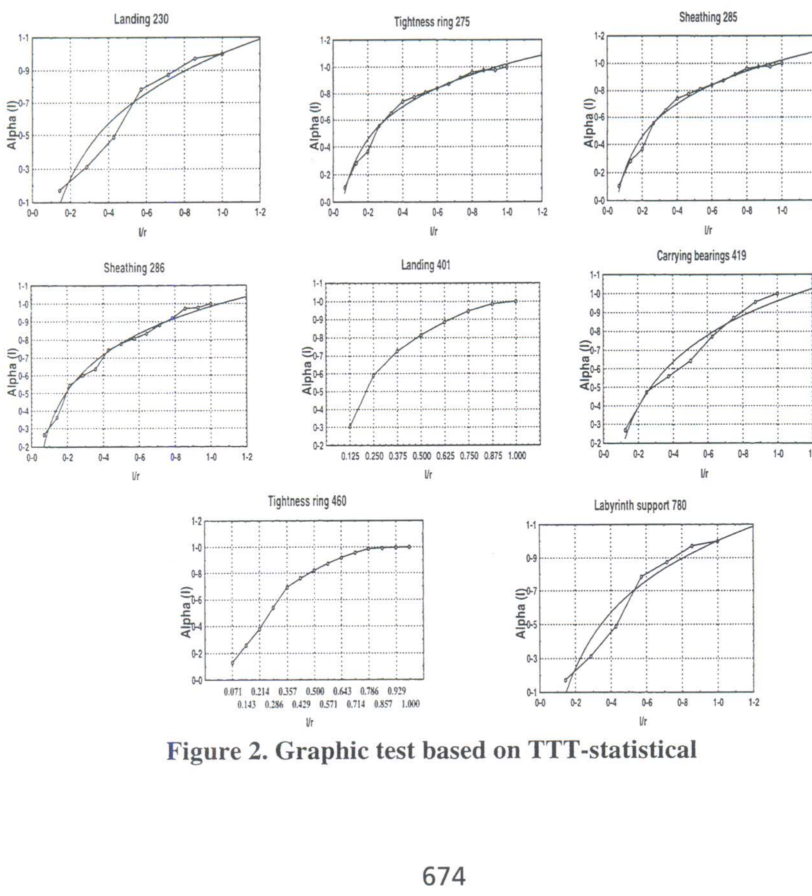

Figure 2. Graphic test based on TTT-statistical

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