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Reliability-centered maintenance methodology for goliath crane of transmission tower

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Abstract: *Reliability centered maintenance (RCM) methodology was originally developed by the U.S. commercial airlines industry in the year of 1960 for identifying applicable and effective preventive maintenance tasks. Safety systems are usually stand by systems and they are periodically to reveal and repair failures that may have occurred since the previous activation or inspection.RCM approach has been applied to the goliath crane system of transmission tower industry for research work reported in this paper.RCM methodology can be applied to Indian industry for reduction of breakdowns as well as optimization of preventive maintenance cost. In the present study preventive maintenance task suggested for power transmission subsystem, guiding and transportation subsystem, hydraulic subsystem and supply current subsystem in goliath train.*
Keywords-*Goliath crane system, optimization ,rcm, transmission tower*

I. Introduction

RCM starts with a comprehensive, zero-based review of the maintenance requirement of each asset in its operating context. Reliability-centered maintenance, often known as *RCM*, is an industrial improvement approach focused on identifying and establishing the operational, maintenance, and capital improvement policies that will manage the risks of equipment failure most effectively, which specifies that RCM address, at a minimum, the seven questions:
What is the item supposed to do and its associated performance standards? In what ways can it fail to provide the required functions?
What are the events that cause each failure?
What happens when each failure occurs?
In what way does each failure matter?
What systematic task can be performed proactively to prevent, or to diminish to a satisfactory degree, the consequences of the failure?
What must be done if a suitable preventive task cannot be found?

The answers to the first four questions are recorded on RCM information worksheet and answers to the remaining three questions are recorded on decision worksheet. These are used to record the functions of the asset under review and to list all the associated functional failures, failure modes and failure effects. Functional failures, Failure modes, Failure effects Listing of what actually happens when each failure mode occurs is known as failure effect. Specifically when describing the effects of failure the following should be recorded. What evidence (if any) that the failure has occurred? What physical damages (if any) is caused by the failure? What must be done to repair the failure?

1.Failure consequences Failure prevention has much more to do with avoiding or reducing the consequences of failure than it has do with preventing the failures themselves .A preventive task is worth doing if it deal s successfully with the consequences of failure, which it is meant to prevent. The next stage is to classify evident failure into three further categories in descending order of importance as follows.Safety and environmental consequences, Operational consequences, Non-operational consequences

2. Hidden failure consequences – The only consequence of a hidden failure is increased risk of multiple failures. The performance standard for a hidden function is the availability needed to reduce the risk of the associated multiple failure to an acceptable level.

3. Safety and environmental consequences A failure mode has safety consequences if it causes a loss of function or other damage, which could hurt or kill someone.

4. Operational consequences- A failure has operational consequences if it has a direct adverse effect on operational capability. In general, failures affect operations in four ways namely, output, product quality, customer service, increased operating cost in addition to the direct cost of repair.

5. The non-operational consequences-For failure modes with non-operational consequences, a preventive task is worth doing if over a period of time; it costs less than the cost of repairing the failures, which it is meant prevent.**preventive tasks**The actions which can be taken to deal with failures can be divided into two groups – preventive tasks and defaults tasks which must be undertaken if suitable preventive tasks cannot be found. The three principal categories of preventive tasks are scheduled on-condition tasks, scheduled restoration tasks and scheduled discard tasks.**Scheduled on condition tasks**. On-condition maintenance is based on the facts that many failure develop over a period of time. **Schedule restoration tasks**. Scheduled restoration entails remanufacturing a single component or before overhauling an entire assembly at or before specified age limit, regardless of its condition at the time. **Scheduled discard tasks** .Scheduled discard means replacing an item or component with a new one at preset intervals. [1]

6. Default actions If a preventive task cannot be found which is both technically feasible and worth doing for any failure mode, then the default action, which must be taken, is governed by consequences of the failure. The default actions are scheduled failure finding tasks and no scheduled maintenance redesign.No scheduled maintenance. No scheduled maintenance is valid if

7. Redesign. Redesign refers to any change to the specification of any item of equipment.

II. Rcm Decision Worksheet

The answers to the last three questions are recorded on RCM decision worksheet is shown in tables. It is used to record the answers to the questions in the decision diagram covering the aspects of failure consequences, preventive tasks and default actions.The decision worksheet is divided into columns. The columns headed F, FF and FM identifies failure modes under consideration. They are used to cross-refer the information and decision worksheets. The headings on the next columns refer to questions on the RCM decision diagram as follows; The column headed H, S, E, O and N are used to record the answers to the questions concerning the consequences of each failure mode.The next three columns (headed H1, H2 ,H3) record whether a preventive task has been selected and if so what type of task?If it becomes necessary to answer any of the default questions the columns headed H4 and H5 or S4 are used to record the answers.The last three columns is also used to record the cases where redesign is required or it has been decided that the failure mode does not need scheduled maintenance.

1. Failure consequences. The questions for failure consequences H, S, E and O are asked for each failure mode and answers are recorded on the basis shown in fig. Shows how these answers are recorded on decision worksheet.

2. Preventive tasks. The eighth to tenth columns on decision worksheet are used to record whether a preventive task has been selected as follows: The column headed H1/S1/O1/N1 is used to record whether a suitable on-condition task could be found to anticipate failure mode in time to avoid the consequences. The column headed H2/S2/O2/N2 is used to record whether a scheduled restoration task could be found to prevent failures. The column headed H3/S3/O3/N3 is used to record whether a suitable discard task could be found to prevent the failures. **The default questions**. The columns headed H4, H5 and S4 on the decision worksheet are used to record to the answers to the three defaults question are only asked if the answers to the previous questions are all `no'. **a. Defaults action (H4)** Is a failure finding task technically feasible and worth doing? Record yes if it is possible to do the task and it is practical to do it at required frequency and it reduces the risk of multiple failures to an acceptable level'**s .Default action (H5)** could the multiple failures affect the safety or environment? This question is only asked if answer to question H4 is no. If answer to the question is yes then redesign is compulsory if the answer is no the default action is no scheduled maintenance but redesign may be desirable'**s. Default action (S4)** is a combination task technically feasible and worth doing? Yes if the combination of any two or more preventive task will reduce the risk of failure to the acceptable level. If the answer is no redesign is compulsory. [2]

III. Scope Of This Article

Application of methodology of RCM for selection of proper maintenance strategy is still a new concept in Indian industry. Although this concept has been applied widely in various countries, its relevance to the Indian industry has not been realized so far. Indian industry is lab our oriented and information system specifically in context of maintenance is not fully computerized In the present study RCM methodology has been applied to goliath crane of a transmission tower company.

IV. Transmission Tower Company Application

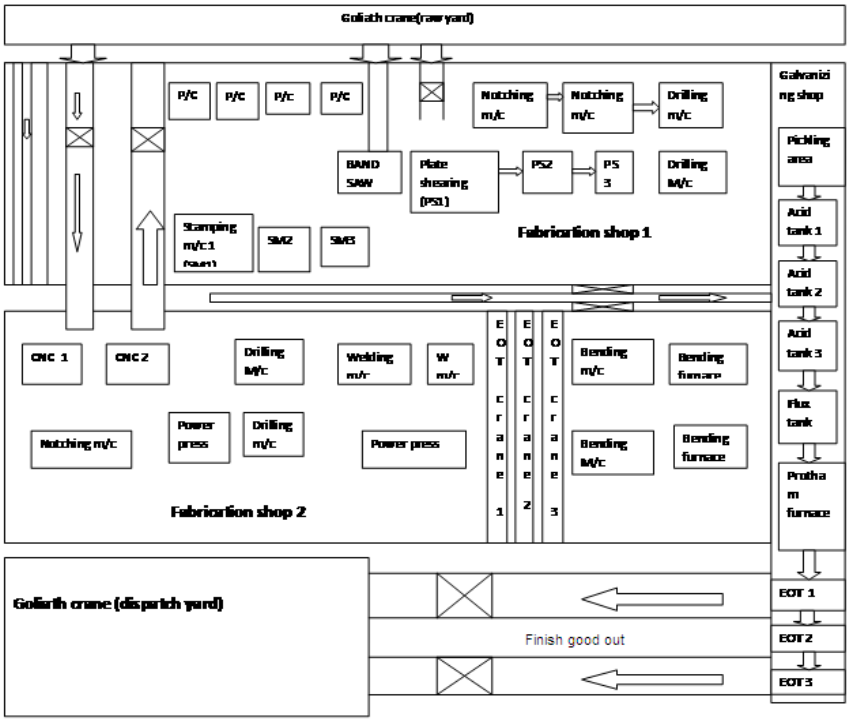
The methodology of RCM has been applied to the transmission tower company. In transmission tower manufacturing company, Goliath crane are used to transfer raw material from raw yard to different machines in fabrication shop. The capacity of goliath crane is 5MT. Layout of transmission tower company (ATSL) is shown in fig. Transmission Tower Company consists of the following sections.

1. Raw Material Section Goliath crane are used for shifting raw materials from raw yard to different machine in fabrication shops.

2. Fabrication section Power Press Punching Machine,Universal Punching & Cutting Machine Plate Shearing Machine,Bending Machine, CNC Machine, Notching & stamping Machine

3. Galvanizing Section Protherm furnace is used to convert semi-finish product to finish product.
4. Dispatch section Goliath crane used for shifting finished materials from dispatch section to different transportation vehicles like container, trailer etc.

Lay-out of transmission Tower Company (Associated transrail structure limited company)



Layout of transmission tower company (ATSL) is shown in fig. Transmission Tower Company consists of the following sections.

1. **Raw Material Section**
   Goliath crane are used for shifting raw materials from raw yard to different machine in fabrication shops.

2. **Fabrication section**
   Power Press Punching Machine
   Universal Punching & Cutting Machine
   Plate Shearing Machine
   Bending Machine, CNC Machine, Notching & stamping Machine

3. **Galvanizing Section**
   Protherm furnace is used to convert semi-finish product to finish product.

4. **Dispatch section**
   Goliath crane used for shifting finished materials from dispatch section to different transportation vehicles like container, trailer etc

5. **Manufacturing process** Associate Transrail Structure Ltd. Company is manufacturing of transmission tower. The raw materials is supplied from raw yard to different machines in fabrication shop through goliath crane. The various operations are performed on raw materials with the help of different machines like punching, cutting, notching and stamping etc. & semi-finish materials transfer to galvanizing section and finally finish product produced. In galvanizing section, semi-finish products are deep in acid tank, flux tank and galvanizing furnace at temp. of 450˚C and finally finish product produced. The finish products are delivered to dispatch section through trolleys. In dispatch section goliath crane also used to supply finish good to different automobile vehicles like as container, truck and trailor etc. In major breakdown of goliath crane , raw materials is not transfer to different machines shops results in high production loss.

V. Identification And Formulation Of Proposed Work

In analysis of goliath crane identify the break down list for a span of two years which revealed that most of the failures occurred due to shot of supply current cable & wear out of wheel collar.RCM concept has been applied to goliath crane. Goliath crane has been categorized in following four sub systems:1.Power transmission subsystem 2. Guiding & transportation sub system 3. Hydraulic sub system 4. Supply current sub system

1. Power transmission subsystem Power transmission sub-system is as shown in fig. The motor is coupled with the reduction gear box by brake drum. The output shaft of reduction gear box is connected to drive wheel of goliath crane by gear coupling. Gear box equipped in the system reduces speed of drive wheel. Power transmission sub-system consists of following components. Motor ,Brake drum, Reduction gear box, Gear coupling, Key.

2. Guiding and transportation subsystem Slide view of the drive /idle wheel is as shown in fig. The wheels are fitted with double spherical roller bearing. The Roller bearing is enclosed with the Plummer block. It is covered by mild steel plate, 10-12 mm thick. The mild steel plate is fixed at both sides of the Plummer block. Guiding and transportation subsystem consists of the following components. Drive or Idle wheel, Double spherical roller bearing, Plummer block, Foundation bolt.

3. Hydraulic subsystem Hydraulic subsystem is used to control the speed of goliath crane. The electro hydraulic thrustor is used in hydraulic subsystem normally it is in close position when crane starts running in vertical, longitudinal & cross movement. When the current is given to thrustor coil through control panel the impeller start rotating and pressure develop inside of the thrustor assembly. These pressure acts in upward movement of the arm at this stage brake liner is free from drum and smooth crane movement occur. Major components of hydraulic subsystem are Electro hydraulic thrustor, Tie rod mechanism, Brake drum, Brake liner.

4. Main control panel (MSEB) Supply current subsystem is used to supply current to motors and thrustors in all movements like lateral travel, cross travel and hoist (up-down). The current supply from main control panel (MSEB) to crane panel through trolley cable of size 10 sq-mm 4 core & 60m length. Trolley cable rotates continuously in forward and reverse direction due to cable damages or shot.

VI. Rcm Information Worksheets

RCM information worksheets were prepared for power transmission subsystem, guiding and transportation subsystem, hydraulic subsystem and supply current subsystem to indicate the functions, functional failures, failure modes, i.e. causes of failure..

Table-1 (RCM information worksheet for power transmission subsystem)

Function	Functional Failure	Failure Mode	Failure Effect
(1)The function of reduction gear box is to supply the reduced speed to the drive wheel. The gear coupling connects the two shafts. The proper of coupling is to connect the shaft & transmit the torque.	(A)Reduction gear box not working properly	(1) Oil contamination (2)Low oil level (3)Teeth damage	Frictional power loss increase. Tooth wear & transmitted speed variation will increase For excessively worn out teeth transmitted speed variation level will increase which will induce noise in gear box.
	(B)Gear coupling fails	(1) Teeth wear	Impact will increase, due to this induced stress in coupling increase,

		(2) Hub damage. (3)Coupling bolts broken	hence coupling fails then it is not transmit motion to drive wheel. Transmitted speed will be very low may lead to breakage of damage hub. Due to loose fitting of bolts or jerkish motion , induced stress on coupling bolts & it will broken.
	(C) Incorrect key clearance	(1) Loose key (2) Tight key (3)Shear deformation	Impact on driven rotating member, therefore it can reduce the life of driven rotating member. It can cause key failure. Rise in initial compressive & shear stress. It will further increase during power transmission cause early key failure & reduces life. Heavy pressure on edges of key. Under the effect of slight relative displacement between edges of key & shaft at one end & driven wheel at other, key edges gets worn out

Table-2 (RCM information worksheet for guiding and transportation subsystem)

Function	**Functional Failure**	**Failure Mode**	**Failure Effect**
The function of the system is to provide smooth movements of drive wheel, bearing is provided at both the ends of drive wheel. Roller bearing is enclosed with Plummer block	(A) Drive wheel not working properly	(1) Due to failure of key (2) Due to bearing seizure**.** (3) Drive or Idle wheel collar wear out	Drive wheel does not get motion , key wear out & power transmission stop Noise in drive wheel & shaft get jammed. Due to improper alignment between wheel & rail (I-beam)wheel collar wear out.
	(B) Roller bearing fails	(1) Due to wear out sieve bearing fails (2) Improper lubrication (3)Roller wear	Interrupted contact between wheel & shaft .This causes additional friction & power loss. Hence sieve bearing fail. Frictional power loss increases & bearing temp. rises so Bearing parts surface damage takes place. Due to improper alignment between wheel & rail (I-Beam) stresses will increase & bearing fail occurs
	(C) Plummer block damage	(1) Dynamic load (2) Vibrations	Stresses will increase, vibration will increase which may lead to initiation of crack & eventual failure. Additional stress due to vibration will increase leading to crack initiation.
	(D) Foundation bolts fails	(1) Dynamic load (2) Vibration (3) Thread wear	Will increase stress & vibration. This leads to accelerated crack formation. Due to vibration, it will add to all adverse effects of increase in dynamic load. It will loosen the foundation bolts It will weaken the thread because of weak thread, it will lead to shear off & thread failure.

Table - 3 (RCM information worksheet for hydraulic subsystem)

Function	Functional Failure	Failure Mode	Failure Effect
Hydraulic system is used to control the speed of goliath crane like as cross travel, lateral travel & hoist up-down.	(A) Hydraulic brake thrustor fails	(1)Low oil level (2)Thrustor coil shot.	Due to minimum oil level pressure not develop in cylinder Due to oil seal damage, oil enters in coil.
	(B) Hydraulic cylinder	(1)Leakages **(**2) Corroded (3) Damaged	Oil leakages from hydraulic cylinder so the pressures not develop. Increase in friction between piston & cylinder will increase power loss. Inside surface roughness increases or distortion along the axis takes place.
	(C) Brake liner	(1)Wear out	Not proper control the speed of crane if brake liners wear out.
	(D) Arm	(1) Bush wear	Motion will become jerkish. Increase impacts at the bush which will cause additional unwanted stresses occur in bush.
	(E) Tie rod mechanism	(1)Wear out	Due to up & down movement of thrustor stresses will induce in tie rod mechanism.

Table- 4 (RCM information worksheet for supply current subsystem)

Function	Functional failure	Failure mode	Failure effect
.(1) The main important function is to supply current to all electrical accessories like motors, thrustor and contactor etc.	(A) Crane not work	(1) Main MCB trip (2) Main supply cable shot(10 sq-mm 4core) (3) Main contactor not work (4) Fuse shot (5) Crane panel switch not work	Due to overloading MCB trip. Stretching of cable due to revolving in forward and reverse direction, it is shot or damages. If main contactor fails then it is not supply current to all electrical accessories. Due to shot circuiting of cable. Supply current wire break, new dummy wire fitted.
	(B) L.T.,C.T & Hoist not work	(1) Contactor not works. (2) Motor not works.	Due to continuous up & down movement, contactor shot or not works. Motor slip ring wire break, jointed it.

VII. Rcm Decision Worksheet

RCM decision worksheet were prepared for power transmission subsystem, guiding and transportation subsystem, hydraulic subsystem and supply current subsystem, to reveal the nature of hidden, safety, environmental and operational.

1. RCM decision worksheet for power transmission sub-system

RCM decision worksheet							Unit subsystem						Power transmission
			Component				(a) reduction gear box (b) Geared coupling (c) Drive wheel key (d)Motor (e) Brake drum						
Information reference			Consequence evaluation				H1	H2	H3	Default action			
							S1	S2	S3				Proposed task
							O1	O2	O3				
F	FF	FM	H	S	E	O	N1	N2	N3	H4	H5	S4	
1	A	1	Y	N	N	N	N	Y					Scheduled restoration, checking of oil
1	A	2	N	N	N	N	Y						Schedule on condition. Human senses
1	A	3	Y	N	N	Y	N	N	Y				Schedule discard
1	B	1	Y	N	N	Y	N	N	Y				Schedule discard
1	B	2	N	N	N	Y	N	N	N				No scheduled maintenance
1	B	3	N	N	N	N	Y	N	N				Schedule on condition
1	C	1	Y	N	N	Y	N	N	Y				Fit proper key size. Schedule discard at major overhaul
1	C	2	Y	N	N	N	N	N	Y				Fit proper key size. Schedule discard at major overhaul
1	C	3	N	N	N	Y	Y						Change key on condition

2. RCM decision worksheet for guiding and transportation sub-system

RCM decision worksheet							**Unit**						**Guiding & transportation subsystem**
Component - bolts							**(a) Drive wheel (b) Roller bearing (c) Plummer block (d)Foundation**						
Information reference			**Consequence evaluation**				**H1**	**H2**	**H3**	**Default action**			
							S1	**S2**	**S3**				**Proposed task**
							O1	**O2**	**O3**				
F	**FF**	**FM**	**H**	**S**	**E**	**O**	**N1**	**N2**	**N3**	**H4**	**H5**	**S4**	
1	A	1	Y	N	N	Y	N	N	N				No scheduled maintenance
1	A	2	N				N	Y					Greasing of bearing Schedule restoration
1	A	3	N	N	N	N	N	N	N				No Scheduled maintenance
1	B	1	N				N	N	N	N	N		No scheduled maintenance
1	B	2	N				Y						Check bearing for lubrication. Schedule on condition
1	B	3	N				N	N	Y				Bearing replacement. Schedule discard
1	C	1	Y	N	N	Y	Y						Plummer block check. Schedule on condition
1	C	2	Y	N	N	N	Y						Vibration check. Schedule on condition
1	D	1	Y	N	N	Y	Y						Check for foundation bolts. Schedule on condition
1	D	2	Y	N	N	N	Y						Vibration check, schedule on condition
1	D	3	N				N	N	N	N	N		No scheduled maintenance

3. RCM decision worksheet for hydraulic subsystem

RCM decision worksheet			**Unit**				**Hydraulic subsystem**						
Component- (a) hydraulic cylinder (b) Thrustor coil (c) Piston (d)Impeller (e) Brake liner (f) Spring (g) Tie rod mechanism													
Information reference			**Consequence evaluation**				**H1**	**H2**	**H3**	**Default action**			
							S1	**S2**	**S3**				
							O1	**O2**	**O3**				**Proposed task**
F	**FF**	**FM**	**H**	**S**	**E**	**O**	**N1**	**N2**	**N3**	**H4**	**H5**	**S4**	
1	A	1	Y	N	N	Y	Y						Check oil level. Schedule on condition
1	A	2	Y	N	N	N	N	Y	N	N	N		Scheduled restoration task
1	B	1	Y	N	N	Y	N	N	N				Scheduled restoration task
1	B	2	N	N	N	N	Y						Check cylinder when shut down. Schedule on condition
1	B	3	Y	N	N	Y	N	N	N				No scheduled maintenance
1	C	1	N	Y	N	N	N	N	Y				Replace brake liner. Schedule discard
1	D	1	Y	N	N	N	N	N	Y				Replace bush. Schedule discard
1	E	1	N	N	N	Y	N	N	Y				Replace tie rod, schedule discard.

4. RCM decision worksheet for supply current subsystem

RCM decision worksheet								**Unit**						**Supply current subsystem**
Component-(a)L.T,C.T,Hoist motor (b)Supply cable 10 sq-mm 4 core ©Contactor (d)Fuse														
Information reference		**Consequence evaluation**						**H1**	**H2**	**H3**	**Default action**			
								S1	**S2**	**S3**				**Proposed task**
								O1	**O2**	**O3**				
F	**FF**	**FM**	**H**	**S**	**E**	**O**		**N1**	**N2**	**N3**	**H4**	**H5**	**S4**	
1	A	1	N	N	N	Y		Y	N	N				Check MCB, On condition task.
1	A	2	Y	N	N	Y		N	N	N				No scheduled maintenance
1	A	3	N	N	N	Y		N	Y	N				Clean contactor tips, scheduled restoration task
1	A	4	Y	N	N	Y		Y	N	N				Changed fuse, scheduled discard task
1	A	5	Y	N	N	Y		N	N	N				No scheduled maintenance
1	B	1	N	N	N	Y		N	Y	N				Clean contactor tips, scheduled restoration task
1	B	2	N	N	N	N		N	Y	N				Jointed wire, on condition task

VIII. CONCLUSION

In the present study, preventive maintenance tasks suggested for power transmission subsystem, guiding and transportation subsystem, hydraulic subsystem and supply current subsystem in goliath crane are 12 scheduled on condition tasks, 06 scheduled on restoration tasks, 09 scheduled discard tasks. Whereas for 08 failure modes no scheduled maintenance has been proposed. Existing maintenance schedule for goliath crane indicates the maintenance action as and when required. Hence RCM based schedule specifies that additional preventive maintenance tasks need to be executed as compared to none initially. In power transmission subsystem significant aspects are proper lubrication schedule restoration task is required in gearbox and gear coupling. In supporting system failure of bearing and wheel collar wear out occurs due to scant lubrication and mis-alignment of wheel and I-beam (rail). Maintenance task such as greasing of bearing proper lubrication are to be carried out.In hydraulic subsystem, significant aspects are scheduled restoration task is apply on oil leakages from hydraulic thrustor and scheduled discard task has been suggested in brake liner, arm and tie rod mechanism. No scheduled maintenance is proposed to hydraulic cylinder.In supply current subsystem, high breakdown occurs in supply current cable system. Hence no scheduled maintenance is proposed because these are related to damage or shot of cable during revolving in forward and reverse direction. So to avoid this problem redesign will be required. If bus-bar system used instead of existing supply current cable trolley system then breakdown is negligible.

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