Indian National Society for Aerospace and Related Mechanisms
BANGALORE CHAPTER

E-Newsletter
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From the Editor

My Dear Colleagues,

I am delighted to share with you a glimpse into the amazing work being done by our esteemed colleagues and members of the INSARM Bangalore Chapter. Importance of reliability, especially for the aerospace systems, cannot be overemphasized; each component is critical but must be designed within the utmost constraints on resources. We are thankful to Mr. Sujithkumar for his contribution for understanding the reliability issues for mechanical systems in space.

In last few months, INSARM Bangalore Team organized several online events on diverse topics of relevance that includes two technical talks by leading experts for knowledge dissemination, a half-day seminar for knowledge upgradation and three webinars for familiarization with advanced software tools. Many of you attended and directly benefited. Let us all thank the concerned team for the meticulous organization of the events. Glimpse into the events through pictures is included in this edition of the Newsletter.

Please share with us your special achievements and brief story of any interesting result from your work to let all the members know through this newsletter. We would like to share more of your stories through this medium.

Please go through it and let us know how you liked it!

With best regards,

Prof. Dibakar Sen,
Professor, CPDM, IISc-Bangalore
Chief Editor

CONTENTS

Quote:

"All knowledge that the world has ever received comes from the mind; the infinite library of the universe is in our own mind''

Swami Vivekananda

FROM INSARM BANGALORE CHAPTER

Reliability of Mechanical Systems used in Space

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Introduction

Reliability requirements of aerospace systems are of higher order since they are non-repairable (in case of spacecrafts) and involve human life (in case of aircrafts). Any failure of Spacecraft/Aircraft will result in huge loss, both financial and reputational, to the organization. Successful performance of aerospace mechanisms throughout the designed life is essential for successful operation of a Spacecraft/Aircraft. Reliability management for aerospace systems includes specifying reliability requirements, incorporating them in design, realizing the system and operating it as designed for full life. This article briefly cover activities carried out as part of reliability management.

As specified by the customer, designers consider reliability as one of the design objective and strive to achieve it. Reliability specification, allocation, component selection, optimization, testing and analysis of field failures are major activities carried out to ensure system reliability. Knowledge of failure theories, loading patterns and operating environment give insight to designers for designing a reliable system. Mathematical theory of reliability provides theoretical method to quantify system reliability from component failure data and system architecture.

Definition: Reliability (R) is the ability of a system to perform its intended function during its designed life. It is expressed as probability (of not failing) with a defined confidence level (1-α) for useful life (α is significance level and (1- α) is corresponding confidence level).

Reliability specification

Reliability specification originates from the customer requirements and constrains like life (how long the system is expected to operate), availability, cost, space occupied, mass, operating environment. For example space systems may not be repairable, medical equipments cannot fail during surgery, mass or volume of the systems cannot be more than the capacity of vehicle used for carrying it like rockets or helicopters, systems have to work under sever environment conditions etc. Typical reliability specification for satellites is R=0.75 with confidence level of 0.6 for 15 years of life.

Allocation of Reliability

Reliability allocation is the process of assigning reliability of sub-systems/sub-assemblies and components to meet reliability specification of the system. Allocation depends on the system configuration represented by reliability block diagram (figure1), component failure rates and other constrains like cost, mass etc.

Components or parts selection should address the uncertainties related to estimated load, material properties, geometry, manufacturing process, stress concentration, assembly operation etc. Any difference between test specimen and test environment with actual component and operating environment shall be accounted. Failure rate of components shall be estimated by life tests. Frequency of scheduled repairs and system availability depends on these failure rates. Burn-in or proof loading shall be carried out to weed out defective components from assembly.

Qualitative Techniques in Reliability Analysis

Failure Mode Effects and Criticality Analysis (FMECA), Event Tree Analysis (ETA) and Fault Tree Analysis (FTA) are qualitative techniques used in evaluating a design. In FMECA, possible component failure modes are listed along with its effects and criticality. It is carried out from initial stages of design and information obtained is used to account for failures (through margins, redundancy etc.) in the product. ETA lists events, both success and failure. FTA collects all failure events from ETA and tracks them to the lower level events through sub-assemblies to components. Inputs from these studies will be valuable in establishing cause effect relations in future failures.

Reliability Modeling

A system is called a series system if failure of any component in the system causes system failure. If systems failure requires failure of all the components it is called parallel system. If failure of k components required for failure of the system with n components, it is called k out of n systems. A system that cannot be represented in the above manner is called complex system and can be modeled using cut-set method. Reliability of series systems (R_s) and parallel systems (R_p) with component reliabilities R_1 and R_2 are given by

$$R_s = R_1 R_2$$

$$R_p = 1 \quad (1 \quad R_1)(1 \quad R_2)$$

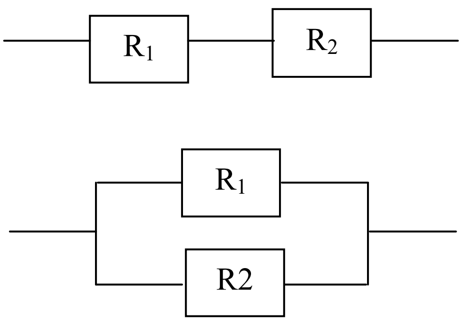


Figure 1: Block diagram representation of series and parallel systems.

If $R_1 = 0.9, R_2 = 0.9$ then $R_s = 0.81$<R_p=0.99, which implies that with no other factors affecting (like reliability of switching) and component reliability remains the same, parallel systems give better reliability than series systems.

Reliability of k out of n systems is given by

$$R_{(k,n)} = 1 \quad \sum_{i=k}^{n} \binom{n}{i} [1 \quad F(t)]^i \, [F(t)]^{n-1}$$

With $f_k(t) = \frac{dF(t)}{dt}$, where $f(t)$ and $F(t)$ denotes the probability density function and cumulative distribution function respectively of the failure time of the components.

Enhancement of reliability

Increasing reliability by redundancy or increasing margin is limited by constrains like mass, space or available power. Reliability of switches comes in to play when cold redundancy is introduced. For a mass (M) hanging in a wire rope, margin can be increased by increasing diameter of the wire rope. As we increase the diameter of the wire rope its mass (m) increases. If M and m are comparable, margin starts decreasing at some point. Above factors necessitates optimization of reliability of the system with respect to relevant constrains.

Reliability Demonstration

Reliability is demonstrated by planned testing and field data. Study of field failures will reveal operational environment and operational modes not envisaged in the design and resulting failure modes that are not addressed during design. Failure data from reliability tests and field failures are feedback for designers.

Failure test data is represented by Bath-tub curve (plot of hazard rate i.e. instantaneous failure rate against time). Initial part of decreasing failure rate is called infant mortality (where defective component fails), middle part with constant failure rate where only random failure occurs is called useful life and third part of increasing failure rate is called wear out period. Techniques like proof loading and burn-in are used to identify and eliminate defective components. Useful life starts after this elimination and failure in useful life is assumed due to random causes. Failure data can be modeled using distributions like exponential, weibull etc.

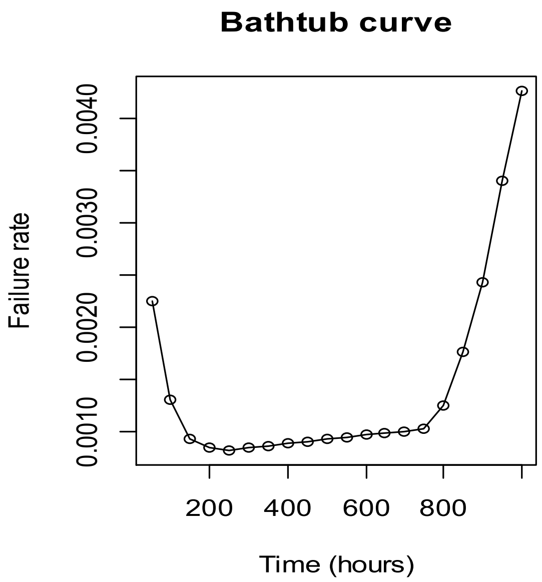


Figure 2: Bathtub curve from reliability test data*

Reliability of the component or system at time t is given by

$$R(t) = \frac{N_s(t)}{N} = 1 \quad \frac{N_f(t)}{N}$$

Where $N_s and N_f$ are number of working and failed components respectively at a given time during testing of Ncomponents. Modeling useful life using exponential distribution (assuming constant failure rate λ), the reliability at time t will be given by

$$R = e^{-\int_0^t \lambda t} dt$$

One-shot devices (systems like missiles, deployment mechanisms, pyro devices) that act once can be modeled by binomial distribution. Non parametric binomial model for one-shot device test data is

$$1 \quad CL = \sum_{i=0}^{f}(1 \quad R)^i R^{n-i}$$

Where CL is confidence level, f is number of failures, n is sample sizes or number of tests and R is reliability. The above equation reduces to $1 \quad CL = R^n$ when no component fails in the test.

With CL= 0.6 (60% confidence level) number of continuous successful tests required to demonstrate R=0.999 is 912 (CL=0.95, n=2980).

Stress-strength interference theory can be used when reliability is modelled as strength greater than load. Suitable distribution of strength (normal, log-normal, weibulletc.) and load can be used after testing data against distribution. Empirical distributions can be used in case of no standard distribution match with data.

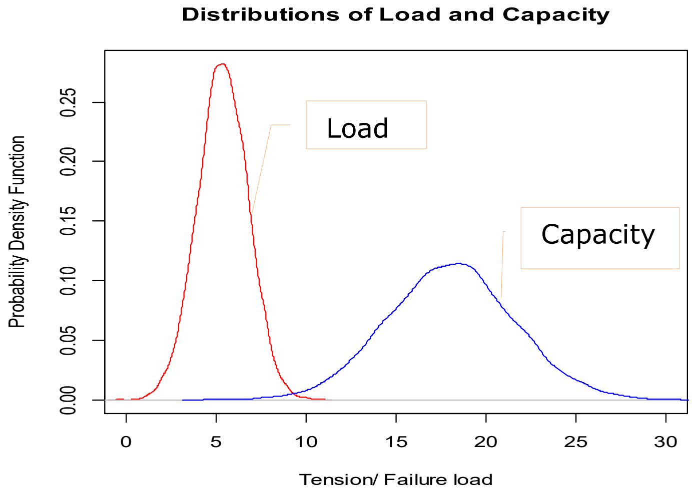


Figure3: probability distribution of load and capacity

If L, S and R represents load acting, strength (capacity) and reliability of the system respectively and $f_L(L)$, $f_S(S)$are probability density function ofS & L, then reliability is given by$P(S \quad L > 0)$.

Conclusions

- Reliability management of aerospace mechanical systems are crucial throughout the life of Spacecraft/Aircraft.
- Reliability requirements shall be stated clearly and converted to specifications.
- Reliability allocation, from subsystems, sub-assemblies to components shall be carried out to meet reliability specification.
- Design shall be studied and analyzed to identify failure modes and failure events and measures to mitigate them shall be addressed in the design phase.
- Reliability shall be modeled and optimized for parameters like cost, weight, power, time etc.
- Reliability shall be demonstrated through reliability tests and field data.

References:

[1] Reliability Engineering, S.S Rao, Pearson Education Inc.

Highlights of Activities of INSARM - Bangalore Chapter

The INSARM - Bangalore Chapter has been actively involved in promotion of the Aerospace mechanism through technical talks and webinars. The chapter hosted 2 Technical Talks and a Webinar since Sept 2021. The technical talks and seminar were conducted in online mode. The following Table provides details of the Technical Talk organised by the chapter.

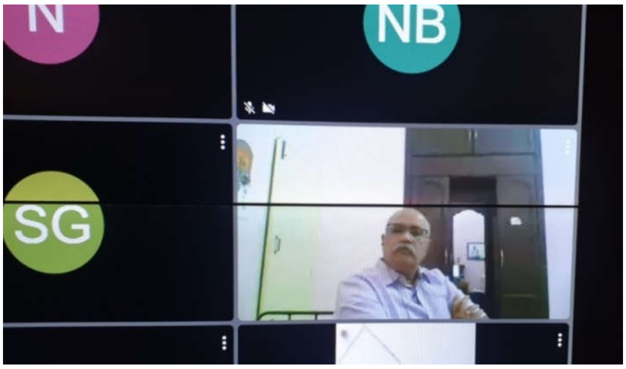
No	Date	Speaker	Topic
1	16-Sept-2021	Shri. S Shankar Narayan Former Division Head, Experimental Structures Division, Structures Group, URSC, ISRO	Dynamic Testing of Spacecraft Mechanisms
3	28th Mar 2022	Prof. Anindya Deb Centre for Product Design and Manufacturing Indian Institute of Science	Simulation of Real-world Engineering Systems using Explicit Dynamic Analysis

The Chapter also organised a half day seminar in Web mode on the Topic "Optimal Design of Mechanisms using Computer Aided Analysis". As part of the webinar, 3 sessions were organised where in experts from industry in the field of Computer aided analysis spoke about multi-body dynamics simulation, design optimisation using FE and simulation and design of light weight mechanisms. More than 75 members of the chapter from various parts of the country attended the webinar and got benefitted.

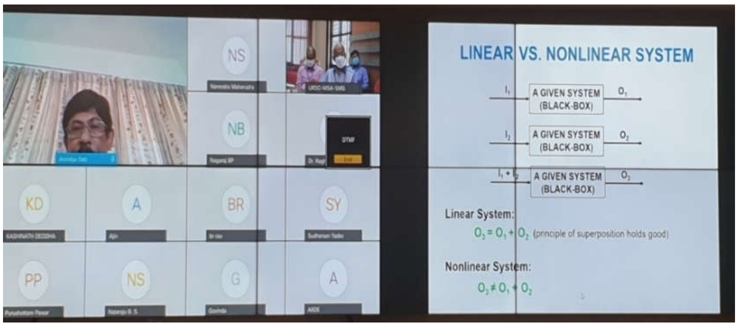
Webinar on Optimal Design of Mechanisms using Computer Aided Analysis Date : 24-Nov-2021		
Session-1	Shri. Karthik Y R Sr. Technical Manager- Technical Simulations, M/s SOLIZE India Technologies Private Limited, Bangalore	Design of Experiments in Multi-body Dynamics Simulations using ADAMS INSIGHT
Session-2	Shri. S Balaji Country Manager-Technical Simulations, M/s SOLIZE India Technologies Private Limited, Bangalore	Design Optimisation using MSC Nastran
Session-3	Mr. Prakash Pagadala, Mr. Ranjit Gopi Industry Process Consultants, Dassault Systems India	Realistic Simulation to design light-weight & durable mechanisms using Dassault Systems SIMULIA Solutions

Photos of Technical Talk organized by INSARM-BC

1. Shri. S Shankar Narayan delivering talk on Dynamic Testing of Spacecraft Mechanisms



2. Prof. Anindya Deb's technical talk on Simulation of Real-world Engineering Systems using Explicit Dynamic Analysis



3. Webinar on Optimal Design of Mechanisms using Computer Aided Analysis

Overview of National Conference and Exhibition on ARMS -2021

The 12th National Conference and Exhibition on Aerospace and Defence Related Mechanisms (ARMS-21) was held during 02-04 December 2021 at Armament Research and Development Establishment (ARDE), DRRO, Pune. The conference was attended by members of INSARM and experts working in the area of aerospace mechanisms. The conference kick started with a session of Tutorial in the morning of 2nd December 2021. The tutorial benefited lot of budding young Engineers who are eager to make a career in the field of Mechanisms.

The conference was inaugurated on the evening of 2nd December 2022. Dr. V Venkateswara Rao, President INSARM delivered the welcome address followed by address by Shri P K Mehta, DS & DG (ACE), DRDO and address by Dr. C P Ramanarayanan, VC, DIAT, Pune. Dr. G Satheesh Reddy, Secretary, DD (R&D) & Chairman, DRDO was the Chief Guest of the event. Dr. V K Sarawat, Member NITI Aayog, Govt. of India was the Distinguished Guest. Shri. S Somnath, Director, VSSC (Presently Secretary, DOS/Chairman-ISRO) delivered the Key Address on the occasion.

INSARM recognised several of the contributors in the field of Aerospace Mechanisms during the ARMS Conference. Shri. N. Viswanatha, Former Group Director, Spacecraft Mechanisms Group was awarded with Life Time Acheivment Award-2021. Shri. Phani Dinakar B S, Scientist/Engineer-SE of Spacecraft mechanisms Group, URSC received the Young Scientist Merit Award for the year 2021. Shri. M V Ramakrishna, Retired Scientist/Engineer-SG, Spacecraft Mechanisms Group, was felicitated for the immense contribution towards the realisation of spacecraft Mechanisms.

Inauguration of ARMS-2021 Conference   Keynote Address by Shri. S Somanath

Shri. N Viswanatha Receiving the INSARM Life Time Achievement Award-2021

Shri. M V Ramkrishna being felicitated during ARMS-2021 Conference

Shri. Phani Dinakar. B S receiving Young Scientist Merit Award-2021

Invitation for Active Participation

We invite you to send technology news, technical articles, members' news and suggestions/comments on e-newsletter and the web contents to Chief Editor to improve the newsletter. The technical articles may be limited to 400 words only in MS Word format with two photographs. The direct extracts from references may be avoided. Kindly provide your e-mail & mail address to enable us to contact you.

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