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APPLYING THE RELIABILITY IMPROVEMENT PROCESS IN ROBOTICS EQUIPEMENTS PRODUCTION

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Abstract: Knowledge of theequipment life cycle is important because it provides a basis for understandinghow and where reliability engineering enters into the process of designing, producing, andoperating the automationequipment. The equipment life cycle is broken into distinct phases, eachrepresenting a unique portion of the equipment life. These phases provide the framework fortracking reliability throughout the life cycle of the equipment and guidance on when and where toapply resources.

Key words: *Reliability, Maintainability, Equipment's reliability, Feasibility, Product development*

1. INTRODUCTION

The *reliability improvement process* provides a means for making revolutionary advancements when it is applied to automation equipment early in the design stage, or during major design upgrades, or for making revolutionary improvements to existing equipment. Also, the *reliability improvement process* provides a means for systematically improving reliability throughout the equipment life cycle. However, it is important to improve reliability throughout the life of the equipment to meet reliability goals and objectives.

The reliability improvement process is an iterative process that is applied at each phase of the equipment life cycle. It consists of five basic steps:

1. Establish reliability goals and requirements for equipment;
2. Apply reliability engineering or improvement activities, as needed;
3. Conduct an evaluation of the equipment or equipment design;
4. Compare the results of the evaluation to the goals and requirements and make a decision to move either to the next step/next phase ;
5. Identify problems and root causes ;

The process then returns to Step 2, and Steps 2 through 5 are repeated until goals and requirements are met (see flowchart in Fig. 1).

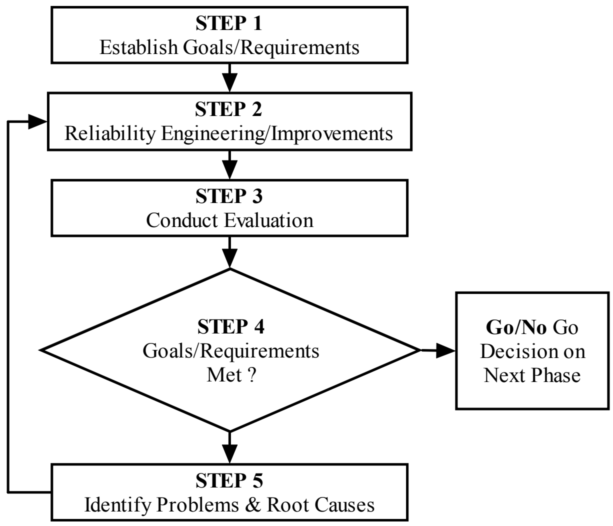

Fig.1. The reliability improvement process

2. CONTENT

2.1. Establish reliability goals and requirements

For this first step is important to make a distinction between goals and requirements. Goals are more internally driven and may or may not be met. Requirements, on the other hand, are more specific and are customerdriven.Requirements are usually included as deliverables in contractual agreements. Goals (see the figure 2) are the starting point, but are modified to satisfy customer requirements early in the equipmentlife cycle. All goals have certain common characteristics. The following criteria can be used to assist in establishing goals:

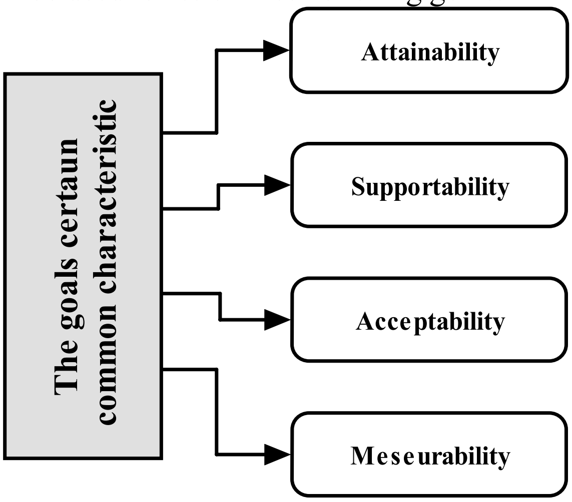

Fig.2. The reliability goals

- *Attainability:* Goals should be set atlevels reasonably attainable within the available time span. Large goals over long periods should be avoided to maintain interest and commitment. Sub goals over shorter times are more attainable and more cost effective
- *Supportability:* Support and resources must be available at the time they are needed to achieve goals. Advance planning is needed to determine the resources and the extent to which they can or will be provided.
- *Acceptability:* Goals must be acceptable tothose who will be actively involved in pursuing these goals. Acceptance is influenced by relevance, perceived importance, reasonable-ness, and desirability of outcome.
- *Measurability:* Goals provide standards against which performance may be assessed and, therefore, should be selected for suitability and defined in a way that enables measurement.

To make them measurable, goals must be defined qualitatively, quantitatively, and in terms of performance parameters, values, and time scales.

2.2. Reliability engineering and improvements

Once goals and requirements have beenestablished, design-for-reliability practices, or reliability improvement activities are applied to enhance the reliability of equipment that is in any phase of the life cycle, or for equipment already in existence.

There are some basic practices that can be applied to improve reliability (see figure 3). These include:

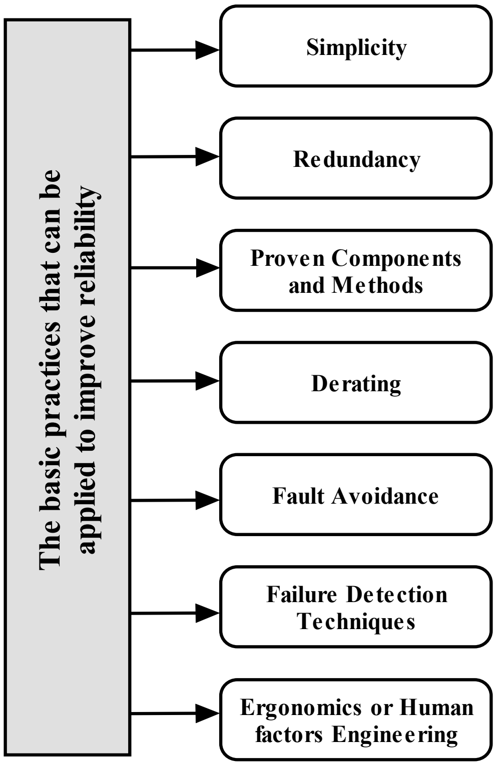

Fig. 3. The basic practices that can be applied to improve reliability

- *Simplicity.* Simplification of equipment configuration is one of the basic principles of designing-for-reliability. Added parts or features increase the number of failure modes. A common practice in simplification is referred to as component integration(the use of a single component to perform multiple functions).
- *Redundancy.* Another reliability improve-ment practice is to include more than one way to accomplish a function by having certain components or subassemblies in parallel, ratherthan in series. Beyond a certain point, redundancy may be the only cost-effective way to design reliable equipment.
- *Proven Components and Methods.* To the extent possible, designers should use components and methods that have been shown in similar applications. Using proven compo-nents can minimize analyses and testing to

verify reliability, thus reducing time and costs of demonstrating reliability of the equipment.

- *Derating* is the practice of using components or materials at environmental conditions or loads that are less severe than their limiting condition. Under these conditions, the component or material is expected to be more reliable.
- *Eliminating Known Causes of Failure (Fault Avoidance).* This can be accomplished through screening and burn-in procedures to eliminate weak components before equipment is actually shipped to the customer.
- *Failure Detection Techniques*. Reliability of equipment can be improved by incorporating failure detection methods or self-healing devices such as periodic maintenance schedules, monitoring procedures, automatic sensing and switching devices.
- *Ergonomics or Human Factors Engineering*. The activities of humans can be very important to equipment reliability. The equipment design must consider human factors aspects such as the person-machine interface, human reliability, and maintainability.

2.3. Conduct evaluation

The next step in the reliability improvement process is to conduct an evaluation of the equipment or equipment design to assess its reliability level. A powerful tool for conducting this evaluation is *reliability modeling*.

For equipment in the early phases of the life cycle, reliability modeling can be used to predict the equipment's performance to provide information for design changes or for evaluating design alternatives.

For equipment that is already in production or is operational in the field, reliability modeling, combined with testing and failure data analysis, can be used to identify critical components and help guide resource allocation and reliability improvement decisions.

There are a number of reliability prediction models (see figure 4). These include:

- *Block diagram models*. A block diagram is used to logically represent the equipment being modeled by breaking it down into subsystems and components. Equipment reliability is modeled using failure data on the subsystems and components.
- *State transition (Markov) models*.

Equipment reliability is modeled by identifying the various operating conditions (states) that the equipment, subsystem, or component can experience, and the probability of transition from one state to another.

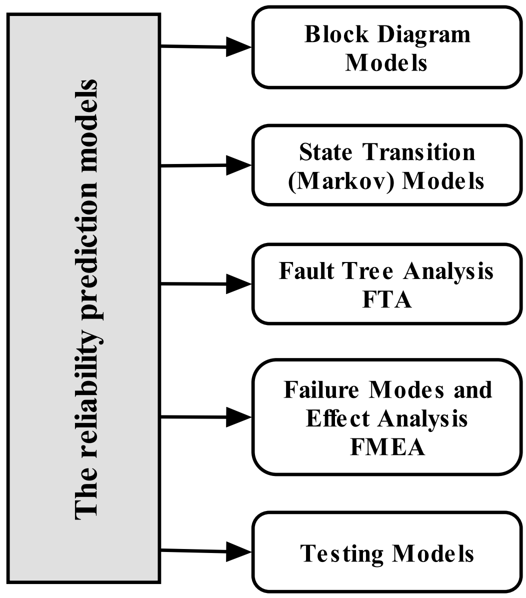

Fig. 4. The reliability prediction models

Other techniques for evaluating equipment reliability and identifying design weaknesses include:

- *Fault tree analysis (FTA).* A "top down" approach beginning with an undesirable event (usually equipment failure) at the top or system level and identifying the events at subsequent lower levels that can cause the undesirable top event.
- *Failure modes and effects analysis (FMEA).* A technique for systematically identifying, analyzing, and documenting the possible failuremodes within a design and the effects of such failures on equipment performance.

Testing is another tool for evaluating equipment reliability. Typically, three different categories of testing are applied:

1. *Component tests* - useful in flushing out basic weaknesses in critical components
2. *Systems tests* - intended to explore effects of component interactions
3. *Reliability demonstration tests* - used to demonstrate equipment capability

2.4. Are goals and requirements met?

Results of the evaluation process are compared to reliability goals and requirements. If goals and requirements are not met, the problems and root causes should be identified as described in Step 5, and reliability improvement activities should be initiated.

If goals and requirements are met or exceeded, then approval can be given to move to the next phase of the life cycle, or goals and requirements can be updated and additional analyses carried out. For example, if the equipment is in the concept and feasibility or design phase of the life cycle, *sensitivity analyses*(see figure 5)can be conducted to evaluate design and cost trade-offs.

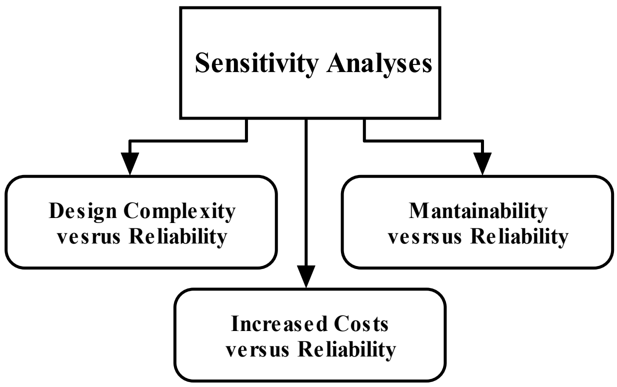

Fig. 5. The sensitivity analyses

If goals are, or can be exceeded by a significant margin, then the supplier should capitalize on the situation by turning it into a competitive leadership position. Upon completing design trade-off studies, approval can be given to move to the next phase of the equipment life cycle where the reliability improvement process is again initiated.

2.5. Identify problemsand root causes

If reliability goals and requirements are not met, the reasons need to be identified and corrective actions should be taken. Test data on prototypes or actual equipment in the field can be used to supplement information on equipment reliability generated from predictive modeling. Testing can also help to identify causes of failure and any potential reliability problems.

A key tool useful for reporting and analyzing failure data is the *failure reporting, analysis, and corrective action system (FRACAS).* Test data and all reported failures should be investigated to verify that a failure occurred.Failure verification can be performed by subjecting the component to the same conditions as those reported when the "failure" occurred.

The reliability improvement process now returns to Step 2, where reliability improvement and growth activities are initiated, or upgrades and modifications to reliability goals and requirements are made. Reliability growth activities generally fall into the following major categories (see figure 6):

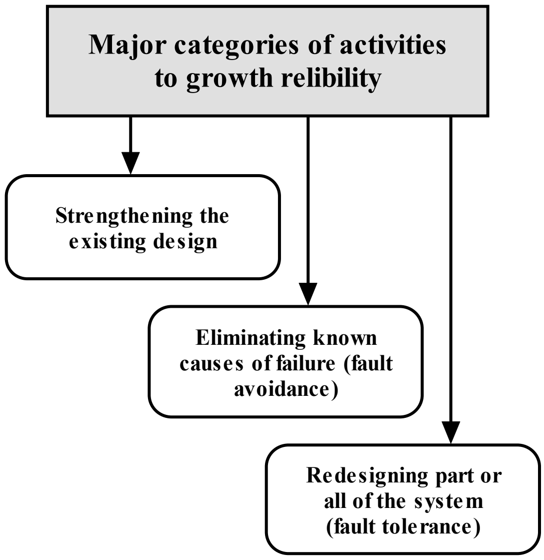

Fig. 6. The sensitivity analyses

- *Strengthening the existing design*, by testing or modeling (or both) to identify optimal design changes to improve reliability. The process ofidentifying weak areas can be aided by performing sensitivity studies using the reliability model of the system.
- *Redesigning part or all of the system (fault tolerance)*, which includes studying ergonomic–enhancing software, adding redundancy, and incorporating error detection techniques.
- *Eliminating known causes of failure (fault avoidance)*, which includes using screening and burn-in procedures to eliminate weak components, and using more reliable parts.

Steps 2 through 5 repeated until goals and requirements met. The process may require several cycles of goal setting, evaluating, comparing, and improving. Approval can give to move to the next phase of the life cycle, where the reliability improvement process is again applied.

3. APPLYING THE RELIABILITY IMPROVEMENT PROCESS

Optimal benefits from use of the reliability improvement process are clearly realized when the process is applied to equipment in the concept and feasibility phase of the life cycle and then continuously applied thereafter.

Benefits can also be realized when the improvement process is applied to equipment that is in some advanced phase of its life cycle. It is important to address equipment reliability throughout the life cycle. For example, reliability improvements may be necessary:

- *Following the Prototype Phase*, because of design deficiencies or parts problems uncovered during prototype testing
- *Beginning the Pilot Production Phase*, due to reliability related issues resulting from manufacturing a new equipment line
- *During the Production and Operation Phase*, because feedback from field personnel and customers indicate reliability problems due to unanticipated failure mechanisms.

4. ACTIVITIES

Activities associated with applying the reliability improvement process to the equipment life cycle remains basically the same from one phase of the life cycle to the next.

Fig. 7. The activities of the Concept & Feasibility macro-phase

Others, however, vary because of the change in focus from phase to phase. For example, focus in the concept and feasibility macro phase is primarily on "planning and allocating;" focus in the design and development macro phase is primarily on "predicting and verifying;" and focus in the production and operation macro phase is primarily on "evaluating and improving."

The activities also vary depending on whether the improvement process has been continuously apply to equipment as it moved through its life cycle from concept and feasibility to phase out, or whether it is being applied for the first time to equipment that is in some advanced phase.

For example, consider equipment in the prototype phase: If the reliability improvement process has been applied continuously to the equipment in the concept and feasibility phase and in the design phase, then the reliability goals and requirements already exist. Thus, the reliability goals and requirements activity consists, primarily, of updating the goals and requirements; the primary focus would be on prototype testing and corrective action activities.

Fig. 8. The activities of the Design & development macro-phase

However, if the reliability improvement process was applied to equipment for the first time during the prototype phase, then developing reliability goals and requirements should be a major focus because these goals and requirements do not exist.

Figures 7, 8 & 9 provides a high-level view of the main activities associated with applying the reliability improvement process to each of the three macro phases of the life cycle. This is provided primarily to illustrate the flow from one macro phase to the next. Some of the activities will vary as the reliability improvement process is tailored to a particular need or equipment line. However, the reliability improvement process remains unchanged.

Fig. 9. The activities of the Production & Operation macro-phase

4. CONCLUSION

The reliability improvement process can be apply continuously as equipment moves through its life cycle phases. Activities associated with applying the process may vary as the equipment moves from one phase of the life cycle to the next. This variation results from a change in focus from phase to phase, and from the fact that an activity performed in one phase lays the foundation for activities in subsequent phases.

Activities will also vary depending on whether the improvement process is applied continuously as equipment moves through its life cycle (from concept and feasibility to phase out), or whether it is applied for the first time to equipment that is in some advanced (other than concept and feasibility) phase.

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Procesul de îmbunătățire a fiabilității echipamentelor de automatizare

Rezumat: Lucrarea încearcă să aprofundeze problematica îmbunătățirii fiabilității echipamentelor din domeniul automatizărilor industriale, prin aplicarea continuă, pe toată durata ciclului de viață, a măsurilor celor mai adecvate. Cunoaşterea foarte bună a ciclului de viață a unui produs este importantă deoarece aceasta asigură o bază de înțelegere asupra modului cum pot fi aplicate măsurile de creştere a fiabilității pe toate fazele, de la concept şi fezabilitate, la design şi dezvoltare şi până la fabricație şi operare. Ciclu de viață este departajat în faze distincte, fiecare reprezentând o secvență unică a vieții echipamentului. Aceste faze asigură cadrul urmăririi fiabilității şi cunoaşterea momentului şi modului de aplicare a măsurilor de îmbunătățire a fiabilității.

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