Issue 7 January 2013

SFA Newsletter

HAPPY New Year!

About SFA

Objectives

Local centers

Welcome you all to join as members of SFA! Please find the membership form inside; kindly fill in and contact Secretary of SFA through email.

Experts and experiences:

- Prof. Suhas Joshi, IIT, Bombay
- Sri.P.Jayapal, CEMILAC, Bangalore

Message from our President

Dear readers,

I wish all of you all the very best on the dawn of New Year 2013! I am sure that you may find the seventh issue of SFA newsletter useful as you observe and appreciate some of the experiences narrated by the experts in the rare fields like machinability issue and quality-demands in aero sector worth reading.

It is appreciated that the local centres of SFA convene one-day meetings sharing valuable expertise to younger generations. It is my humble appeal to all my members to nurture brotherhood and revelry towards one another.

While you appreciate that our professional work involves one who produce and one who consume, I call your attention to a saying that: Important lessons of the past may steer us to win-win situations in the year ahead!

Best wishes to all the readers!

K.Tamil Mani
PRESIDENT, SFA

Edited by: Dr.T.Jayakumar & Dr.P.Parameswaran, Metallurgy & Materials Group, IGCAR, Kalpakkam

“

From the Desk of Editors

Happy New Year 2013! It is indeed nostalgic to look back when you browse through the seventh issue of the Newsletter of Society for Failure Analysis (SFA). Our efforts to build the society have seen progressive growth with the conduct of several activities by our local centres at various places. The centres have started organizing their own general body meetings which is a sign of autonomy that has evolved among local centres.

In this issue, we solicited articles from experts in the rare area of machinability on the one hand and another from a quality conscious field of aero sector.

We thank the authors for their contributions which are worth their efforts.

We take this opportunity to appeal to the Indian industry to use SFA as a forum to share their experiences on trouble shooting. A great way to add content to this newsletter is to include a calendar of upcoming events. The details of important forthcoming international and national events are included; so also the books recently published on the topics of the subject.

We value your comments, which really boost our enthusiasm to perform better. Therefore, as always, your views and comments, mailed to tjk@igcar.gov.in or param@igcar.gov.in are welcome. We wish you all free from failures and a joyful life!

You may visit our web site for your comments/suggestions or any queries : www.sfaindia.org

Kalpakkam (T.Jayakumar)
31-01-2013 (P .Parameswaran)
Editors

We encourage you to join the society, Kindly fill up the application form (enclosed at the end of the newsletter) and contact secretary: pjayapal59@yahoo.co.in; alternatively, post your application with draft to Dr N.Eswara Prasad, Regional Director, ***RCMA,*** *CEMILAC, Kanchanbagh, Hyderabad, 500 058*

About the society

Aims and Objectives of Society for Failure Analysis

The aims and objectives of the Society shall be:

To serve as National Society to promote, encourage and develop the growth of "Art and Science of Failure Analysis" and to stimulate interest in compilation of a database, for effective identification of root causes of failures and their prevention thereof.

To serve as a common forum for individuals, institutions, organizations and Industries interested in the above.

To disseminate information concerning developments both in India and abroad in the related fields.

To organize lectures, discussions, conferences, seminars, colloquia, courses related to failure analysis and to provide a valuable feed back on failure analysis covering design, materials, maintenance and manufacturing deficiencies / limitations.

To train personnel in investigation on failures of engineering components and their mitigation.

To identify and recommend areas for research and development work in the Country relating to failure analysis.

To establish liaison with Government, individuals, institutions and commercial bodies on failure analysis, methodologies and to advise on request.

To cooperate with other professional bodies having similar objectives.

To affiliate itself to appropriate international organization(s), for the promotion of common objectives and to represent them in India.

To organize regional chapters in different parts of the country as and when the need arises.

To do all such other acts as the Society may think necessary, incidental or conducive to the attainment of the aims and objectives of the Society.

Know your local centers

Never worry about the delay of your success compared to others, because construction of a palace takes more time than an ordinary building.

FAILURE ANALYSIS IN AVIATION

P. Jayapal
CEMILAC, Bangalore

INTRODUCTION:

Failure in engineering is defined as inability of a system or component to perform its intended function. When one considers thousands of components which are fabricated and placed in service, it is not unusual to expect that some of them will fail prematurely. Simply from statistical view point it is not reasonable, with the present engineering practices, to expect NO FAILURE. However, even though the number of failures of a particular component may be small, they are important because they affect manufacturer's reputation for reliability.

In some cases, particularly when failure results in personal injury or death it leads to expensive law suits. It is not unusual for aerospace industry under prodding from users to recall hundreds of aircrafts/components to correct a design or manufacturing defect even though the actual number of failures is very small. Hence failure investigation and analysis plays a vital role in aviation.

INCIDENT/ACCIDENT INVESTIGATION:

Whenever an aircraft or helicopter meets with an incident or accident, identifying the root causes of the incident or accident by a team of specialist is mandatory in aviation industry. The causes of the incident or accident could be one or more of the following:

- Failure of a vital component/system
- Inadequate design
- Wrong assembly of parts
- Pilot error
- Bad weather
- Sabotage
- Change in operating environment
- Improper/poor maintenance of the aircraft/helicopter

There are various methodologies being followed by the experts in identifying the most probable causes for the incident/accident, and evolving suitable remedial measures for implementation to stop recurrence of such failures in future.

FAILURE INVESTIGATION:

In case of an incident or accident occurred due to failure of a vital part/component /system, failure investigation and analysis play a vital role. In any failure analysis, it is important to get as much information as possible from the failed component itself along with an investigation of prevailing conditions at the time of failure.

The general questions asked during the course of investigation/analysis are:

"Success is no accident. It is hard work, perseverance, learning, studying, sacrifice and most of all, love of what you are doing or learning to do- *Pele*

- How long the part/component/system was in service
- Was the part/component properly assembled and maintained
- What was the nature of stresses at the time of failure
- Was it subjected to any in-service abuse
- Whether the correct/specified material was used or not
- Whether correct manufacturing and heat treatment process was followed or not
- Was there any manufacturing deviation on the part
- Was there any change in the operating environment

Identifying answers to all these questions and required laboratory studies would reveal the most probable cause of the failure of the part/ component/system.

CORRECTIVE ACTION:

In aviation industry it is important and mandatory to evolve and institute corrective /remedial measures to avoid recurrence similar failures in future once the most probable causes for the incident or accident are identified. In case of a failure of part/component/system, recurrence of similar failure can be avoided by one or more any of the following:--

- Change of design of the failed part/component/system
- Change of material
- Change of manufacturing/heat treatment processes
- Following correct assembly procedure etc.,

Under these circumstances, it is very important to identi the service and kept on ground without flying till the affected part/component/system flying is replaced with a serviceable part manufactured as per the above corrective measures. By this, it is assured that the aircraft/helicopters is fully serviceable and airworthy and can be released for further flying/use. In some cases, the affected aircrafts/helicopters are withdrawn from the service in a phased manner depending upon the criticality of the failure and action required thereafter.

CONCLUSION:

In any system, failure is inevitable. However, it should be contained/ avoided. Failure Analysis plays an important role in this regard. Systematic methodology of failure investigation and analysis is being followed in the aviation industry in respect of investigation at component level, system level, aero engine level and aircraft/helicopter level. To identify the root cause of the failure of the components, sophisticated equipments and the knowledge of the experts for interpreting the results are very much essential. By pooling all the data related to failure analysis and precautionary measures available and following the same during the design and manufacturing stage, failures in any system can be minimized.

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Tool Wear in Machining of Titanium Alloys: A Review

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India

Change means movement. Movement means friction. Only in the frictionless vacuum of a nonexistent abstract world can movement or change occur without that abrasive friction of conflict- Saul Alinsk

1. Introduction

Titanium alloys have wide applications range in aerospace, chemical and medical industries due to high strength-to-weight ratio, corrosion resistance, and ability to maintain strength at high temperature. However, major challenge faced by these industries is to minimize the tool wear that occurs during machining of titanium alloys. The properties of titanium alloys that cause high tool wear are its poor thermal conductivity, low modulus of elasticity, chemical affinity with tool material and strength at high temperature [1, 2]. These properties introduce several difficulties in machining of these materials. For example, poor thermal conductivity causes accumulation of heat at cutting edge, low modulus of elasticity induces chatter during machining and chemical affinity of titanium adversely affects the strength of tool material. Also, the ability to maintain strength at high temperature causes relatively large magnitude of cutting forces. Therefore, titanium alloys are usually classified as 'difficult-to-cut' materials and extensive research is carried out to improve their machinability.

This article presents an overview of important tool wear mechanisms that prevail in machining titanium alloys. It also dwells upon the influence of machining environment on tool wear and methods to improve the tool performance. Finally, recommendations to reduce tool wear have been presented.

2. Tool wear mechanisms in machining of Ti-alloys

These mechanism are summerized in Table 1. There are five main mechanisms of tool wear that usually prevail in machining of titanium alloys. Thease are-

***a*. Abrasion** : It involves removal of grains from tools by adhering chips or work piece. It occurs both on rake face and flank face, see Table 1. This wear intensifies with the passage of time and causes serious damage to the tool cutting edges [3].

***b*. Adhesion**: Due to seizure at

The best and most beautiful things in the world cannot be seen, nor touched, but are felt in the heart.
- Helen Keller

work-tool interface, a strong bond between chip and tool gets formed. The adhered chip material gets removed during cutting process but in the process, removes a portion of cutting tool material with it [4], see Table 1.

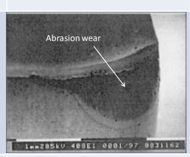
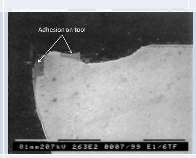
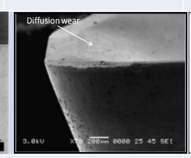
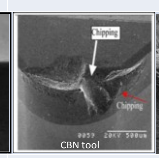
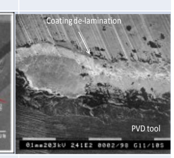
c. **Diffusion**: High tool work temperature and severe contact between tool-chip provide ideal conditions for diffusion of atoms from tool material. Diffusion of cobalt atoms reduces the bonding strength of carbide tools thereby causing accelerated crater wear on the tool face [3].

d. **Chipping and fracture**: High temperature and stresses at the chip-tool interface combined with brittleness of tool causes this kind of wear. Many a time, an increase in rake face wear leads to chipping and fracture [2], see Table 1.

***e*. Coating de-lamination:** It is the initial tool wear observed mainly on the rake face which is followed by the flank and rake face wear. It is attributed either to chemical reaction or the crack propagation at the interface due to difference in thermal coefficient of expansion between coating matrix and substrate. Smaller de-laminations are observed in CVD coated tools due to greater adhesion of these coating [4], see Table 1.

The tool wear mechanisms described above are further explained with reasons for wear, typical figure, cutting tool material and processing parameters in Table 1.

Table 1 Various tool wear mechanisms in machining of titanium alloys

Tool wear mechanisms in titanium alloys					
Tool wear	Abrasion	Adhesion	Diffusion	Chipping and fracture	Coating de-lamination
Reasons	• Presence of hard particles in work •Irregular material flow past the cutting edge at low cutting speed • Built up edge formation at the cutting edge. It is dominated at flank face and nose.	• Seizure of chip with the rake face due to high temperature and pressure. •Thermal softening at high temperature increases this wear. It is dominated on the rake face	•Higher cutting speed causes increased temperature at rake face and gives rise to smooth dissolution-diffusion wear. •Diffusion of cobalt and tungsten atoms on the chip shows this kind of wear	•Existence of high temperature and stress at the cutting edge coupled with brittleness of material causes chipping •Poor chip-groove utilization and a very sharp cutting edge	• Work-tool interface temperature activates chemical reaction of coating with substrate, •Crack at interface of coating and substrate causes this kind of wear
Typical photo-graphs					
Titanium alloy	Ti6Al2Sn4Zr6Mo	Ti6Al4V	Ti6Al4V	Ti6Al4V	Ti6Al4V
Machining parameters	Turning operation, surface speed 60-100 m/min, feed rate 0.25 and 0.35 mm/ rev, depth of cut 2mm, dry machining.	Face milling, cutting speed 55-100 m/min, feed 0.1.0.15 mm/tooth, axial and radial depth of cut 2mm and 58 mm respectively. Coolant-Hocut-808 6-7% concentration	End milling, cutting speed for carbide insert 40-120 m/min. For PCD insert 120 to 250 m/min, axial depth of cut 1 mm and feed 0.1 mm per tooth. Full immersion cutting.	Turning operation, cutting speed 150-250 m/min depth of cut, 0.5 mm feed rate 0. 15 mm/rev. Conventional coolant flow	Face milling, cutting speed 55-100 m/min, feed 0.1.0.15 mm/tooth, axial and radial depth of cut 2 mm and 58 mm respectively. Coolant-Hocut 808 6-7% concentration
Tool material	Carbide insert CNMG 120408-890, CNMG 120408-883	Coated carbide tool with coating of PVD + TiN and CVD + TiCN / Al2O3	Uncoated carbide inserts R245-12-T3K-MM2030, PCD inserts R245-12-T3E-CD10	CBN and uncoated carbide tool	Coated carbide tool with coating of PVD + TiN and CVD + TiCN / Al2O3
References	[3]	[4]	[5]	[2]	[4]

3. Influence of machining environment on wear mechanism

Wear mechanisms during machining of titanium alloys change with the machining environments, see Fig. 1 *a-d*. It shows SEM images of worn out coated tungsten carbide inserts at room temperature and LN2 environment during orthogonal turning [6].

At room temperature, wear is observed on the rake face. It appears smooth as there is a continuous contact of chip on the tool rake face. After delamination at the rake face, removal of substrate particles by abrasion process takes place. However, the material removal appears to be uniform with no fracture or crack on the rake face.

However, completely different wear mechanisms operate when cryogenic cooling environment is employed in machining, see Fig. 1 *c,d*. After coating delamination, chipping of tool nose occurs. Instead of rake face, wear progresses on the tool flank. The wear appears non-uniform with no contact of chip to the rake face. The fracture of tool takes place with the crack appearing at the tool nose, see magnified image of Fig.1*d*.

Thus, a comparison of the worn out tool insert used at room temperature and LN2 machining environment shows different wear mechanisms. At room temperature, wear is observed on on the rake face and at LN2 temperature, wear takes place on the flank face. At room temperature, uniform attrition wear is observed on the rake face. On the other hand, at LN2 temperature, the chipping and fracture on the tool nose as well as flank take place.

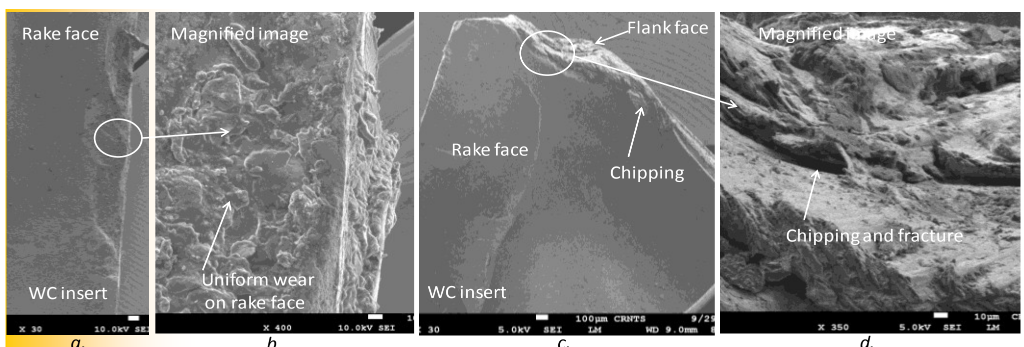


Fig. 1 *a-d* Influence of machining environment on tool wear mechanism [6]

4. Methods of reducing tool wear

This section gives a brief overview on recent investigations on improving the cutting tool performance in machining of titanium alloys. The key focus areas for the research are on tool coating, advanced tool material, machining environment and lubrication system which are described in a tabular form, see Table 2. The effectiveness of various tool coating, multi-coating on tool, and change in tool properties during machining operation are widely investigated. Also, the performance of advanced tool materials like BCBN, PCD and CBN tools is evaluated and compared with the carbide tools. The Table 2 describes various methods adopted for improving cutting tool performance, cutting tools used, tool wear criteria, processing parameters and the results achieved in terms of the tool performance.

Table 2 Summary of research to minimize the tool wear in machining

Method	Cutting tool	Tool life criteria and Processing parameters	Results
Plasma boronizing cutting tool [9]	Boronized and non boronized WC inserts.	VB = 0.3 mm i)Orthogonal turning v -70 m/min; f - 0.2–0.35 mm/rev ii) Face milling cutting v - 50-163 m/min; f - 10–40 mm/min (dry machining)	Tool life - 63 min Thermo-chemical diffusion of boron atoms diffuse to the too surface making hard boride zone. Tool life increased by 300%.
Multi-layer coating on inserts [10]	Uncoated, TiAlN coated, TiAlN + cBN coated single/ multi-layer WC inserts	Orthogonal turning of Ti6Al4V, V - 120 m/min; f - 0.075, 0.1, 0.125 mm/rev,(dry machining)	cBN and TiAlN + cBN coated WC/CO inserts exhibit largest cutting forces at higher speeds. cBN coated tool shows smallest wear zone.
Tool coating [5]	Uncoated-carbide and TiAlN–PVD coated-carbide drills	i) VB2≥0.15 mm ii)Maximum flank wear≥0.2 mm iii)chipping≥0.2 mm iv)catastrophic failure Drilling Ti6Al4V, v- 25- 55 m/min, f -0.06 mm/rev,6%conc. of water-soluble coolant	The highest tool life recorded for TiAlN-coated-drill was 7.8 min after drilling the 25th hole at the lowest v - 25 m/min, f - 0.06 mm/rev.
Thermal conductivity of tool material [7]	i)CVD multi-layer coated ii)Uncoated WC insert with cobalt binder	Localized flank wear VB3 > 0.9mm End milling of Ti-6242S cutting speeds, v - 60–150 m/min, f - 0.10-0.20mm/tooth, axial depths of cut 2–2.5mm	Tool life - 4.5 min and 3.5 min for tool1 and 2at 125 m/min. Wear in tool coating makes tool tip thermally congested which activates the tool wear mechanism
Advanced Tool material [8]	CBN and BCBN inserts	Average flank wear reached 0.4 mm, or when catastrophic fracture of the edge. High-speed slot milling Ti–6Al–4V Cutting v - 300-400 m/min, depth of cut - 0.050-0.100 mm, f - 0.050 - 0.100 mm/rev.	Tool life of 39.7 min at 400 m/min of cutting speed. Non-uniform flank wear on BCBN. The higher v and lower f are desirable.
Advanced tool	i)Uncoated WC–Co	VB- 0.3 mm, End milling of Ti6Al4V, v - 40- 160 m/min	Tool life of 15 and 22 min for tool 1 and 2 at v – 55m/min and f -

5. Summary and recommendations

In this article, major tool wear mechanisms in machining of titanium alloys have been presented. The mechanisms of tool wear change with the machining environment. Also, the recent areas of focus to improve the tool performance in machining the titanium alloy are discussed.

In order to minimize tool wear in machining of titanium alloys, controlling temperature at the cutting edge plays an important role. Low machining temperature prevents de-lamination and weakening of the cutting edge. Further, tool temperature changes the thermal conductivity of the tool material, which creates thermally active zone at cutting edge. This phenomenon accelerates the tool wear mechanism. Therefore, to improve tool performance, the authors' research group has concentrated on controlling the work-tool interface temperature, optimization of processing parameters and on changing the machining environment. Atomized mist jet lubrication technique appears to be a promising technique, as it directs pressurized mist of oil and lubrication at the cutting edge of the tool. Also, development of advanced tool material and coating material that withstand the high cutting temperature are the key areas to improve performance of cutting tools in machining of titanium alloys.

Acknowledgement

The authors acknowledge the financial support of National Centre for Aerospace Innovation and Research at IIT Bombay (A Department of Science and Technology, The Boeing Company and IIT Bombay Collaboration).

References

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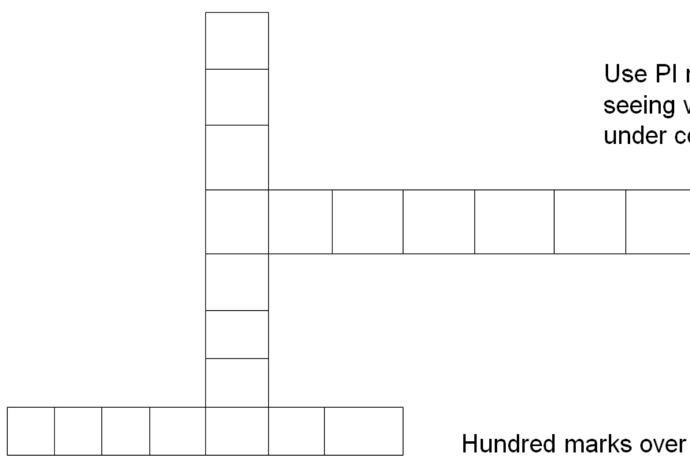
Cross word puzzle on failure analysis terminology

See page 14 for answers:

Ring finds rest as embedded inclusion [8]

Use PI model for seeing what happens under compression [7]



Hundred marks over NH [7]

Society for Failure Analysis

Application Form

Society for Failure Analysis
C/O Centre for Military Airworthiness & certification, RCMA (Materials)
Hyderabad550 058

Phone: 040-24340750; 24348377;
Fax : 040-24341827
E-mail: rdrcma.mat@cemilac.drdo.in

Please √ applicable **member** ☐ **Life Member** ☐

1. **Name in Block Letters**

First Middle Last

2. **Date of birth**
3. **Father's Name/ Husband's Name**

4 **Present Occupation /Designation and office address:**

Phone:
Mobile:
Fax:
Email:

5 **Academic & Professional Qualifications**:

6 **Home address:**

Phone:
Mobile:
Fax:
E-mail

6. **Address for correspondence:** **office** ☐ **Home** ☐

7. **Professional Experience**:
8. **Endorsement by SFA Member**

Name	Membership No.	Signature

9. **Primary Field of Interest: (please mark 1,2,3 in the in order of preference**)

Strategic ☐	Power ☐	Foundry ☐	Welding ☐	Heavy industry ☐	transport ☐
Design & Failures ☐	Quality control ☐	Petrochemical ☐	Consultancy / services ☐	Materials and manufacturing ☐	Education ☐

10. **Name of the Chapter you intend to be attached**____________________________________
(Please refer to Chapters' list)

11. **Subscription details:**
Payment should be made by cheque / DD favoring **"Society for Failure Analysis"**, payable at Hyderabad. Outstation cheques not accepted.

Amount Rs. Cheque / D.D. No Dated

Bank Name Branch

Category	Amount Payable		
	Admission Fee (One time)	Yearly Subscription	Total on joining
Member	Rs.50	Rs.200 (annual)	Rs.250/-
Life Member	Rs.50	Rs.1500	Rs.1550/-

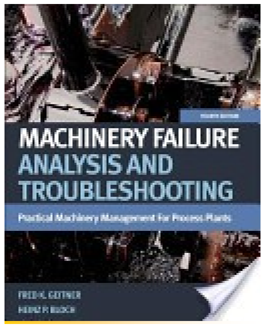
12 **Declaration by the applicant**

If elected, I agree to accept to pay the prescribed yearly subscription, to abide by the Articles of Association of the Society and to promote its aims and objects.

Signature of the Applicant

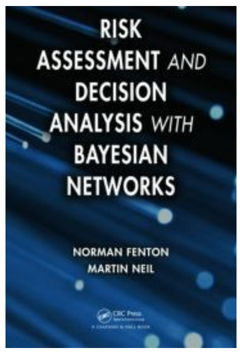
13.	Office Use Only					
	Membership No.		Date of Enrolment		Chapter	
	Amount Paid (Rs)		Receipt No. / Date			

Books



Machinery Failure Analysis and Troubleshooting: Heinz P. Bloch, Fred K. Geitner, Butterworth-Heinemann, 10-Dec-2012, 760pp

Structured to teach failure identification and analysis methods that can be applied to almost all problem situations, this eagerly awaited update takes in the wealth of technological advances and changes in approach seen since the last edition published more than a decade ago. Covering both the engineering detail and management theory, Machinery Failure Analysis and Troubleshooting provides a robust go-to reference and training resource for all engineers and managers working in manufacturing and process plants.



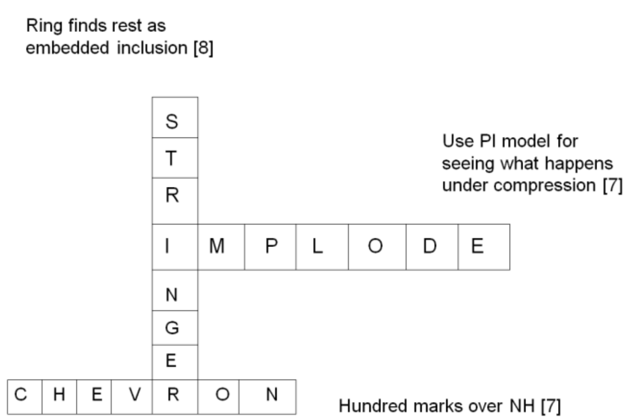
Risk Assessment and Decision Analysis with Bayesian Networks

Published:
November 07, 2012 by CRC Press - 524 Pages
Author(s):
Norman Fenton, **Queen Mary University of London, UK**; Martin Neil,**Queen Mary University of London, UK**

Although many Bayesian Network (BN) applications are now in everyday use, BNs have not yet achieved mainstream penetration. Focusing on practical real-world problem solving and model building, as opposed to algorithms and theory, **Risk Assessment and Decision Analysis with Bayesian Networks** explains how to incorporate knowledge with data to develop and use (Bayesian) causal models of risk that provide powerful insights and better decision making.

- Provides all tools necessary to build and run realistic Bayesian network models
- Supplies extensive example models based on real risk assessment problems in a wide range of application domains provided; for example, finance, safety, systems reliability, law, and more
- Introduces all necessary mathematics, probability, and statistics as needed

Answers to the crossword:



Events in the pipeline

1st International Conference on Structural Integrity (ICONS-2014)

The First International Conference on Structural Integrity (ICONS-2014) is being organised during February 4-7, 2014 by Indira Gandhi Center for Atomic Research (IGCAR) in Kalpakkam, in joint collaboration with Indian Institute of Metals (IIM), Kalpakkam Chapter, Indian Institute of Welding (IIW), Chennai Branch and Society for Failure Analysis (SFA), Chennai Center. Delegates from R&D and academic institutes and industry will take part in ICONS-2014 to share the state-of-the-art advances in various aspects of structural integrity. International experts will deliver invited talks in structured technical sessions. The scope of ICONS-2014 includes all aspects of structural integrity, but not limited to

- Mechanical property evaluation
- Numerical modeling and validation
- Fatigue and fracture mechanics
- Creep and Corrosion
- Design and stress analysis
- Fabrication technology, CAD, CAM
- Metal joining and welding
- Hard facing and tribology
- Microstructure characterisation
- Nondestructive evaluation
- Quality assurance
- ISI, Condition monitoring and robotics
- Reliability and regulatory aspects
- Failure analysis and life prediction
- Damage mechanics
- Structural health monitoring

For more details, please contact:

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