

Life Cycle Performance for manufactures of production facilities

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Keywords: Life-Cycle, Manufactures, Production Facilities, TCO

ABSTRACT

Operators of production facilities increasingly demand forecasts and obligatory promises about Life-Cycle-Costs and performance values from manufactures. On one hand these values are being used by the operator for supplier comparison during purchase. On the other hand the manufacturer must take over negotiated cost shares and possibly optimize the equipment in case of cost overrun. Goal of the research project LICMA – Life-Cycle Performance for manufactures of productions facilities is to optimize the forecast of Life-Cycle-Costs and performance values for the operator and manufacturer. Manufacturers must not only be able to support their clients actively through Life-Cycle with optimization of machines and productivity, but also establish a profitable cooperation based on partnership.

Introduction

While in the past the focus was on the reduction of the initial cost of a machine or plant nowadays the consideration is extended to the complete life cycle. Early on precursors in this field have been the enterprises of transport technology which were forced by their clients to make costs and proceeds potential of their products transparent over the complete Life-Cycle [1][2]. This approach is expressed through the term “Life-Cycle-Performance” [Figure 1].

International trusts also increasingly demanded the “Total Cost of Ownership” (TCO) of capital goods for cost reduction [3]. Until today the target of cost reduction and transparency by TCO concepts are mainly at the expense of the manufactures. However, trusts are starting to intensify the cooperation with the manufactures as a key role to obtain their aims. Particularly for the manufacture of production facilities the chance consists in displaying their strength. By regarding the Life-Cycle-Cost instead of the pure initial costs of capital goods a new argumentation treat opens up in the field of international competition [4].

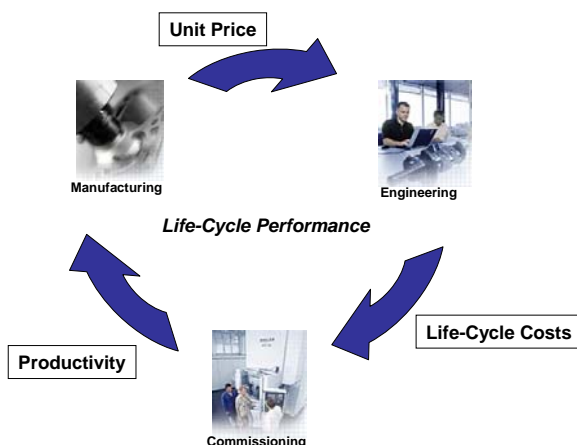


Figure [1]: Life-Cycle Performance

The cooperative approach between operators and manufactures of production facilities leads to a continuous improvement of the production facilities. From this extended point of view a situation arises from which the two cooperating partners can profit. In this way the manufacture is enabled to offer their customers additional optimization as a result of recessed field information of his products. The outcome of this collaboration are new services such as preventive maintenance and condition based monitoring. Additionally long term business relations with important customers can be generated.

The creation of new tools to support the Life-Cycle-Management between operators and manufactures is an integral part of the research project LICMA. The project content integrates mainly into areas such as intelligent networking of production facilities and cost optimization through the Life-Cycle.

Definition of the LCP- Life-Cycle Performance Indicator

The LCP indicator was developed at the Institute of production engineering at the Research University of Karlsruhe. The abbreviation LCP stands for Life-Cycle Performance. With the help of the LCP indicator technical production systems become increasingly comparable through their life cycle. The general requirements, such as user-friendliness and traceable are taken into account [5]. For the comparison of a machine or plant over the Life-Cycle the benefit as well as the costs which the plant implements are important. The LCP indicator therefore defines itself as a quotient from the sum of the benefit and the costs over the complete Life-Cycle of the plant:

$$LCP = \frac{\sum_{LC} Benefit}{\sum_{LC} Costs} \quad (1)$$

Unlike existing approaches for example of the cost accounting at which the benefit is defined as the quantified added value of the investment with the aim to describe the rate of return on investment [6], this approach renounced consciously the monetary quantitative analysis. The benefit is rather defined in the technical sense as the complete production of all products over the Life-Cycle of the machine. Therefore the advantage is that any market influences are filtered out:

$$\sum_{LC} Benefit = \sum_{Product} Output_{theoretical} (\Delta t_{Product}) * \overline{OEE}_{Product} \quad (2)$$

The calculation is based on the theoretical output and the mean average value of the indicator OEE (Overall Equipment Effectiveness) which is put together by the availability, performance rate and the quality rate:

$$OEE = Availability * PerformanceRate * QualityRate \quad (3)$$

The TPM (Total Productive Maintenance) approach subdivides the OEE decreasing loss sources as follows [7]:

- Availability: Break down and setting up time of the machine,
- Performance rate: Empty running and reduced fixed cycle,
- Quality rate: Non-reaching the quality objective.

The theoretical output is the most possible production quantity in equation (2) per product related to the product Life-Cycle $\Delta t_{Product}$:

$$Output_{theoretical} = \frac{1}{FixedCycle} * \Delta t_{Product} \quad (4)$$

The real output calculates itself by multiplying the theoretical output and the mean average value of the OEE over the production Life-Cycle. In this case it is assumed that the function OEE(t) is steady. Therefore the function of the middle OEE rises as follows:

$$\overline{OEE}_{Pr\ oduct} = \frac{\int OEE(t)dt}{\Delta t_{Pr\ oduct}} \quad (5)$$

The benefit described above is put into relationship in the LCP indicator with the sum of the costs which the machine or plant implements over its complete life cycle. In accordance with the Life-Cycle-Cost (LCC) approach [8] a variety of cost positions which are subdivided into product dependent and product independent can be considered. This way all of the Life-Cycle costs can abstractly but generically be presented as follows:

$$\sum_{LC} Costs = \sum_{LC} [Costs_{Pr\ oduct\ independent}] + \sum_{Pr\ oduct} \left(\int_{\Delta t_{Pr\ oduct}} Costs_{Pr\ oduct\ depending}(t)dt \right) \quad (6)$$

Summarized the LCP indicator arises with that:

$$LCP = \frac{\sum_{LC} Benefit}{\sum_{LC} Costs} = \frac{\sum_{Pr\ oduct} \left[\frac{1}{FixedCycle} * \int_{\Delta t_{Pr\ oduct}} OEE(t)dt \right]}{\sum_{LC} [Costs_{Pr\ oduct\ independent}] + \sum_{Pr\ oduct} \left(\int_{\Delta t_{Pr\ oduct}} Costs_{Pr\ oduct\ depending}(t)dt \right)} \quad (7)$$

For the practical use the VDI guideline 2884 offers a detailed choice of Life-Cycle-Costs (LCC) [9] which are subdivided into initial costs and operating costs such as maintenance costs. In the following a reference model is described which helps to calculate each figure of the LCP indicator.

Reference model of LICMA

In the joint research project LICMA a reference model has been developed which allows the IT supported prediction of the reliability and maintainability of machines and plants over the Life-Cycle. Furthermore a continuous monitoring and optimization of the installed machines are to be taken place.

For the optimization of the Life-Cycle Performance a conflict of objectives arises between the increase of the reliability of the machine and the reduction of the maintenance costs. An increase of the reliability has the consequence of higher maintenance costs. For the assortment of the optimal maintenance strategy the knowledge of the reliability is therefore essential. The reliability is described in the reference model as the property of a system which fulfils predefined function of business characteristic over a particular time period [10]. The reliability behaviour of a component or system can be demonstrate with the help of reliability characteristics, in which relevant aspects of the availability are reflected, for example Mean Time Between Failure (MTBF). The machine or system reliability finally results of the knowledge of the individual component behavior.

In one of the first steps a combined reliability analysis and prognosis methodology was developed. With this methodology an exact statement of the reliability indicators of machines and plants in dependence on load can be done. During the analysis period the available data has been identified and collected. The systematic classification of data into Life-Cycle-Cost (LCC), Overall Equipment Effectiveness (OEE) and Machine and Process Monitoring (MPM) is used as the base of the reference model (Figure 2). Within the section Life-Cycle-Cost (LCC) all field data are contained from Life-Cycle-Costs such as maintenance operations. In the Overall Equipment Effectiveness (OEE) the operation data collection and the machine data

collection are captured and processed. The supplement is the classification of Machine and Process Monitoring (MPM) in which sensor data will be entered to allow an improved condition orientated maintenance. All those sections are furthermore classified in actual, target and actual-target-lines. The actual-line is amongst others the collection and analysis of data from an individual operator/client and his machine. Individual client data of the effectiveness and the formation of costs are collected and analyzed separately. The target-line defines the client specific requirements for the machine. Those are recorded in the requirement specification in terms of predicted load collectives. The synchronization and comparison between the predefined requirements and the installed machine takes place in the actual-target-line.

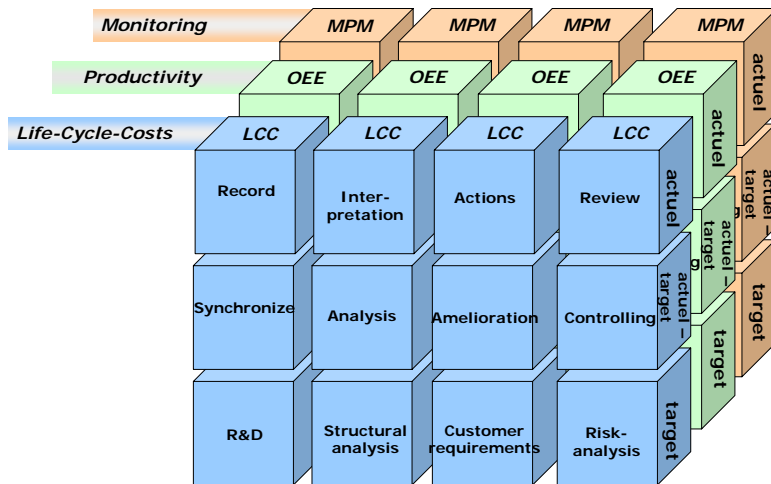


Figure [2]: Reference model

Therefore the weak points are detected based on the database and improvement potentials that are worked out. For the generation of the database all available sources (operator and manufacturer data) have to be considered and inspected for their applicability [Figure 3] [11].

The data sources of operators of production plants are the following:

- Operation data: Field data of existing machine populations gathered under real operating conditions is fundamental for any reliability analysis and prognosis.
- Maintenance data: If planned machine busy times are known, records and statistics of the operator's maintenance services theoretically enable the calculation of MTBF and MTTR values.

The data sources of the manufacturer are usually the following:

- After sales service: The customer service documents the reliability-relevant failures commissioned by a customer for repair or warranty claims. In common business models this is primarily the case during the warranty period, wherefore later records are limited.
- Spare part needs and sales: This data source is of special interest if only little maintenance and service data is available. Failures within component level, oftentimes even related to individual machines, can be concluded from the booking of spare part sales.
- Test and simulation data: Test and Simulation data often exists on the manufactures side, especially on component level, since this data is needed for the development process.
- Dimensioning calculation: The classical approach towards reliability prognosis is component dimensioning following norms and component supplier specifications.
- Expert knowledge (FMEA and FTA): Expert estimation is used as substitute or to enrich existing data. Expert estimations can also be used to judge the quality of real data. The degree of subjectivity has to be taken into account regarding the choice of an estimation method. The essential methods of determining reliability-relevant data by expert estimation are the FMEA (Failure Mode and Effect Analysis) and the FTA (Failure Tree Analysis).
- Value analysis: Functional structure and costs from value analysis can be used to structure and complete the data model in the introduced approach.

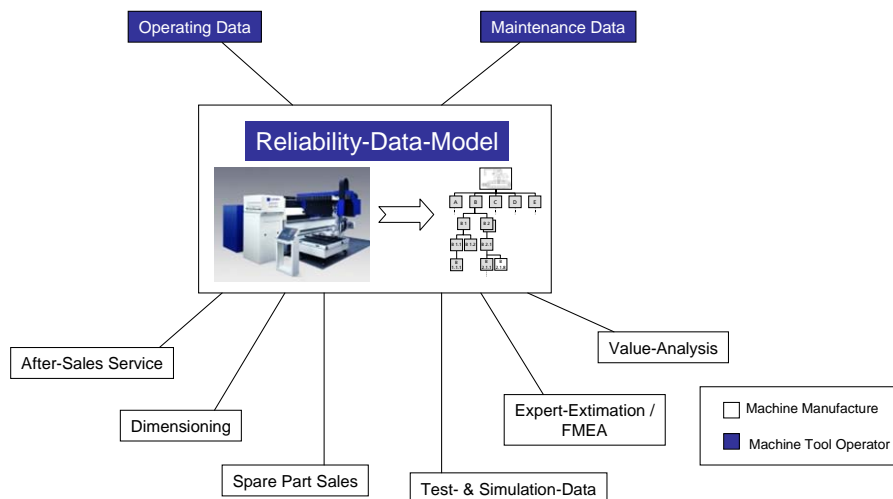


Figure [3]: Data sources

After the selection of the relevant components and the mapping of the data sources the analysis takes place. If the data base of the components is sufficient the Weibull-Distribution is calculated and the failure functions are determined. Based on that data base the corresponding MTBF-value of each component could be directly calculated whereas the operating conditions in terms of loading classes have been taken into account. If there is not enough information available to predict downtime characteristics of components, simplifications such as the use of the exponential distribution on the base of expert estimations are documented.

This combination of analysis has been used to minimize incertitude and to prove the probability of occurrences. Furthermore control loops between the analysis and prediction results help to systematically accomplish the necessary corrections due to wrong estimations or weak point improvements. With the help of these proceedings the prediction quality can be estimated and the risk is better rateable.

Conclusion

The shown approach was developed in the surroundings of the research project LICMA – Life-Cycle Performance for manufactures of production facilities which is sponsored by the BMWi (Bundesministerium für Wirtschaft und Technologie). For attainment of the complete target LICMA pursues individual aims which focus on the different phases between component suppliers, manufactures and operators of the machine cycle. A central target of this approach is the construction of a reference model which describes the complete attempt at reducing unit costs. Therefore the LCP-Indicator is used for the comparison of the Life-Cycle Costs and the productivity. In the further project course the necessity exists to carry out a standard for the data interchange between the enterprises and to thereby make a continuous improvement for the machines and plants possible.

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