PREDICTIVE MAINTENANCE MODEL DEVELOPMENT USING LIFE PREDICTION METHODOLOGY

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ABSTRACT

"Predictive Maintenance Model Development Using Fatigue Life Prediction Method" is a platform to reach zero breaks down in any production system. FMEA and FLP are the core methodologies to be used to develop the model. The model is evaluated in a system of hydraulic press unit. For the case on execution. A hydraulic press PSPR 18 (60 TON HYDRAULIC PRESS) is selected based on failure history .FMEA concept is applied to find the high prone failure components. The major highlighted components are hydraulic seal, cylinder and hydraulic oil.

The selected component is analyzed to determine the service life. The CAD model of hydraulic seal and cylinder whose service life is analyzed through explicit dynamic analysis using ANSYS work bench 11.Hydraulic oil service life is predicted based on the viscosity behavior of oil in regular intervals. Where the above predicted service life is compared with actual period of maintenance. The model result conclude with saving a period of usage and cost incurred in it .And reduce the time and labor involved in actual maintenance.

Key words: predictive maintenance, seal failure, service life

I. INTRODUCTION

It is a well-established fact that as soon as an industrial facility is commissioned, its operational availability over time heavily depends on its utilization rate and maintenance consistency levels. A component failure, whatever its cause, can generate operational unavailability of the industrial facility it belongs to, alone or through a domino effect. Failure of the same component in another subsystem of the same facility – if this has several – will not necessarily cause consequences of the same extent. In general, component criticality referenced to the operational availability of an industrial facility depends on the component's role in sustaining production in a safe and efficient way, whereas this role, apparently, does not have the same weight for the different components of the entire system.

Critical failures of production systems are a typical example of events associated with loss. This consists of lost production, cost of intervention and cost of repair/replacement. Currently, *production availability* is used commonly by the industry (e.g. the oil and gas industry) to estimate the losses from failures and to rate design solutions. It is defined as the ratio of the actual production and the maximum production capacity. Production availability is a useful measure for estimating whether a contracted level of production will be achieved but it does not create a correct picture about the losses from failures and cannot serve as a sound basis for revealing the reliability value. Industrial facilities and assets tend nowadays to become more complex and sophisticated. The availability of such facilities is greatly influenced by the maintenance policy of the factory.

The ability to optimally choose a maintenance policy for a production system (planning inspections and repairs) is very important for every enterprise to improve its *production availability*. Knowing the deterioration stage of the equipment or a component of the equipment (or even better ± the remaining lifetime) the person responsible for the equipment can make a decision concerning further exploitation, repair of individual elements or replacement with new ones. The maintenance policy is aimed at achieving failure-free operation of the system and prolonging the remaining life of equipment. The remaining lifetime of a device depends to a large extent on two factors ± frequency of making inspections (technical surveys) and the quality of repairs (for given part of a device either the most crucial and necessary repairs can be made or a complete overhaul can be provided). Defining both, times when the inspections should be performed and which components should be repaired, are difficult tasks. Usually when an inspection takes place, the equipment is temporarily unavailable (that results in additional costs). As a result, utilization costs can be overestimated, due to the fact that inspections are made too frequently.

Though maintenance activity is considered as income-consumer of the company, without which it is not possible to run the production equipment's forever. It is thought generally that the maintenance involves stoppage of production machines for maintenance aims. To decrease maintenance cost yearly, several strategies have been developed. However, most of them require huge budget to keep the machine in good condition. That is why; companies seek a maintenance technique to spend money just in time. The technique accepted by the most companies is Predictive Maintenance.

The objective of this project work is to develop a Predictive Maintenance Model (PMM) using service life prediction approach. This model is proposed in a live industrial ground where the existing maintenance and asset management practice is a breakdown and a periodic maintenance. The past maintenance model have several draw back which consume much cost, time and resource. In the shop floor, breakdown of a single machine makes failure of complete product flow. In this case study, a machine, PSPR 18 hydraulic press is considered for improving it availability through the proposed approach. Unpredictable failure of the press affects the product flow to the series machines. In the case of model development, a Failure Mode Effect Analysis (FMEA) is carried out to the selected machine to find the critical component which fails frequently. RELEX 2011 is an IT tool used to carry out FMEA. The Risk Priority Number (RPN) index is determined by calculating the product of Severity, Occurrence and Detection indexes.

Rod Seal, Piston seal and hydraulic oil pertaining to subject machine found with higher RPN indices in the FMEA analysis. Rod and piston seal used in the press system are made of Polyurethane shore (PUR) of grade 95 A. The hydraulic oil used is an ISO grade system 68 oil (Trade Name - servo system 68) which having initial viscosity of 68Cst. In order to predict the service life of the critical components, a critical limit is to be maintained. Sliding movement of the piston seal inside the cylinder barrel and rod inside the rod seal causes a friction over the sealing element. This friction causes a deformation in the seal element if the deformation exceeds the critical limit the internal and external leakage of oil occurs.

Friction force acted on the piston and lip seal is been calculated. Limit is to be set base on the maximum allowance chart prescribed by the sealing industry. A critical limit of 0.53 mm for Rod seal, 0.64 mm for piston seal.

To predict the life of the rod and piston seal ANSYS WORK BENCH V12 is been used. In which the each seal is analyzed to predict the life of the sealing system .Maximum deformation is consider as a critical limit and the life evaluated of each seal .By the above analysis the life predicted for Rod seal is 11,00,000lakh cycle and life predicted for the piston seal is 13,00,000lakh cycle. Similarly the Hydraulic oil whose service life is predicted based on the viscosity deviation analysis by a methodology called SACODE Methodology .Here in our case oil viscosity is consider as a important parameter. Which is been condition monitored using a Say Bolt viscometer at 40^0c for a period of interval with respect to the production cycle in the particular machine. A caution limit of 72Cst and a critical limit of 75Cst are set based on the industrial recommendation. Graphical interpretation of the production cycle against the periodic viscosity value with respect to the caution and critical limit the life of the oil is been estimated as 12, 76,748 cycles.

The application of proposed maintenance model has shown a savings of both time and cost. By the above model of analysis usage period of the component is been increased. An amount of cost wasted in previous maintenance model of replacing a component is saved in the predicted model of replacement. And the failure of the component is predicted so the replacement is made as per the predicted maintenance schedule .there by the sudden failure of the component and machine can be arrested. Unwanted downtime and production losses can be reduced.

II.PREDICTIVE MAINTENANCE

Predictive Maintenance (**PdM**) techniques help determine the condition of in-service equipment in order to predict when maintenance should be performed. This approach offers cost savings over routine or time-based preventive maintenance, because tasks are performed only when warranted.

The main value of Predicted Maintenance is less maintenance since you know what equipment that needs maintenance, when it needs it, but also what equipment that doesn´t need maintenance in near or midterm. The key is "the right information in the right time". By knowing which equipment that needs maintenance, the maintenance work can be better planned (spare parts, people etc) and what would had been "unplanned stops" are transformed to shorter and less "planned stops" thus increasing plant availability. Other values are increased equipment life time, increased plant safety, less accidents with negative impact on environment, an optimized spare parts handling etc.

III. LITERATURE SURVEY

1. Sedat Karabay , Ibrahim Uzman **[1]** it covers The importance of early detection of maintenance problems in rotating machines in management of plants with Case studies from wire and tyre plants. In this article, importance of application of predictive maintenance concept appreciation of the subject was performed with the help of data collected cases related to maintenance problems from Plants A and B.

2. V.S. Deshpande, J.P. Modak **[2]** it covers RCM and predictive maintenance used to determine the maintenance requirement of any physical asset in its operating context. Where FMEA is a tool used to find the failure in the case discussed.

3. V. V. Burenin **[3]** where clearly explained about the numerical and experimental method to calculate the friction force in a hydraulic cylinder.
4. Steven N. Herzog, RohMax USA, Inc., Horsham, PAThelma E. Marougy, Eaton Corporation, Southfield, MIPaul W. Michael, Benz Oil, Milwaukee, WI [4] were clearly explained the basic criteria of hydraulic fluids properties and fluid selection

5. Noria Corporation, the paper is about the systematic approach of oil analysis and SACODE Methodology. It gives an overview of viscosity analysis and oil analysis interpretation.

IV. HYDRAULIC PRESS

A hydraulic press is used for lifting or compressing large items. Hydraulic mechanism is used to generate the force which increases the power of a standard mechanical level. Hydraulic presses are widely used in a manufacturing environment.[6,7] A large lifting or compressive force is applied using hydraulic press for a specific purpose. Today, in the highly technically advanced world, hydraulic presses are the most widely-used, demanded and efficient modern press, used in various industrial applications. There are different hydraulic press machines, ranging from small table top units to huge machines used to create metal sheets and parts. Hydraulic press is available in a wide variety of sizes and styles and in capacities ranging from small hydraulic press of 1 ton or less to large machines of 10,000 tons or more. Manual hydraulic press, automotive hydraulic press is popular hydraulic press designs available in the market

V.PROBLEM IDENTIFICATION IDENTIFYING CRITICAL COMPONENT BY MFMEA

Predictive maintenance is to be carried out to the hydraulic power press .In which whose component service life is predicted .for which a preliminary step is FMEA (FAILURE MODE EFFECT ANALYSIS) to identify the critical component in the press. Failure Mode and Effects Analysis (FMEA) uses Risk Priority Number (RPN) to evaluate the risk level of a component or process. The RPN index is determined by calculating the product of severity, occurrence and detection indexes.[14]

SI.NO	COMPONENTS	FUNCTION	FAILURE MODE
1.	Hydraulic Cylinder	A Barrel In Which The Piston Extends And Retracts. Seal Which Prevent The Leakage Of Oil And Spill	Oil Leakage • Seal Get deformed • Bore Diameter Enlarged • Internal and external leakage
1 a.	Piston Seal Rod seal		
2	Cushioning Cylinder	Cushioning support to the table to prevent the impact of piston against the job. Prevent oil leakage.	Fail to provide suspension to the table • Oil leakage • Cylinder get Deteriorated
2 a	Cushioning Cylinder Seal		
3	Motor	To run the pump to supply the hydraulic oil from intensifier to the cylinder.	Bearing get defected due to continuous operation. Coil failure.
3a.	Bearing		
3b.	Coil		
4	Switches	To operate the piston to and fro and ON & OFF entire machine	Failure due to continues operation Accidental failure
5	Solenoid Valve	To trip the extension and retraction stroke of piton in the cylinder	Coil failure inside the solenoid valve. Absence of tripping action.
6	Pressure Relief Valve	To release the high pressure fluid to the cylinder. when it reaches the working pressure 120 bar	Failure in disk and lip portion Leads to escape of fluid at low pressure
7	Oil	Source to operate the piston to and fro inside the cylinder	Contaminations affect the function of oil. Affects the other subcomponents
8	Hydraulic Hose	A supplier of hydraulic fluid to and fro from cylinder	Failure of hose ends due to high pressure and continuous impact. Which leads to leakage of oil at the ends.
9	Pump	pump and supply hydraulic fluid at pressure 120 bar	Inner surface get detoriated
10	Cooling Fan Bearing	To cool the hot oil coming from cylinder during retraction.	Failure results increase temperature of oil lead to physical damage to the seal ,hose , and cylinder too Failure occur due to failure of cooling fan bearing

Hydraulic cylinders and hydraulic oil are one of the basic components in the drives of heavy duty machines equipment. One of the main directions in R&D of hydraulic cylinders is the sealing system of the cylinder, especially the sealing of a piston rod. The development is focused on the elimination of oil leakage into the environment, the reduction of friction and extension of operation time. The proper design and assembly of sealing components enable the extension of durability and operational reliability. [9,10,11]

TABLE II ACTUAL MAINTENANCE PRACTICE

Components	Period of replacement	Disadvantage	Condition
Rod seal	9 months	External leakage	If Production cycle > exact service life
Piston seal	1 year	Sudden internal leakage , not exact service life , cost of seal maintenance	
Oil	1 Year	Loss of lubricating properties, Effect other Components	

A periodic maintenance practice is carried out in the press unit. In which the series of components are studied and a periodically the condition is monitored and replace if necessary .A period interval of 6 months – 1 year is set. And the components condition is monitored.

PROBLEM IN ACTUAL MAINTENACE:

1. Exact service life component is unknown
2. Not predictive one, sudden failure may occur
3. Loss of machine down time cost, labour cost, balance life of the component.
4. Labour dependable
5. Stocking excess inventory in warehouse

VI. EXPLICIT DYNAMIC ANALYSIS:

ANSYS explicit dynamics engineering simulation solutions are ideal for simulating physical events that occur in a short period of time and may result in material damage or failure. These types of events are often difficult or expensive to study experimentally. Simulation provides insight and a detailed understanding of the fundamental physics taking place and gives engineers a chance to make necessary changes before their products are put into service, when mistakes in design can be costly. ANSYS Explicit STR technology enables users to complete their analysis significantly faster than with any other tool in the industry. Competition and economic conditions demand innovative, reliable products that can be designed, manufactured, tested and delivered to customers quickly. At the same time, manufacturing and material costs continually need to be reduced. ANSYS Explicit STR software operates within the ANSYS Workbench platform, which provides a seamless interface to CAD geometry for analysis, automatic meshing and parametric design optimization; users can leverage their expertise without needing to deal with arcane details of simulation methods.

OIL ANALYSIS:

Oil analysis is a powerful condition monitoring tool and an important contributor to plant reliability. This technology can be applied in both predictive maintenance and failure root cause investigation and is a keystone of proactive maintenance.

BACKGROUND ON THE SACODE METHOD:

The SACODE method is a systematic method of oil analysis interpretation, where:

1. "sa" stands for individual oil properties "co" stands for contaminant materials in the oil, and "de" stands for wear metals

The following measured properties can be categorized relating to oil health (S), contamination (C) and wear (D).

- Viscosity (S)
- Acid Number (S)
- Water (C)
- Oil Cleanliness (C)
- Zinc (additive) (S)
- Viscosity Index (S)
- Flash Point (S)

From the base of SACODE methodology, The viscosity analysis is considered. In which the oil sample is tested in a regular interval of period. And the viscosity deviation is studied and compared with the limits fixed.

VII. ANALYSIS OF ROD SEAL:

Explicit dynamic analysis of rod seal was done using ANSYS work bench.3D model was done using a CATIA V5 software .The model is meshed using ANYSY software. Figure shows deformation attained at 11lakh cycle [maximum deformation]

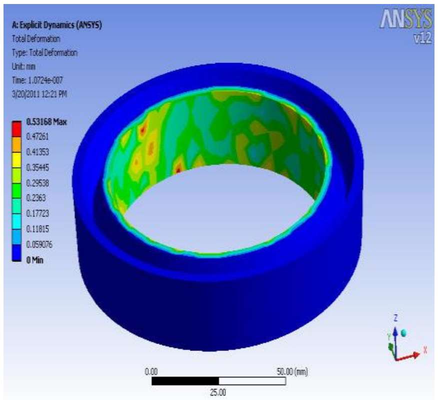

Figure 1 shows Deformation attained at 11lakh cycle [maximum deformation]

ANALYSIS OF PISTON SEAL:

Explicit dynamic analysis of Piston seal was done using ANSYS work bench.3D model was done using a CATIA V5 software. Figure shows Deformation at 13lakh cycle [maximum deformation]

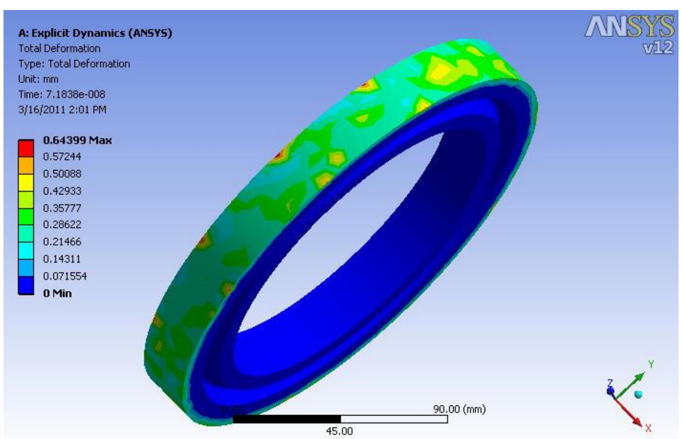

Figure 2 shows Deformation at 13lakh cycle [maximum deformation]

ANALYSIS OF HYDRAULIC CYLINDER BARREL:

Explicit dynamic analysis of cylinder barrel was done using ANSYS work bench.3D model was done using a CATIA V5 software .The model is meshed using ANYSY software. Figure Deformation at a maximum 13 lakh cycle

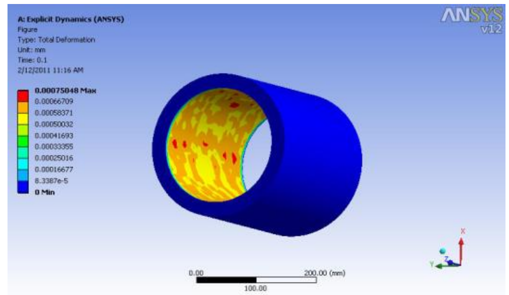

Figure 3 shows Deformation at a maximum 13lakh cycle

The deformation value is very minimum at the friction force applied. So the deformation of cylinder is neglected.

VIII. RESULTS

ROD SEAL:

Actual period of replacement: 9 months

Actual replacement cycles = 7, 26,276 cycles

Predicted replacement cycles = 11, 00,000 cycles

Service life saved = 3, 37,724cycles

The graph shows the deformation curve against the machine running cycles. The rod seal reaches the critical limit of 0.531 mm at a cycle of 11lakh. It is the life predicted by explicit dynamic analysis. At this point the seal reaches a maximum deformation limit which made the oil to leak externally

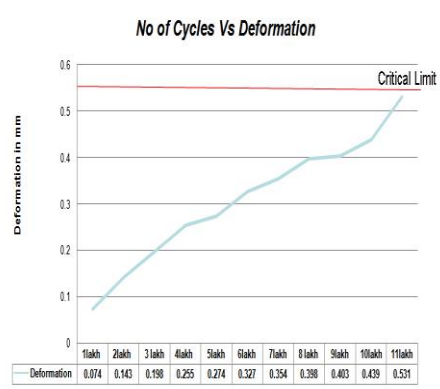

Figure 4 shows Rod Seal Deformation Curve Service Life Saved By Predictive Replacement

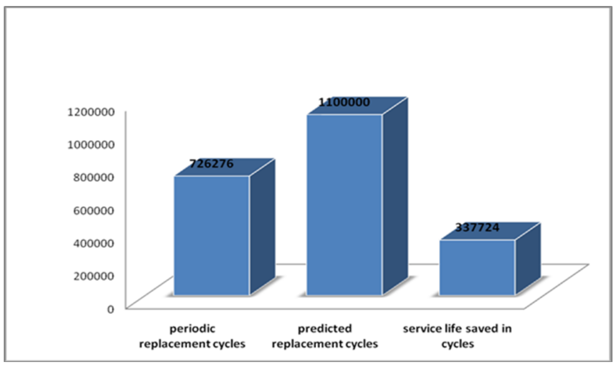

Figure 5 shows Rod Seal Comparison with Predicted and Periodic Maintenance

The previous replacement is made at interval of 9 months at a running cycle of 7, 26,276 cycles. By the above predictivereplacement at a life cycle of 11lakh. A life span of 3, 37,724cycles has been saved. The rod seal can be extensively used for 3 to 4 months than the previous replacement. The predictive replacement made seal to replace before the leakage occurs so it is possible to maintain the quality of the product and break down of the machine.

PISTON SEAL:

Actual period of replacement: 12 months

Actual replacement cycles = 10, 26,984 cycles

Predicted replacement cycles = 13, 00,000 cycles

Service life saved = 2, 73,016 cycles

The above graph shows the deformation curve against the machine running cycles. The rod seal reaches the critical limit of 0.643 mm at a cycle of 13lakh. Its is the life predicted by explicit dynamic analysis. At this point the seal reaches a maximum deformation limit which made the oil to leak internally.

The previous replacement is made at interval of 12 months at a running cycle of 10, 26,984 cycles. BY the above predictive replacement at a life cycle of 13lakh. A life span of 2, 73,016 cycles has been saved. The piston seal can be extensively used for 3 months than the previous replacement. The predictive replacement made seal to replace before the leakage occurs so it is possible to maintain the quality of the product and break down of the machine.

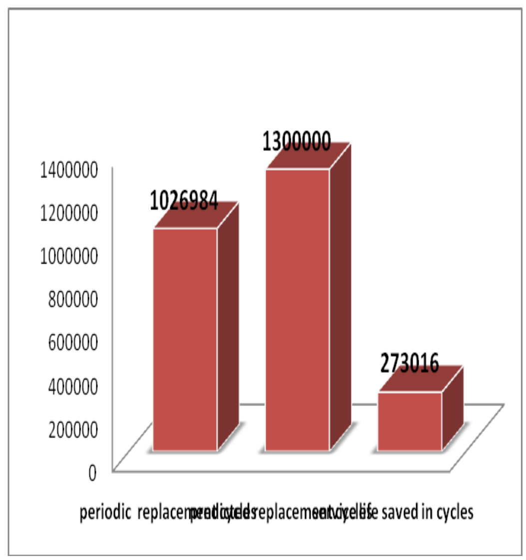

Figure 6 shows piston seal comparison with predicted and periodic maintenance

HYDRAULIC OIL:

Actual period of replacement = 12 months

Actual replacement cycle = 10, 26,984 cycles

Predicted replacement cycles =12, 76,748 cycles

Service life saved = 2, 49,764cycles

Above is a graphical interpretation of oil samples over a period with a caution limit of 72 Cst and a critical limit of 75 Cst .From the above analysis the oil reaches a critical point of 75 Cst at point of 12, 76,748 cycles. By the predictive replacement of hydraulic oil a service of 2, 49,764cycles is been saved from previous model.

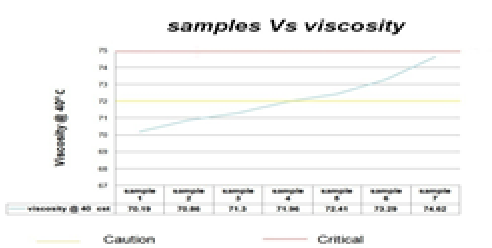

Figure Shows Viscosity Analysis Curve Service Life Saved By Predictive Replacement

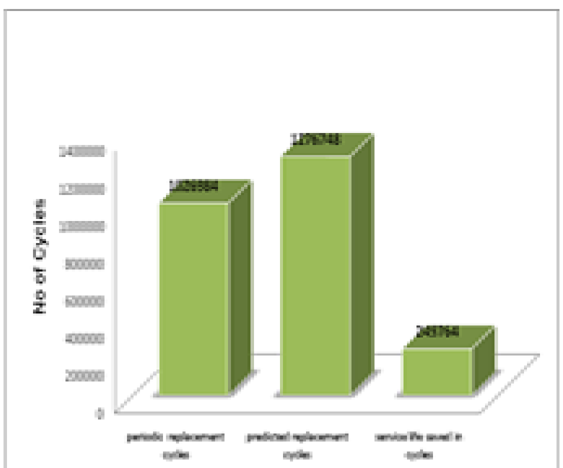

Figure 7 shows Hydraulic Oil Comparison with Predicted and Periodic Maintenance

The above graph shows the service life saved by predictive replacement model. The hydraulic oil can be extensively used for 3 months than the previous replacement.

TABLE III SHOWS COST SAVED BY THE PREDICTIVE MODEL

Components	quantity	Cost per year	Cost per month Rs	Service life saved in cycles	Service life in months	Total cost saved Rs
Hydraulic rod seal	1	2800	233	3, 37,724	4	1,000
Hydraulic Piston Seal	2	10,000	833.3	2, 73,016	3	
Hydraulic oil	261 litre	29,493	2457	2,49,764	3	

The above cost has been saved for a single machine .if the current model exists in the shop floor.

MAINTENANCE SCHEDULE:

By the above analysis, the predicted maintenance approach lead the machine to a zero breaks down. Below table show a maintenance schedule for the critical component to reduce the down time and cost incurred due to improper maintenance schedule.

TABLE IV SHOWS MAINTENANCE SCHEDULE FOR THE COMPONENTS

NO OF CYCLE	1,00,000	2,00,000	3,00,000	4,00,000	5,00,000	6,00,000	7,00,000
Rod seal	-	-	-	-	-	-	-
Piston seal	-	-	-	-	-	-	-
Oil	-	-	-	-	-	-	-

From the above maintenance schedule it's been studied that the lip seal has a lower life than piston seal. In order to make the maintenance down time unity. Both the lip seal and piston seal has to be replaced at a cycle interval of 11, 00,000 cycles. And the oil at an interval of 12, 50,000 cycles

CONCLUSION:

By the above predictive maintenance model schedule. It is possible to replace the component before failures occur. The Rod and Piston seal is to be replaced at a interval of 11, 00,000lakh cycles and the hydraulic oil is to be replaced at a interval of 12, 50,000lakh cycle. By the above model component can be replaced before failure occurs. The cost incurred in actual maintenance is reduced. Machine down time for maintenance can be reduced by once in a year by which the machine idealness in actual maintenance is reduced to unity. Inventory can be maintained in a limit with references to production cycle. Suggest going for a better material such as thermo plastics to lip seal. So that the life of the rod seal can be improved by which the maintenance cycle interval can be increased

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Dr. P.V Senthiil is currently working as Prof & Head, Mechanical Engg at St Peter's University, Chennai, India. He lectures modules in CNC machines, Rapid Prototyping and AI and Robotics. He is also guiding 11 researchers in different disciplines.

Dr. Senthiil’s work experience as a Factory consultant / knowledge transfer partnership associate working for electronic goods consumer industry in south Africa, France, UK. He was involved in developing, implementing & documenting operating procedures in advanced applications CNC industries for inventory reduction activities within various sectors of the company.

Prior to start of his research, Dr Senthiil was working as a Professor at Coimbatore Institute of Technology between May 1986 to Jun 2011. He did his masters in Mechanical Engineering at PSG Tech, April 1985, Bachelor's at PSG Tech, in Mechanical Engineering, April 1983.

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