Life Cycle Assessment of Turbine Blade

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Proceeding of 3rd Afro - Asian International Conference on Science, Engineering & Technology
AAICSET-2015
ISBN: 9-780993-909238

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(Paper ID: Bharuch2k15C0203)

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Abstract: Life-cycle assessment (LCA), also known as life-cycle analysis, eco-balance, and cradle-to-grave analysis, is a technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave. The types of method available for LCA. This paper aims to study in detail about methodology that may be implemented to understand and estimate the effects of manufacturing variability on the manufactured components. An approach for dimensionality reduction is employed that uses prior knowledge on the measurement error obtained from analyzing repeated measurements. The proposed methodology also helps in capturing the effects of manufacturing drift with time and the blade to blade manufacturing error.
Keywords: Life cycle Assessment method.

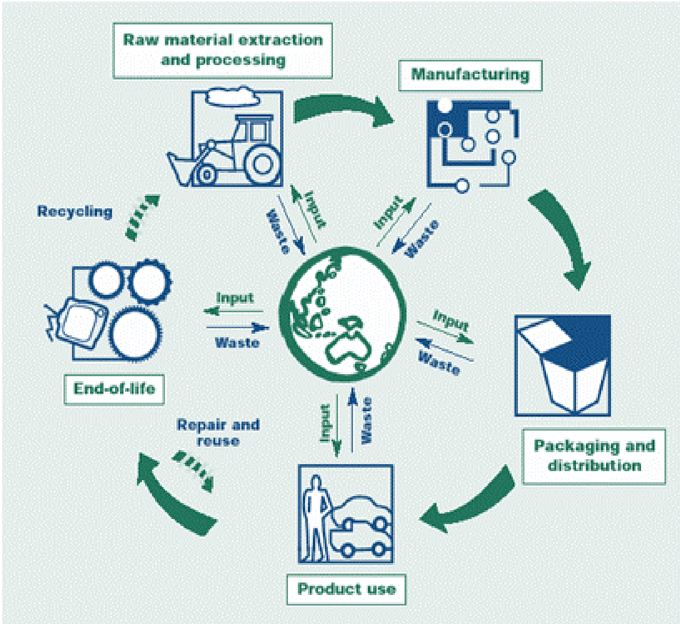
I. INTRODUCTION

Life of Component/product [1]

For products or component, the life cycle begins when raw materials are extracted or harvested. Raw materials then go through a number of manufacturing steps until the product is delivered to a customer. The product is used, then recycled or disposed of.

Life Cycle Assessment (LCA) [2]

Life Cycle Assessment (LCA) is a step-by-step method to map the complete environmental impacts of product and service. This method is based on the life cycle of the product or service, ‘from Cradle to Grave’. An LCA is often combined with an economic analysis, to assess the economic feasibility. Such a combination of environment and cost, also called eco-efficient, gives insight into environmental and economic aspects.



(Figure-1 Life Product life cycle stages and the interactions with the environmental system)[3]

II. METHODS OF LIFE CYCLE ASSESSMENT OF TURBINE BLADE[4]

The LCA methodology, as defined by International Organization for Standardization (ISO) 14040/44, is typically divided into four separate and interrelated components:

- **Planning:** Life Cycle Scope and Goal Definition includes the clear statement of the purpose of the study; the system to be studied; the intended use of the results; limitations on its use for other purposes; data quality goals; reporting requirements; and the relevant type of review process. The scope also defines a description of the geographical and temporal boundaries, system boundaries; data requirements; decision rules; and other assumptions.

- **Inventory analysis**: Life Cycle Inventory Analysis (LCI) is the phase of LCA involving the compilation and quantification of inputs and outputs through the live cycle

ISBN: 9-780993-909238

of a product or service, including the stages of resource extraction, manufacturing, distribution, use, recycling and ultimate disposal.

- **Impact assessment**: Life Cycle Impact Assessment is the phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts of a product system.

- **Improvement analysis:** Life Cycle Interpretation is the phase of the LCA technique in which the findings of the inventory analysis and impact assessment are combined together in line with the defined goal and scope. The findings may take the form of conclusions and recommendations to decision-makers, consistent with the goal and scope of the study.

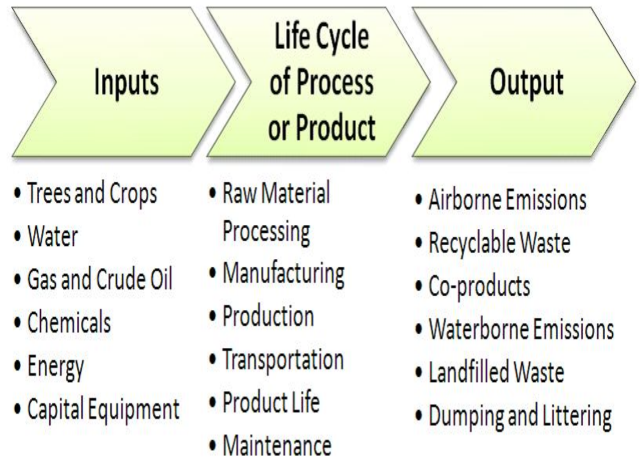
III. STAGES OF LIFE CYCLE ASSESSMENT

- **Raw material extraction and processing:** The raw material is extracted from Earth's core and brought up to service by processing it. Many process can be used for processing.
- **Manufacturing:** The manufacturing process is used for making different parts as per the requirements using raw material. The manufacturing is referred to making, innovating and maintaining of any material or component. For example**:** The manufacturing casting of Gas Turbine blades which are made up of Titanium alloys or Stainless steel**.**
- **Packing and distribution:** The packing and distribution are one of factor in LCA. The good and economic packing and distribution can be done by replacing the packing way and distributing.
- **Product use:** The value addition of the raw material is called product. The consumer goods or components been used and then maintained in the time of life.
- **Repair and reuse/End of life:** The product is use again by repairing and maintaining, if until the product tends to fail, then it is replaced and the previous product's life is ended.
- **Recycle:** The waste obtained from the product during manufacturing and also the product when its life is over, it is recycled to form new product. For example: the waste obtained from casting process namely runner and riser material are re-melted in furnace with other material to get new product.

IV. IMPORTANCE OF LIFE CYCLE ASSESSMENT [5]

The most important goal of LCA, according to a survey of organizations actively involved in LCA, is to minimize the magnitude of pollution. This chart lists some of the other goals: conserve non-renewable resources, including energy; ensure that every effort is being made to conserve ecological systems, especially in areas subject to a critical balance of supplies; develop alternatives to maximize the recycling and reuse of materials and waste; and apply the most appropriate pollution prevention
And/or abatement techniques.

At the beginning of a LCA helps an analyst to identify the major input and output materials.



(Figure 2 shows the life cycle stages of a general process. Creating a similar process list/diagram) [6]

Advantages

• To minimize the magnitude of pollution.
• conserve non-renewable resources.
• conserve ecological systems.
• develop and utilize cleaner technologies.
• maximize recycling of materials and waste.
• apply the most appropriate pollution prevention and/or abatement techniques.
• It increases the efficiency of the plant up to 50%.
• It increases the satisfaction of customer and thus it reduces the defect possibilities.

V. PITFALLS AND GUIDANCE [7]

Streamlined life-cycle assessments and life-cycle concepts have a particularly important role to play in green engineering, even more so than comprehensive life-cycle assessments. This is because of the nature of the design cycle of a product or process. There is a rule of thumb that 80% of the environmental costs of a product are determined at the design phase. Modifications made to the product at later stages can therefore have only modest effects. Thus it is in the early design phase that life-cycle studies for improving the environmental performance of a product are most useful. However, in the design phase, materials have not been selected, facilities have not been built, packaging has not been determined, so a comprehensive, quantitative life-cycle assessment is impossible at the time when it would be most useful. Instead, preferable materials and processes can be identified through the use of an abbreviated life-cycle study early in the design cycle where it is most effective.

T. E., *Streamlined Life-Cycle Assessment*, Prentice-Hall, Inc., Englewood Cliffs, New
Jersey, 1998

VI. CASE STUDY: PROBABILISTIC LIFE ASSESSMENT OF GAS TURBINE BLADES

- **Introduction**

ISBN: 9-780993-909238

The case study is an Improvement analysis method of LCA. Recent years have seen a growing interest by the research community and leading aircraft engine manufacturing companies in characterizing the effects of manufacturing variability on gas turbine engines. In view of this, there has been a lot of emphasis on capturing and modelling uncertainty and performing probabilistic analysis during the design phase [9, 10]. The aircraft propulsion industry(For example: Rolls Royce) is focusing on areas of research wherein uncertainty plays a pivotal role, e.g., application of probabilistic approaches for matching engine cycle models to test data, application of probabilistic analysis methods for estimating part life in engines, and understanding the role of uncertainty in engine materials selection and insertion [11]. **Garzon** [12] used statistical and probabilistic techniques to assess the impact of geometric and operating condition uncertainties on axial compressor performance and observed discrepancies of up to 20% between nominal and mean loss (mean-shift). **Sidwell** [13] performed probabilistic analysis on a commercial jet engine to quantify the variability in turbine blade cooling flow and oxidation life due to the variability in the operating conditions and uncertainty in the flow capability of the internal blade cooling passages. **Moeckel** [14] investigated the effects of manufacturing variability on first-stage turbine blades and proposed the tolerancing of input parameters in distribution ranges, which make non-conformances less likely. **Kumar** [15, 16]. Simulated manufacturing variations with process capability data using a combination of **Hick–Hennes** functions and splines in the search for compressor blade geometries that are robust in performance in
The presence of geometric uncertainty.

The data obtained in LCA paper which addresses the problem of analyzing measurement data on air-cooled intermediate pressure (IP) turbine blades to understand the nature and sources of manufacturing variability and estimate its effects on blade life.

Manufacturing of turbine blades starts by creating the molds that are used for casting the blades. A separate
Core model is manufactured from ceramic based material for the internal cooling air passages and assembled into a wax model of the blade. For this, the core models are held in dies into which molten wax is poured to create geometric representations of the desired blades. The resultant wax models are assembled together and molding material is coated over these assemblies to create the final mold that will produce the blades. Once the molds are ready, hot air at high pressure is passed through the mold assembly to melt and remove the wax. This results in hollows into which molten nickel alloy is poured (tip first) and left for solidification. These cast blades still have ceramic cores inside them and these are removed by chemical leaching. The final blades obtained are then ground and polished to remove any irregularities on the external blade surface.

There are various sources of manufacturing variability in the casting process described above.

(1)The ceramic cores are held slightly loosely in the dies used for creating wax models to allow sufficient space for the cores to expand or drift from their base positions when the molten wax is poured in. This may cause the cores to deviate to larger extents than expected.

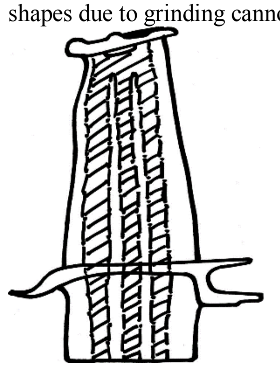
(2)The high temperature and pressure at which air is passed through the final mold assembly for wax removal may cause the ceramic models to deflect from their desired positions.

(3)The high temperature of the molten metal that is poured into the casts along with the hydrostatic pressure exerted by this metal on the core may result in the core becoming semi-plastic in nature and therefore instigate undesirable deformation.

(4)The ceramic core models may have air bubbles inside them, which may increase or decrease the blade wall thicknesses. The high temperature of the molten metal may cause the air trapped inside the bubbles to expand and hence reduce the
Blade wall thickness values, or the high hydrostatic pressure exerted by the molten metal may end up compressing these
Bubbles, resulting in an increase in the thickness values.

(5) Changes in the surrounding temperature and humidity levels may cause manufacturing drift with time.

(6) Wear and tear of the tools and the variability in turbine blade shapes due to grinding cannot be ignored.

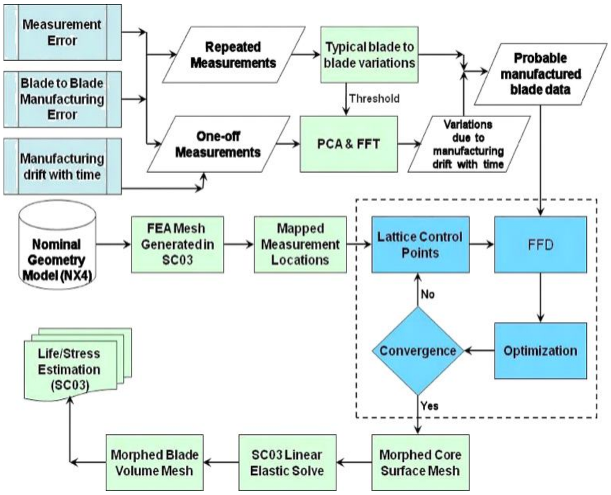


(Fig 3 A typical turbine blade model with internal cooling core shape)[8]

VII. Methodology of Life Cycle Assessment of Turbine Blade

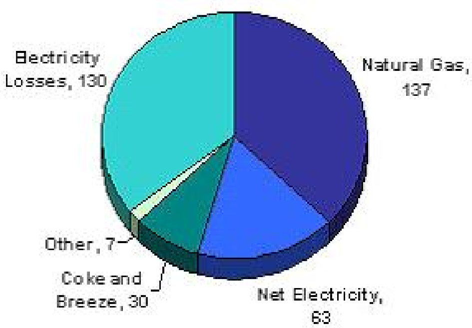
- **Analysis of Measurement Data and Noise Filtering Strategies[8]**
- **PCA and Dimensionality Reduction Using Measurement Error Information.**
- **Reconstruction of 3D Models Using Free Form Deformation and Mesh Morphing[8]**
- **Reconstruction of Geometry Using an Inverse FFD Approach.**
- **Formulation of the Objective Function for Mesh Deformations.**
- **Computational and Implementation Aspects[8]**

ISBN: 9-780993-909238



(Figure 4 Flowchart representation of the proposed methodology for de-noising measurement data, estimating geometric variability from limited measurements and calculating life for the probable manufactured blade shapes.)[8]

VIII. STATICS[16]



(Figure 5)[17]

IX. CONCLUSION

By the LCA methodology, the increase in life of component and reduce to ecology problems can be obtained. LCA helps to understand environmental impacts associated with the product. LCA cover planning, inventory analysis, impacts assessment and Improvement analysis of turbine blade. This will be helpful to improve productivity and eco-efficiency of manufacturing unit.

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