World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:4, No:9, 2010

Predicting the Life Cycle of Complex Technical Systems (CTS)

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***Abstract*—**Complex systems are composed of several plain interacting independent entities. Interaction between these entities creates a unified behavior at the global level that cannot be predicted by examining the behavior of any single individual component of the system. In this paper we consider a welded frame of an automobile trailer as a real example of Complex Technical Systems, The purpose of this paper is to introduce a Statistical method for predicting the life cycle of complex technical systems. To organize gathering of primary data for modeling the life cycle of complex technical systems an "Automobile Trailer Frame" were used as a prototype in this research. The prototype represents a welded structure of several pieces. Both information flows underwent a computerized analysis and classification for the acquisition of final results to reach final recommendations for improving the trailers structure and their operational conditions.

***Keywords*—**Complex Technical System (CTS), Automobile Trailer Frame, Automobile Service.

I. Introduction

COMPLEX systems have been considered recently as a hot field in scientific research by many researchers and from various disciplines. A complex system can be defined as a system which involves a number of elements (such as machines, humans, technical systems, etc.), arranged in a structure which can exist on many scales [1,2,9]. These systems goes through several processes of change that are not describable by a single rule nor are reducible to only one level of explanation; these levels often include features whose emergence cannot be predicted from their current specifications. Complex systems theory also includes the study of the interactions of many parts of the system. Examples of such complex systems include ground/air transportation systems, health care systems, supply chain systems, and military systems. These systems are typically highly complex and dynamic with tightly coupled interacting components (or subsystems). In our paper we study an automobile trailer frame which includes one or more cross member/suspension system, mounting assemblies which mount axle/suspension systems and provide support against the twisting, parallelogram and S-shaped deflections typically caused by vertical, lateral, longitudinal and roll loads commonly bump into each other by the automobile vehicle trailer during operation, and which can cause premature wear of trailer frame components [14]**.**

During the life cycle of CTS quantitative changes are collected which leads to quantum leaps in operation suitability [6]. The description of CTS (a zero point of its life cycle) provides integrity of states.

At the examination of CTS some problems could occur, for example, poor quality of manufacturing, absence of reviewing the drawing details, connections and welded seams [8]. Thus, during the assembly of an object, there may be various defects in it. Product exploitation (or testing) comes to the end during the moment corresponding to the limited design state, i.e. exhaustion of its resource.

As specified above, the condition of CTS exploitation is the accumulation of undefined various characters and derivations.

During the prediction phase of the life cycle of complex technical systems (CTS), the initial information used is extracted from the design of the analyzed variables, the generated data from tests conducted on the trial sample, the statistical information about the external conditions and behavior of this complex system and the ground tests on the system during the exploitation phase. The first two serve as the primary source for obtaining experimental and calculated data on the deformed conditions of the technical system under review. The remaining two sources are used for modeling the expected damages the system shall sustain throughout its life cycle [3].

The data collected at the final stages does not necessarily correspond to the principle requirements for plotting of stochastic models for systems similar in type and characteristics for all observations and control phases of the system [5,9]. These projects are complex enough for its varying conditions and functions. Therefore, it is difficult for empirical data to be matched since it differs from one project to another.

II. Previous Studies

Many of today's vehicles include a wide range of systems and components that perform various operations while the vehicle is in use. Over time, repeated use of the vehicle may cause failure of individual systems or components. As such, most vehicles are equipped with an onboard diagnostic computer in communication with the various systems and components included on the vehicle. The onboard computer may monitor the operation of the systems and components by logging diagnostic data generated during use of the vehicle.

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Although the onboard diagnostic computers may log data generated in response to operation of the vehicle, the diagnostic computer may not be capable of analyzing the data to identify the ultimate failure source plaguing the particular vehicle.[10]

As such several diagnostic and support tools have been developed with the aim of providing the owner of the vehicle with vehicular diagnostic information. For instance, several handheld diagnostic tools have been designed to offer the owner of the vehicle a means of accessing and retrieving the diagnostic data logged by the onboard diagnostic computer. Once the diagnostic data is retrieved, it may be analyzed to determine a failure source.[10].

A. Applications in related work:

Abnormality analysis system for vehicle and abnormality analysis method for vehicle - When an abnormality of a vehicle is detected based on a vehicle state value that indicates the vehicle state; an abnormality analysis system for the vehicle estimates a cause of the abnormality. The abnormality analysis system includes: a factor identifying information extraction unit that extracts factor identifying information which is used to identify a factor of the abnormality based on the vehicle state value; a database that contains data groups which correspond to respective categories of the factor identifying information and which store causes of abnormalities and vehicle state values at the time of occurrence of the abnormalities; and an abnormality cause estimation unit that executes a process for estimating the cause of the abnormality of the vehicle with the use of the data group that corresponds to the category of the factor identifying information extracted by the factor identifying information extraction unit.[11]

System and method for adjustment of a steer angle of a wheel of a motor vehicle - A system for adjusting a wheel lock angle of a wheel of a motor vehicle, in particular of a rear wheel, wherein at least one wheel guide member, by means of which a wheel carrier of the wheel is connected to a vehicle body, wherein the wheel carrier can pivot about a rotational axis which runs substantially parallel to the plane of the wheel and the wheel guide member is coupled to the wheel carrier at a distance from the rotational axis, and wherein the length of the wheel guide member can be adjusted by an actuator, wherein at least one actuator is driven by a motor and at least one control unit, and the control unit includes a computer unit with a memory and a communication interface, and the control unit transmits and receives data via the communication interface by means of at least one communication bus.[12]

System and method for cooperative vehicle diagnostics - Embodiments described herein comprise a system and method for corroborative vehicle diagnostic. The corroborative vehicle diagnostic system allows a vehicle to detect a fault indicator experienced by a vehicle subsystem. The corroborative vehicle diagnostic system allows the vehicle to compare the fault indicator with similar and/or dissimilar conditions experienced by one or more additional vehicle located within a geographic region.[13]

As is apparent from the foregoing, it is necessary to the art for a method to retrieve and analyze information to diagnose the vehicle to facilitate the identification of a source of error. The present invention relates to this particular need, as discussed below.

III. Statistical Methods of Prediction of the CTS

To organize gathering of primary data for modeling the life cycle of complex technical systems an “Automobile Trailer Frame” were used as a prototype in this research. The prototype represents a welded structure of several pieces [6] .The information on the current state of the operating trailer arrived in tow discrete series of data. From automobile repair servicing facility (notifying on frame damage) and from operational service (on internal and external conditions leading to the occurrences of these damages) see fig.1.

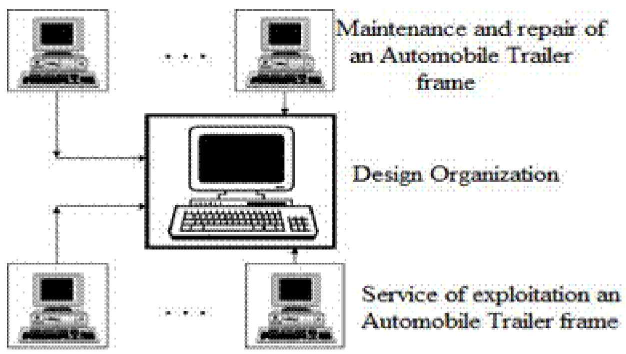

Fig. 1 Scheme of collecting information on the technical state and conditions of an Automobile Trailer frame

Both information flows undergoes a computerized analysis and classification and with other different methods applied with consequent results for the acquisition of final results to reach final recommendations for improving the trailers structure and their operational conditions. The likely cause of failure to guard valuable information, however, additional information is needed before the vehicle will be fully restored. For example, the assertion that the most likely cause of errors, the actual cause of failure may be necessary. In addition, information on the extent of rejection may also be necessary to ensure the most cost-effective repairs.

The data from automobile repair servicing enterprise was processed as follows: by the issues of ground tests the frame structure damages were divided into a finite number of types, actual for this model (fig. 2). At that the occurrence of any other type damage during frame’s life cycle was equalized to zero.

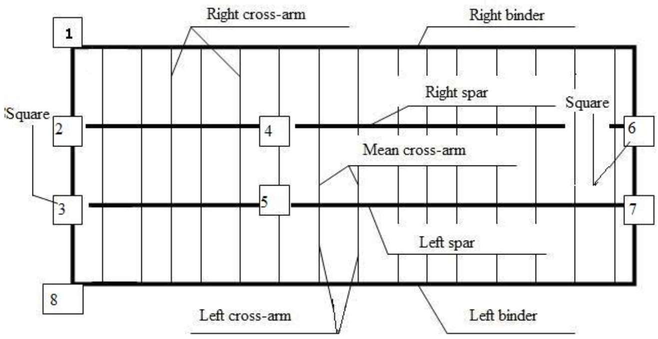

Fig. 2 Scheme of considered automobile trailer frame damages allocation

Every damage type corresponded to the determined areas of frame, and every area correlated to several levels of damage depth, simulating the crack progress (ex. crack generation reaching to frame breakage at corresponding point). The table 1 represents damages types corresponding to numbers at figure 2 as well as every damage type points quantity and number of damage levels at every area. Therefore, the general quantity of object damages sought is 246.

TABLE I
THE QUANTITY AND NUMBER OF DAMAGE LEVELS

No re to fig 2	Damage type (point of crack generation and progress)	Number of points	Number of levels
1	Right binder	16	66
2	Mean cross-arm/right spar	16	50
3	Front cross-arm/Square	2	2
4	Front spar	1	5
5	Left spar	1	5
6	Rear cross-arm/ Square	2	2
7	Mean cross-arm/left spar	16	50
8	Left binder	16	66
	Total	70	246

IV. STATISTICAL RESULTS

Notifications of damages occurring were collected from different automobile service enterprises within discrete time intervals as damages' matrixes Xijξ for every sequential observation's iteration termination

$$X_{ij\xi} = \begin{bmatrix} A_{1,1} & A_{1,2} & ... & A_{1,N} \\ A_{2,1} & A_{2,2} & ... & A_{2,N} \\ ... & ... & ... & ... \\ A_{M,1} & A_{M,1} & ... & A_{M,N} \end{bmatrix}$$

Where Aij – quantity of j-th object damages at i-th automobile service enterprise,

i – automobile service enterprise number,

j – observed object number,

ξ - observation iteration number,

N – quantity of every damage type points (here N =16)

M – damages types quantity (here M = 8).

The automobile trailer refers to restorable engineering structures. That does mean that a given number of previous damages occurred, it is dispatched to repair service, which completely changes to further damages accumulation situation. Actually, the physically "old" trailer disappears, being replaced within operation with a "new" one, which parameters are low-predictable, because of stochastic character of repair works features. Thus the whole vectors' generality Aijξ considering all automobile enterprises is inapplicable at an adequate trailer operation model shaping.

At the same time contemporary mathematical models allow selecting a compact data set, homogenous enough for analytical study. This set representation level relates to the automated classification methods involved. Particularly, this class' problems are resolved with the use of similar observations' generality selection model algorithm, represented by automated classification recurrent algorithm grounded onto maximization of the functional featuring the object density inside of class and using linear dividing functions for dividing surfaces prescription [5].

As the result of analysis affected we obtained some recommendations on trailer improving at the expense of its structural strengthening at the most hazardous points; at cross-arms welding to binders and spars as well as at the points of cross-arm – to square joining.

During the study of the status of complex technical systems, a part of matrix Aijξ, data on operational conditions can be acquired such as: operation intensity, average load and environmental parameters. For automobile equipment primary data acquired are: kind and mass of cargo loaded, methods of transportation, average distances of travel, roads condition, regional climate, technical service level at the enterprise, personnel attitude. Several of these factors is poorly predicted and even has subjective character.

Having obtained initial data classification retrieval onto technical system's state, we can calculate the range for every eventual damage point and for every system operational factor with respect to their contribution into reliability deterioration. Such rating is possible with the use of complex systems development factors' apportionment methods [7]. Results issuing are necessarily needed when similar engineering objects project designing, as that allows firstly accurate strengthening only at those areas, which have essential influence onto object workability, and secondly, that serves to accurate recommendations on diminishing the hazardous influence of deterioration factor at the same time that on reserve parts' assortment both repair set completion.

Let we seek analysis of automobile trailer operation parameters; we've selected from the whole operational characteristics' factors set several ones (see table 2), every being determined with five values and normalized with reference to the basic resource. That allowed eliminating mutual impact of parameters' dimensions.

TABLE I
THE QUANTITY AND NUMBER OF DAMAGE LEVELS

Parameter denomination	Parameters' values Prognostic	Specified	Error percent	Adjusted value
Loading average percent	0,814	0,701	-2,03	0,0
Kind of cargo	0,976	1,007	1,01	0,030
Average single mileage	0,954	0,954	-0,011	0,203
Road condition	1,000	1,005	-1,270	0,016
Climatic factor	0,876	1,000	1,986	0,050
Technical servicing norms respecting	1,002	1,002	-0,012	0,201

V. CONCLUSION AND RECOMMENDATIONS

The method includes receiving diagnostic data of the Automobile Trailer Frame. The data collected by the automatic diagnostic tools for diagnosis, then transferred to the database before the experiment, with information regarding decisions related diagnostic sets of diagnostic data. Prior experience bases are arranged according to the data received diagnoses of possible solutions diagnosis. Decisions of diagnosis and then prioritized according to the document corresponds to diagnostic data obtained in the previous arrangement of diagnostic data stored in the database before the experiment. The possibilities of diagnosing problems related to the combination of diagnostic data highly rated are identified as the most likely solutions.

It is assumed that the present invention can provide accurate and reliable as diagnostic information, which is known systems and methods are available. Data on the diagnostic components of the Automobile Trailer Frame most likely to be compared with results recorded and certified to be associated with a priority of the database recent experience that the most likely cause of failure is the true cause of failure. In addition, it is also clear that the data collected during the process described above, to various remote places of the driver with a network of diagnostic tools are guaranteed. For example, the most likely cause of failure can be transferred to the mobile phone the driver to driver problems with the Automobile Trailer Frame alarm. In addition, the most likely source of non-compliance can be centralized support passed on to customers. Thus, customers can get help on the specific needs of the Automobile Trailer Frame without the operator information centre diagnosis to support customers in the diagnostics. It may be desirable for wireless transmission of data from the automobile diagnostic tool for the dissemination of better diagnostic data.

After using the factor analysis method, we obtained ranges showing the reference point which implies that "average load percent" parameter should be adapted. Therefore, by-factor recalculations of deviations acquired with respect to the maximum factor loads by factor served to determine the three main directions related to operational conditions for improving the reliability of trailers. These parameters were included in the mentioned above recommendations for future enhancements to the design and construction of trailer.

ACKNOWLEDGMENT

The authors are grateful to the Applied Science Private University, Amman, Jordan, for the financial support granted to cover the registration and publication fee of this research paper.

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