reliability analysis

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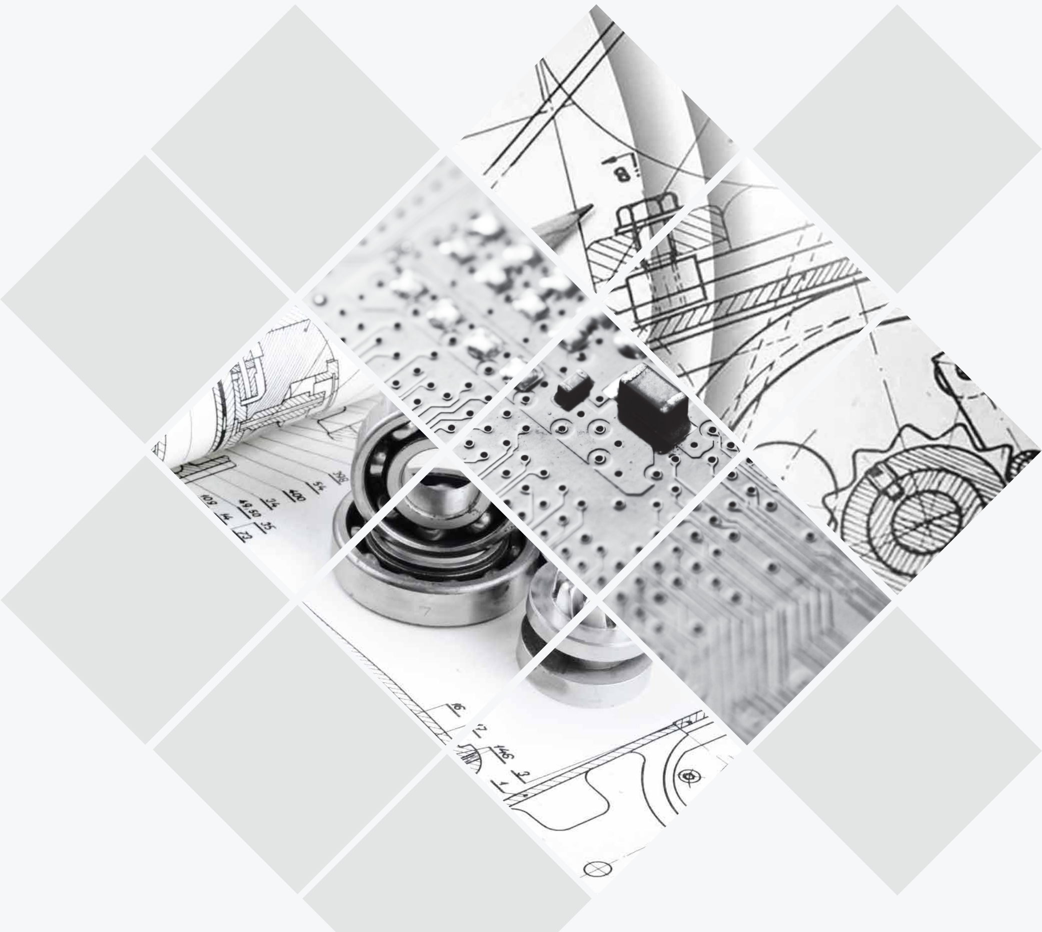

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Introduction

Airlines industry is a capital intensive industry. Due to the growing competition, the return on investment and the profits are reducing and the industry is facing with a big challenge to sustain profits. Aircraft sales directly rely on the aircraft engine market. In the recent times, aircraft manufacturers and airliners demand aircraft engines that provide maximum performance with an optimal purchase and maintenance cost. The reliability of aircraft engines and its components is a major concern to the aerospace industry. Commercial airliners' engine fleet consist of engines that are a combination of both owned and leased. This makes the fleet management even more complex exercise. The airliners now predominantly focus on understanding and predicting total life-cycle costs of aero-engine and its components.

Airliners and Aircraft manufacturers are always driven to improve, manage and optimize their product lifecycles. In such a competitive environment, the airlines need to constantly evaluate cost saving potentials. Lifecycle engineering comes to the forefront to provide an insight into the lifecycle costs by considering the economics of the entire product lifecycle. Lifecycle engineering guarantees efficiency, constant health monitoring, and optimum cost of operation.

Lifecycle engineering comprises of the following activities:

- Engine fleet management
- Engine health monitoring
- Failure data analysis

Engine fleet management is a vital area of revenue generation during the engine in-service life. The more the engine remains on-wing, the more revenue generation for the airlines. The consistent Engine Health Monitoring helps to avoid technical snags by detecting the issue before they occur. Understanding the failure trend and establishing the failure rate is essential to predict the downtime, associated maintenance activities and the turn around time and thereby predict the life cycle cost and maintainability of the aero engine.

The Life Cycle Engineering requires a reliable way of measuring and understanding the failure rate and failure trend and estimate the reliability of the engines to stay on-wing. This paper aims to explore the various aspects of reliability analysis and what are the emerging trends in this field. The paper then focuses on Weibull analysis as one of the statistical analysis methods used to carry out reliability analysis.

Why Reliability Analysis

Modern day engine maintenance is based on on-condition method. In this method, engine removals and overhauls should take place only when the engine condition demands it. In the past, engines were removed and maintained after a fixed time interval, which led to the engine being removed even in case it is still safe to operate and this adds to the life cycle cost.

The aeroengine's safe on-wing operations are directly related to the performance of its components. The longer the components perform, the longer the aeroengine stays on-wing. The longer the engine stays on-wing, less maintenance needed and reduced life cycle cost. For the estimation of life cycle cost, it is necessary to predict the intervals of these engine shop visits.

In-service aero engines need to be scheduled for overhaul shop visits to replace critical and lifed parts and to inspect all other modules. In order to predict the optimum shop visit intervals, it is necessary to understand how reliable the components are and this is where the reliability analysis finds its usage. The reliability analysis is carried out to identify the system or component capability to perform under specified conditions and also to identify the areas of associated risks in the life cycle of the component. This further can help to explore the possible mitigation actions to take care of the risks and hence increase the life cycle.

The reliability analysis is a continuous process which starts with the engine in the concept stage itself and continues throughout the lifecycle of the component. It can broadly be divided into the following three stages:

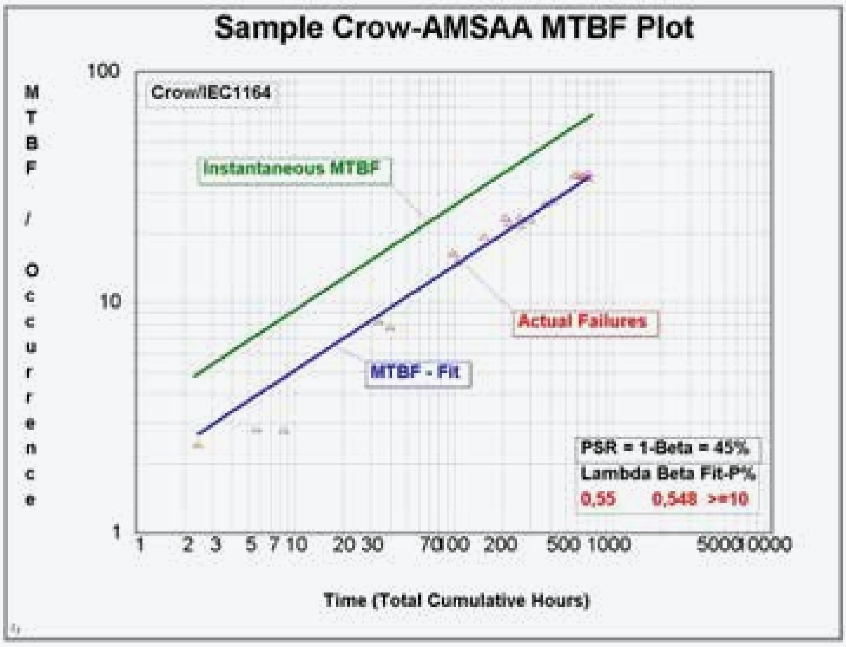
Design: During the concept stage, the theoretical and hypothetical reliability analysis needs to be initiated to understand the possible failure modes of the components, their effect on the performance and also identify the corrective actions to mitigate the risk of assumed failure.

Development: The need for reliability analysis does not end there. It then continues to the development stage in order to identify and mitigate the failure modes identified during the development testing. If these risks are not mitigated, they will continue to the service stage.

Service: This is the longest phase of the product lifecycle where the component/ engine is in practical use. The plan for an engine's shop visit is primarily driven by life-limited parts, but engines can be inducted in shop earlier than scheduled because of unforeseen failures. Depending on the intensity of the failure, an engine may need to be inducted immediately or it might be able to fly for a further period of time, with suitable monitoring against accelerated degradation. A continuous reliability monitoring is necessary based on the service performance so that the potential failures can be identified and appropriate corrective actions can be implemented.

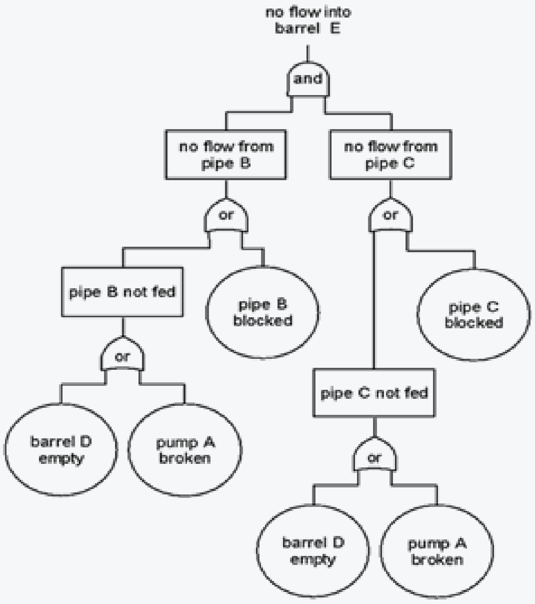
A number of techniques are used to carry out the reliability analysis as detailed below:

a) **CROW-AMSAA** – This method is suitable to analyse total failures vs total time of analysis. This method shows a failure trend over a period of time and also shows how effectively the fleet is being managed. However, this method is good only when there is a substantial failure data supported by a steady failure rate. This method provides a very good visualisation of the failure trend and can show the dramatic changes in the failure modes. However, it is not capable to properly show the non-linear trends. Figure 1 below depicts the linear failure trend over the period of time. This method also helps to understand the instantaneous Mean Time between failures.



CROW-AMSAA Fig. 1

b) **Event Tree Analysis** – This method uses the forward prediction method initiating from a hazardous event. A tree (reference figure 2) of possible events, what are expected to happen, leading to multiple conclusions is plotted and then the analysis of each branch is carried out in order to identify the probable failure mechanism and then to devise the mitigation methods. This method is simple to draw which considers different consequences but also has the associated disadvantage of becoming complex as many branches evolve for the same tree. This method also does not show any change as the fleet grows old.



Event/ Fault Tree Fig. 2

c) **Fault Tree Analysis** – This method of reliability analysis is used to create a model which will help to analyse the failure mechanism of an engineering system. This involves creating a logical diagram which plots the series of faults leading to the failure of the sub system or system (refer figure 2). This method generally involves assessment of failures due to component wear out, failure of materials to perform as desired or malfunctions owing to various reasons. The analysis involves drawing the tree listing various failures.

d) **Monte-Carlo Distribution** – This is a method of quantitatively analysing the risks and thereby arriving at the conclusions. This method helps to arrive at a number of possible outcomes and probability of occurrence of each of these outcomes. It is used to combine the distributions of multiple variables. This method works on the principle of probability distribution, using random samples over a range of attempts depending upon the number of unknowns. Some of the probability distribution methods used in Monte Carlo Simulation method of reliability analysis are given below:

i) Normal or Bell Curve
ii) Lognormal
iii) Uniform
iv) Triangular
v) PERT (Problem Evaluation and Review Technique)

This is the method which can be used when simple equation calculations cannot help in identifying the probability distributions of the risks, however, this method has the disadvantage that any simulation cannot be repeated and it can be inaccurate for extreme values in the distributions.

e) **FMEA or FMECA** – Failure Mode and Effect Analysis.

"FMECA is a technique used to identify, prioritise and eliminate potential failures from the system, design or process before they reach the customer – Omdahl (1988)."

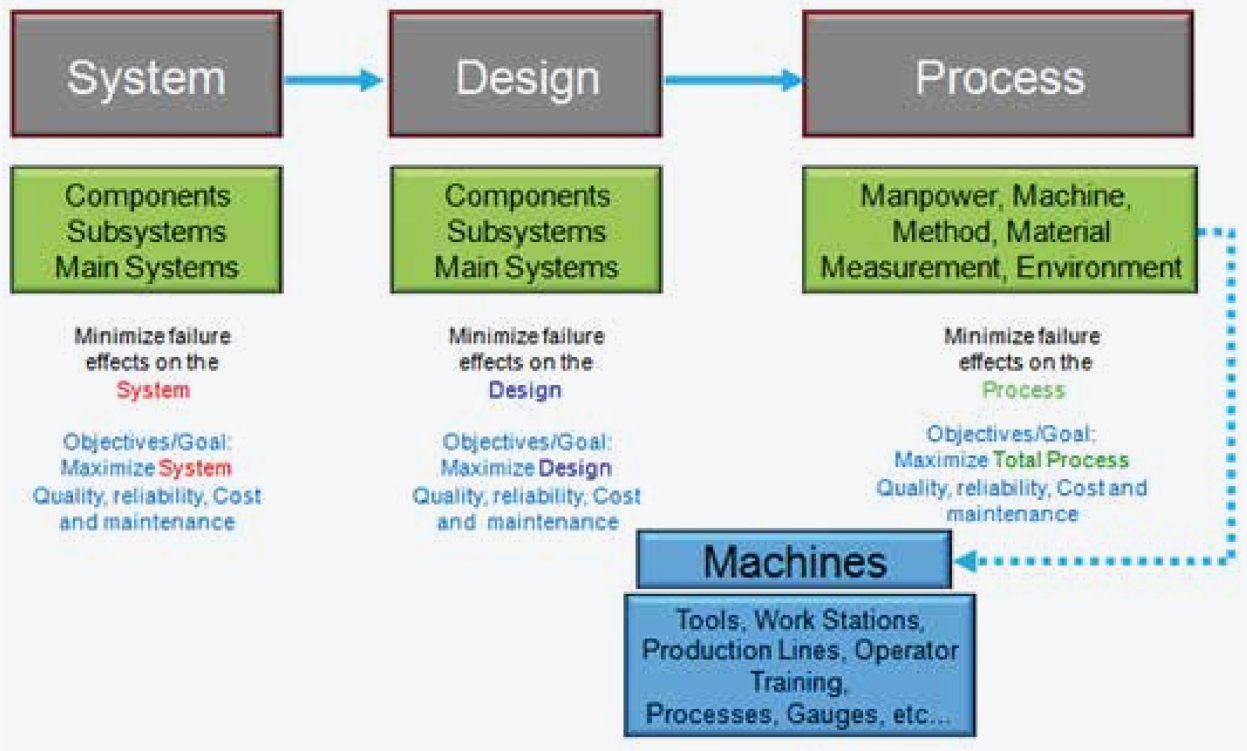
FMECA is a technique to resolve potential problems in a system before they occur – SEMATECH (1992).

This is a systematic method of predicting and preventing system, product and process uncertainties before their occurrence. The focus of FMEA is to prevent problems, enhance the component safety and increase the utilisation cycle. FMEA helps to identify all the possible failure modes of each of the components, processes or the systems, the possible effects of these failure modes as well in identifying the potential means to prevent or mitigate the effects of the failures.

The process of FMEA has further evolved over the period of its usage. Now this has involved the criticality analysis as well into the Failure Mode Effect Analysis and it is more often now referred as FMECA (Failure Mode, Effect and Criticality Analysis).

FMECA can be used at System, Design or Process level of the product life cycle. The System Level FMEA (SFMEA) is used to identify the reliability of the system involving the integration of various sub systems and components. Design Level FMEA (DFMEA) is used to identify the reliability of the product during the design phase and mitigate the risks by implementing various changes before sending to production. Process Level FMEA (PFMEA) is used to understand the reliability of the processes involved in manufacturing or operating the components and systems.

Figure 3 shows the relation between various stages of the product life cycle. The FMECA at each stage addresses the issues related to the particular stage but can also be an input for improvement in the other stages, for example, the design level FMEA can be a useful input for improvement in the System reliability. This is further evidenced in Case Study 1.



FMEA/ FMECA Fig. 3

f) Weibull Distribution - Weibull distribution method of reliability analysis is a three-parameter distribution sufficiently flexible to encompass almost all the failure distributions found in practice. It can help to identify the probability of failures at or before a given life. The Weibull distribution considers the lives of failed as well as non failed components. Weibull analysis is primarily a graphical technique of representing a vast majority of failure modes. Even though Weibull distribution uses graphical representation, it can also represent the results analytically. The analytical solution is, however, generally considered as a poor practice. The analytical solution takes away the picture and replaces it with an apparent precision in terms of the evaluated parameters (refer Probability Density Function).

Fleet Management

The OEMs, manufacturing the aeroengines, use one or more of the above stated methods to calculate the reliability of their products and guarantee certain life of the engines to their customers. This, to a great extent, helps in defining the predicted safe life of the components and engines before failure and hence an effective shop visit planning is possible. However, a small percentage of the fleet may still experience unplanned break down due to various external factors like the bird strike etc.

The failure rate of aircraft engine and its components is measured in terms of the Mean Time between Failures (MTBF) and Mean Time to Failure (MTTF), which requires the engine / component /assembly / module to complete its entire life cycle to establish an accurate failure rate.

The failure rate calculated by MTBF / MTTF is for the failed components in the fleet; however it is important and valuable to consider the in-service non-failed components to establish an accurate failure rate. Therefore a detailed analysis of the factors listed below requires a systematic and modelled approach to observe the aircraft engine and its component product lifecycle.

- Average engine fleet age
- Average hour and cycle usage
- Environment in which the aircraft engines are operated
- Detailed review of Lease Agreements, specifically return conditions and build standards requested by lessors
- Planned engine operational lifespan
- Number of spare engines available
- Airline spare engine policy

Weibull distribution, as explained above, uses the lives of failed as well as non-failed components in the analysis. Hence it is one of the most suitable statistical analysis tools to carry out detailed analysis and to predict the intervals for scheduling the maintenance cycles.

Weibull Analysis

Waloddi Weibull developed this tool in 1937 while he was working on a formula suitable to analyse the failure rate of welds, however he published his research only in 1951. But, the principles of this distribution were also explained and used by Frechet and Rosin & Rammler.

It is now one of the most commonly used methods for fitting equipment life data and is used extensively in the aviation industry to optimise maintenance intervention and to select maintenance strategy.

When performing reliability analysis, Weibull distribution attempts to make predictions about the life of all products in the population by fitting a statistical distribution (model) to life data using representative sample of units. Weibull analysis is also referred as life data analysis. The output Weibull plots help in identifying and defining the significant life characteristics (e.g. probability of failure at a particular life span, the mean life before failure etc.) of the component being analysed.

Pre-requisites to perform a Weibull analysis are

- Life data collection
- Choose the type of distribution which suits to fit the data
- Decide the parameters suitable to the distribution of the data
- Generate the plots and results

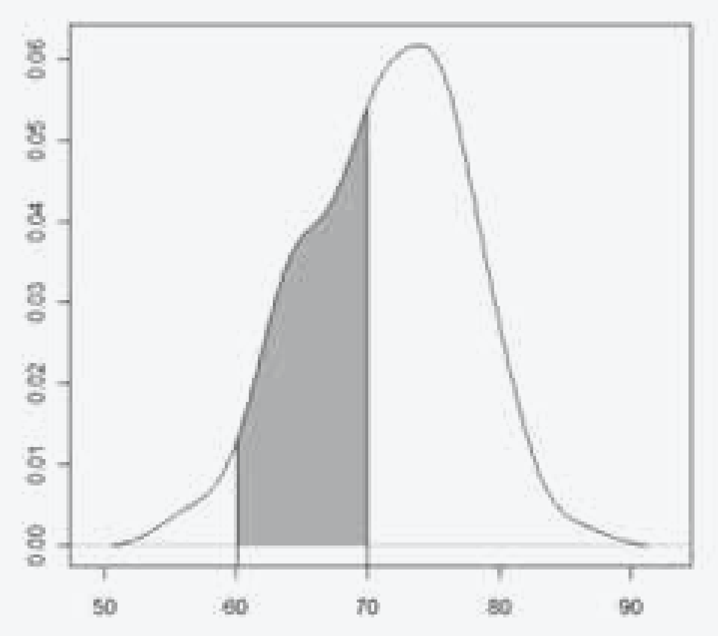
Weibull distribution method of reliability analysis is very flexible tool which can use almost all the practical failure distributions and uses three parameters for plotting the life distributions of various characteristics.

Probability Density Function (PDF)

The three parameters also define Weibull analysis mathematically, using probability density function (PDF) equation. The threeparameter Weibull PDF is given by

$$P(a \leq X \leq b) = \int_a^b f(x)dx$$

Where the probability that X takes the values in the interval [a,b] is the area above this interval and under the graph of density function. The graph of f(x) is referred to as density curve and may be shown as below (figure 4):



Probability Density Function Fig. 4

Weibull parameters

The first stage of Weibull analysis, involves the estimation of the three Weibull parameters, after the data has been fetched.

The three Weibull parameters are

- β: Shape parameter (defines the shape of the distribution)
- η: Scale parameter or characteristic life (defines where the bulk of the distribution lies)
- γ: Location parameter or minimum life (defines the location of the distribution in time)

$$f(t) = \frac{\beta}{\eta}\left(\frac{t-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{t-\gamma}{\eta}\right)}$$

Where

- f(t)≥0, t≥0 or γ
- β>0
- η>0
- -∞<γ<+∞

The parameters of the life distribution are suitably chosen by the life cycle analyst in order to fit a statistical model to the life data available. These parameters are the controlling factors for the shape and location of the function.

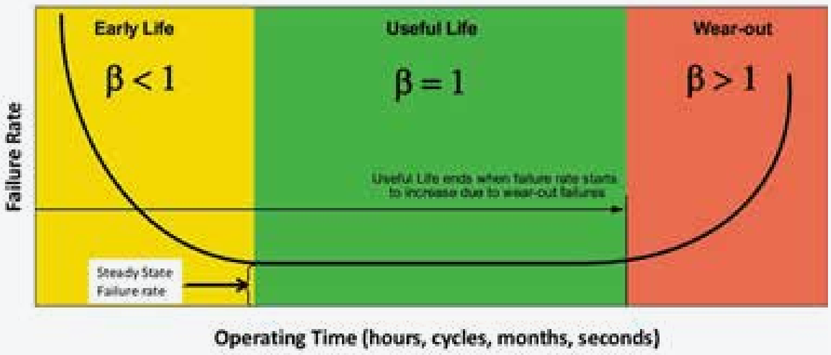
Importance of β (Shape parameter)

The slope of the Weibull plot, beta, (β), indicates which member of the Weibull failure distributions best fits or explains the data.

The shape parameter β is a pure number, i.e. it is dimensionless. Different values assigned to β can have significant effect on the behaviour of the distribution. For example, when β = 1, the PDF of the three-parameter Weibull reduces to that of the two-parameter exponential distribution.

The uniqueness of Weibull's work was to discover that, he could represent the Bathtub Curve using mathematical formula. As stated above, changing the value of the shape parameter, Weibull equation can take the behaviour of other distributions, which were individually of limited use.

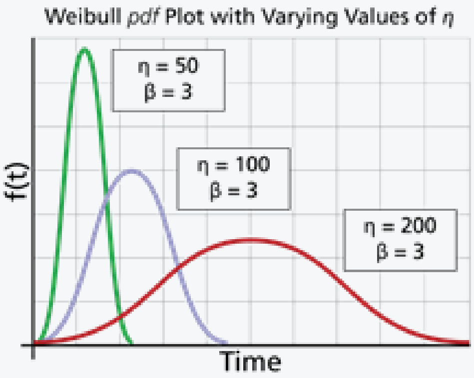
Weibull distribution can represent the entire span of bathtub curve by using the three Weibull parameters -beta β, eta η and gamma γ as shown in figure 5:



Bath Tub Curve Fig. 5

Effect of η (Scale parameter)

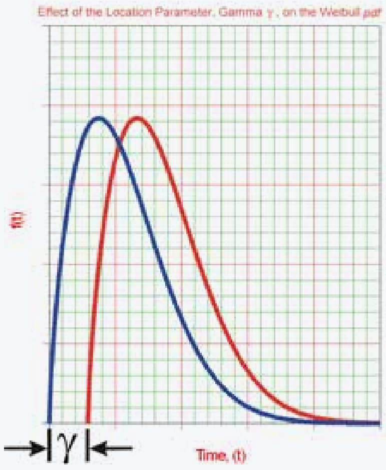
A change in the scale parameter also affects the distribution. The value of η increases while holding β constant. This stretches out the PDF. Figure 6 indicates how the change in value of η will affect the shape of the curve.



Weibull PDF Plot (Varying η) Fig. 6

Effect of γ (Location parameter)

γ, the location parameter, locates the distribution along the horizontal (abscissa) and any change in the value will have sliding effect on the distribution on either side of the Zero depending on the value, as shown in figure 7. If γ >0, the distribution will slide to the right and if γ < 0, the distribution will slide to the left.



Weibull PDF Plot (Varying γ) Fig. 7

Characteristics of Weibull curves

The Weibull curves provide information on failure mechanism, since different slopes lead to different kind of failure predictions.

Value of Slope	Failure Modes
β<1 When slope is less than 1.0, it represents initial failures, which decrease quickly, indicating that the weaker parts have died out. The graph indicates increase in reliability. Quality control and assembly problems may produce infant mortality failures.	• Improper augmentor liner repair • Improper installation of temperature probes • Fuel pump leaks due to installation problems • Overhaul-related failures of various components • Electronic control failures
β=1 This is due to original design deficiencies, unexpected failures; insufficient redundancy. This can deduce a constant failure rate condition.	• Bearing cage failure • Temperature probe failure • Fuel oil cooler failure • Electronic engine failure
β>1 This represents wear out module failure. When the value of β is 1.8 to 3.0, failure predictions will cover long time spans. As the slopes get steeper, failure times become more predictable	• Turbine vane wearout • Temperature probe fatigue • Gear box housing cracks

Engine Maintenance Planning Using Weibull Analysis

The Weibull plot is used for maintenance planning which is also known as Reliability Centric approach.

The value of Beta helps to understand whether the scheduled inspections and overhauls are required. When β is less than one or equal to one, then the overhauls are not economically feasible. When β is greater than one, a periodic or scheduled inspection is necessary and is cost effective.

For components that have wearout failure modes, optimum replacement intervals must be defined for significant reduction of costs. This is done by using Weibull failure forecasting.

Planned maintenance introduces cyclic or rhythmic changes in failure rates. The component lifecycle is affected by the interactions between characteristic lives of the failure modes of the engines, the inspection periods, and parts replacements.

Weibull failure forecasting provides the optimum methods of engine health monitoring. The forecasting doesn’t follow traditional maintenance methods and time intervals. Instead it adopts a more practical approach based on in-depth analysis of failure trends of different components.

The forecasting allows approaching the engine maintenance in the following ways:

- Scheduled and unscheduled maintenance practices
- Forced retrofit of components instead of convenience retrofit
- Non-destructive inspection versus direct parts replacement
- Preventive measures versus "next engine overhaul session”
- Different time intervals between-overhauls
- Optimal replacement intervals.

Approach

A typical cycle of activities for Weibull Analysis on a component is depicted below:

Required Inputs

- Component Life
- Scrap and repair quantity

Factors considered for Weibull analysis

- Scrap
- Repair
- Operating condition
- Stage length

Analysis

- Data collection from the Overhaul shop log sheets of the engine fleet
- Filtering out the gross data which can lead to misinterpretations
- Weibull plots for the factors considered for the analysis
- Failure rate and Trend established
- Fly forward for the failure trends

Procedures followed

- Data Mining and consolidation: Collect the data for the Failure of component (Scrap or Repair)
- Data arrangement: Change data to the Weibull software format on the factors considered for the analysis
- Weibull Plot: Plot the data using Weibull software (multiple softwares are available which can be used to plot Weibull graphs) for the factors considered for the analysis by Rank Regression method using component Life
- Failure analysis: Calculate the current and average failure (Scrap and Repair rate) and Failure trend
- Fly Forwards: Project the Failure rates depending on the failure trend obtained
- Conclude the results obtained from the analysis and effect of the factors affecting the failure rate and failure trend

Outcomes

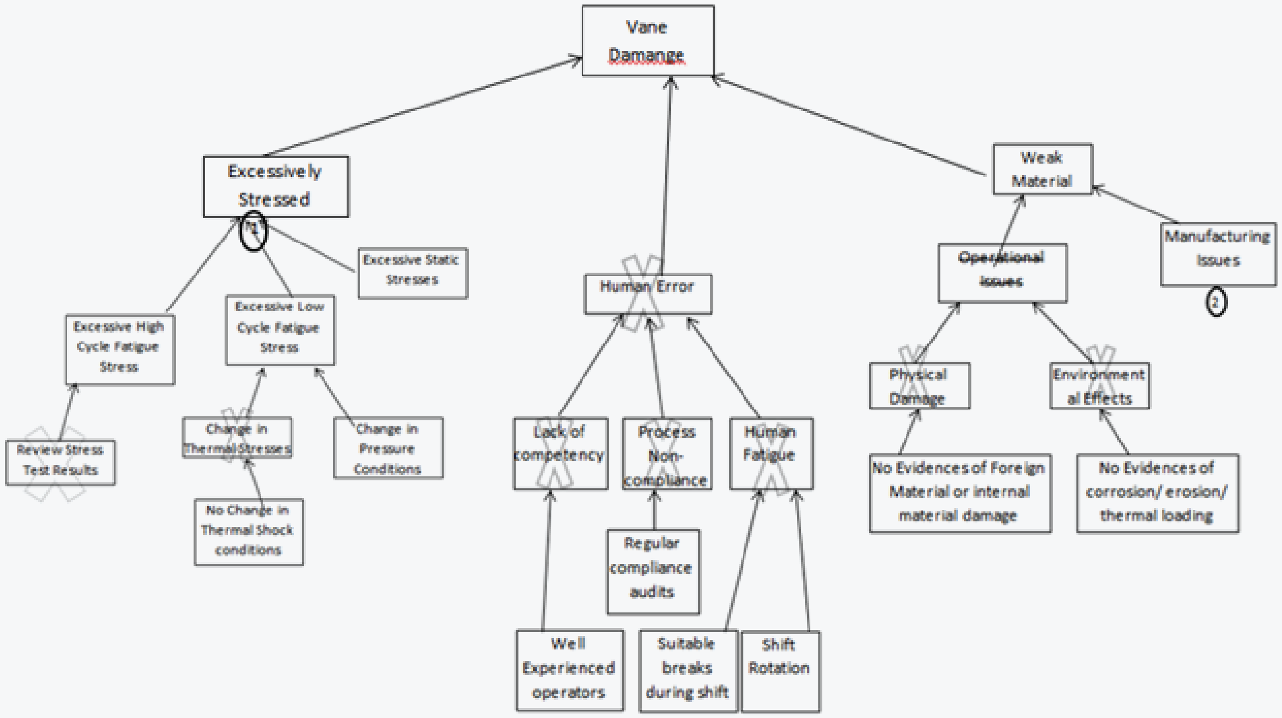
- Optimized maintenance schedules and Spare forecast
- Prevent unplanned frequent shop visits
- Identify the failure trends and failure rates for consistent flight operations
- Overall cost savings

Case Study 1

In a particular type of gas turbine engine, there was a significant rise in number of incidents of Unplanned Engine withdrawal from service because unacceptable cracks were observed in the Vanes. The engines were required to be sent to the overhaul facilities for replacing the vanes even though they had not completed their predicted life.

The FMEA carried out during Design phase (DFMEA) had predicted that these vanes are suitable for two shop visits (typically 10k cycles of operation). Historic evidences had proved that these vanes are suitable for two shop visits as predicted by DFMEA. However, over a period of time, the failure events increased significantly. Even though these failures of the vanes did not lead to any catastrophic or major accident and the cracks were spotted during the routine engine health monitoring or during periodic line maintenance, however, led to a significant maintenance burden as well as disruptions in the fleet operations. As a result and as a containment action, a special technical instruction was issued to replace the vanes at first shop visit. This, however, was not the permanent solution and it added significantly to the maintenance and replacement cost as well. It called for a detailed reliability analysis of the vanes.

The reliability team at QuEST carried out a detailed life cycle analysis of these vanes. As part of the study, a detailed Weibull analysis was carried out on the vanes. The Weibull analysis using MTBUR and MTBF tools revealed a trend in the failure of these vanes. The analysis revealed that there was a significant failure trend in the vanes replaced between a particular period of time. A further analysis of the vanes produced and supplied during this period revealed a quality escape in the manufacturing process which was the cause of premature failure of the vanes. The design review and the Fault Tree created are depicted in figure 8.



Case Study 2

Most of the civil aeroengines are on-condition engines and the overhaul/ refurbishments are controlled by life of the Critical components like the compressor and turbine shafts & discs. Based on the Design phase FMEA, the life of the critical components is predicted under ideal conditions of operations. However, following the safety margin policy of the OEMs as well as the lack of fleet experience at the time of design and production, these components are declared for a truncated life as compared to the predicted life. However, using these components for the shorter life is a heavy cost burden on the owners. Therefore, the life analysis needs to be carried out in order to gain confidence in increasing the lives of the components as close as possible to the predicted life and as early as possible.

The life cycle & reliability analysis team at QuEST supports its customers in gathering the fleet data for these components, analyse the data and recommend life increment, in association with other domain experts like the Laboratories, Stress Analysts, Material and Design Specialists and lifing specialists. Any safety issues identified during the analysis are highlighted and if needed, various operating profiles are recommended depending upon the fleet operations and the various other conditions.

The new lives are declared, agreed with the certification authorities and then released through the appropriate technical documentation.

Benefits and Challenges of Weibull Analysis

Benefits

The Weibull analysis follows a systematic approach in the predicting the failure modes and patterns. Some of the benefits associated with using this method of reliability analysis are:

- It provides a simple and easily understandable plot of failure data
- It is reasonably accurate method of analysis even with small samples
- Weibull analysis also takes operating parameters of aircrafts into consideration
- It has the ability to provide maintenance planning and cost effective replacement strategies
- It helps in optimum spare parts forecasting
- Helps to predict a mixture of failures modes
- Interpretation of alternate aging parameters
- Handling data where some component life and its history is unknown
- Construction of a Weibull curve when no failures have occurred
- Identifying the failure modes that only affect a subset of the fleet (Batch problems)
- Identification of suspected problems

Challenges posed while using Weibull analysis

- Works with only one failure mode at a time
- Cannot analyse data with serious deficiencies
- Even though, Weibull analysis is more reliable than many other techniques but sometimes other analysis techniques provide more accurate results compared to Weibull analysis

Emerging Trends

Till recent past, the safety and reliability analysis techniques were being used only for a very few industries like the Aeronautics and Aerospace and a very limited number of high end automobiles companies. However, with increasing economic challenges and customer demands for more reliable components, more and more industries are putting their foot into this field. Civil Engineering is one such major industry getting into the reliability analysis mode for adopting reliability based designs of the structures, selection of building material, tremor proofing still elegant and sleek designs etc.

The other major sectors where the reliability and safety analysis is being implemented are:

- Home Appliance (Refrigerators, Washing Machines, Televisions, etc.)
- Safety/ Security systems (Fire Fighting, Close Circuit Cameras, Access Control system etc)
- Telecommunication (Reliability of the hardware and associated software, connectivity etc.)
- Trains/ Road Transport (High speed trains, Modernised Buses)
- Power generation systems
- Software
- Healthcare
- Oil/ Gas Exploration

QuEST Global as a Technology and Consulting Outsourcing Partner

QuEST Global Services Pte Ltd, an ISO 9001company, is a diversified Product Development Solutions company. We cater to multiple high technology verticals such as Aero Engines, Aerospace and Defence, Industrial Products, Power Generation, and Oil & Gas. Our portfolio of services and solutions covers all aspects of the product development and engineering process such as Product Design, Product Development, Prototyping, Testing, Certification, Manufacturing Support, Product Support (sustenance, repair, documentation etc) Product re-engineering as well Consulting Services. Our service offerings cover mechanical engineering, electrical as well as electronics and embedded systems engineering of the product development process. With our diversified portfolio and geographic spread we have been able to conceptualize, design & develop, test, manufacture, certify and support different kinds of products worldwide.

QuEST has a well-established capability to carry out Reliability and Safety Analysis supporting multiple customers in Aeroengines, Aerspace & Defence and Oil & Gas sectors at various stages of the product life cycle. The established teams use some of the very high end, sophisticated and latest tools (e.g. Weibull++, CAFTA, RELEX) and techniques to support the workstream.

Conclusion

The economic scenario is becoming tougher and tougher by the day. The customers demand more fancy and modern equipment which is reliable to serve for long time but at a competitive price. More sophistication in the designs brings in more complexity and hence the durability reduces. The reduction in durability will lead to more and more warranty claims. The warranty claims involve not only the replacement or service to the product but also involve significant logistic costs. The warranty claims are a huge burden on the OEMs and are a source of customer dissatisfaction at the same time.

One of the best ways to contain the warranty claims is to improve the quality of the products. In order to ensure that the product meets the warranty conditions, the reliability analysis is the key to identify possible risks and mitigate them before releasing the product in the market.

Reliability analysis also helps to define the periodic maintenance scope as well as the intervals. The users of the products must follow the defined maintenance practices to get the best service out of the product.

More and more OEMs as well as ancillary industries are getting into the reliability analysis system to ensure that they produce the optimum quality product and improve their profits as well as credibility.

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Senior Engineer, Aeroengines, OBU India Ravi Kumar has experience in large aeroengines and industry based research in the areas of Product Reliability, Reliability Techniques, Risk Assessment, Maintainability, Life Cycle Cost and Product Maturity.

He holds the degree of Bachelor of Engineering in Mechanical branch from the National Institute of Engineering, Mysore.

Ravi Kumar is working as senior engineer in the Life Cycle Engineering team and is responsible for ensuring the quality of deliverables.

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Rajesh is specialized in Aftermarket Services for the Aeroengines. He has substantial experience in Life Cycle Cost Analysis, Support of In-Service Products and Managing Maintenance Burden.

Rajesh has served Indian Air Force for 20 years in various capacities. Throughout his career with Indian Air Force, he has been involved in Aeroengine maintenance which includes Line Maintenance and Overhaul/ Major Maintenance.

He is a Bachelor in Mechanical Engineering and Master in Business Administration with specialization in Human Resource Development.

He has created the Technical Processes for Fan Blade Replacement and in-storage preservation of various fuel aggregates for the aeroengine of a Russian Military Aircraft being used by Indian Air Force.

He has published a Whitepaper on Opportunities to reduce Total Cost of Ownership in Aftermarket Services.

Currently he is engaged in Investigations of In-Service Events, Product Improvement, Life Cycle Analysis for Aeroengines, competency development and training activities in the Aftermarket Services.

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About QuEST Global

QuEST Global is a focused global engineering solutions provider with a proven track record of over 17 years serving the product development & production engineering needs of high technology companies. A pioneer in global engineering services, QuEST is a trusted, strategic and long term partner for many Fortune 500 companies in the Aero Engines, Aerospace & Defence, Transportation, Oil & Gas, Power, Healthcare and other high tech industries. The company offers mechanical, electrical, electronics, embedded, engineering software, engineering analytics, manufacturing engineering and supply chain transformative solutions across the complete engineering lifecycle.

QuEST partners with customers to continuously create value through customer-centric culture, continuous improvement mind-set, as well as domain specific engineering capability. Through its local-global model, QuEST provides maximum value engineering interactions locally, along with high quality deliveries at optimal cost from global locations. The company comprises of more than 7,000 passionate engineers of nine different nationalities intent on making a positive impact to the business of world class customers, transforming the way they do engineering.

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