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An Engineered Amelioration and Sustainability Enhancement Technique for Performance Upgrading of a Mechanical System

Mohammed Hasan Mustafa

Ministry of Science and Technology, Environment and Water Directorate

*Corresponding Author Email: mhmustafa_mmaqec@yahoo.com

ABSTRACT: The present work included an endeavor for an active pursuing of an engineered amelioration and sustainability enhancement technique deduced from matching between a recent developing qualitative approach and one of the advanced maintenance engineering methodology. That technique combined two technical approaches: (Site applications of quality characteristics evaluating and activating design standardization (SAQCEADS^{+})) and (pro-active maintenance). The research paper encompasses an applied case in practice through particular emphasis on some dynamic mechanical components of carrying idler assembly for a troughed belt conveyor equipment in an industrial sand conveying system for a casting unit. Improved new designs of those parts had been accomplished and also an analysis and assessment of their performance according to what had been executed for them in the design, manufacturing, and maintenance sides. The conducted improvements which were driven by the present work technique fulfilled the requirements for the application under study, significantly resulted in enhancing quality and upgrading performance of what had been dealt with through considering the present technique orientation by a ratio of about 50%. Pursuing of such a technique contributes for a possible avoiding of performance weakness and major problems that might occur in the system implemented for, and to enrich working life of it.

KEYWORDS: Mechanical System Maintenance Engineering, Quality, Performance, and Sustainability

INTRODUCTION

Maintenance engineering of plants, systems and infrastructures is multidisciplinary in nature, cutting across many disciplines of science and arts. The field of maintenance engineering is changing as rapidly as any other field. One of the main areas of those changes is the growing expectations of maintenance function .The maintenance profession, in general, underwent a transformation from almost dependence on time – directed tasking (preventive or planned maintenance) to much more condition – directed tasking. It is quite common to find that maintenance programs are initiated in response to a particular recurring problem or catastrophic failure. At the present time many sectors are still performing maintenance on machines and equipment in a reactive manner and that assures the necessity for a better understanding about machinery and equipment performance behaviour [1]. It is significant to develop the professionalism and practice for maintenance, replacement and design changes related to those elements (Parts), components and subsystems in the plants (Units or Systems) of several applications and sectors. In a world of competitive climate, the desire and need to reduce operating costs and improve quality have brought with them a need to focus on developing more efficient and effective maintenance techniques. It is of a great importance to pursue a maintenance approach that has been proven to work in one of the most demanding environments of the world today. Maintenance as a reliability function has a significant impact on system or (Plant) availability and reliability. Reliability identifies propensity for failure of a component (Part). It is an important need to deepen the understanding of pro-active maintenance (PAM) approach as a recent and advanced maintenance method, and to empower the maintenance and reliability community to perform PAM practices. Those practices and implementations allow prospering in today world of increasing performance with less recourses and different technical and management challenges within the economic implications involved. In the maintenance and reliability filed, professionals are constantly challenged to implement the best way to ensure equipment or machine is available as and when it is needed at a reasonable cost [2].

The present work attempts to focus its attention to the necessity for adopting and an active pursuing of the ameliorative technique by the maintenance departments in the services, utility, infrastructure and industrial

sectors, in order to pursue a more effective process for maintenance based on important considerations and evolving requirements of that technique.

METHODS AND MATERIALS

Some Considerations for Pro-Active Maintance (PAM) Approach

The cost – saving trend throughout the world is towards a maintenance program that targets the root causes of machine wear and failure, and also by establishing a pro-active line of defense against machines and equipment damage. Advanced and recent maintenance approaches target the warning signs of impending failure and the recognition of small failures that begin the chain reaction that leads to big failure (i.e., Damage Control) .

Condition –based monitoring of the machines and equipment has created the birth of the invisible wrench [3]. It is preferable for maintenance to refocus its efforts on condition monitoring activities during normal operation to uncover those defects or deficiencies requiring action. While production wants to reduce downtime and increase production, maintenance wants to take that one step further. Its advanced maintenance technique encompasses re-functioning pro-actively. By routinely monitoring the machines and equipment of the system dealt with so when testing shows something awry, downtime can be scheduled and supplies ordered in-time before failure occurs.

Pro-active maintenance (PAM) is the maintenance performed to head off failure and breakdown. While correcting machines and equipment failures efficiently and effectively is important, anticipating and heading off failures is also a major part of the maintenance management tool box [4]. PAM approach supplants the maintenance philosophy of "failure reactive" with “failure pro-active” by avoiding the underlying conditions that lead to machine faults and degradation. PAM is the discipline that takes a micro view on machine or equipment damage – concentrating on the causes instead of symptoms of wear. It is quickly being recognized worldwide as a more important method of achieving savings unsurpassed by conventional maintenance techniques [5]. PAM is an approach for identifying the enhancement of both the preventive and predictive maintenance techniques [1]. To further improve upon the practice of maintenance it becomes important to not only know if and when a machine or equipment will fail, but also to know why a machine would fail. This is a more advanced approach and requires both accurate and comprehensive measuring tools and expert knowledge to discern what mechanical problems are indicated by the data. This PAM approach attempts to single out the root causes for a failure and, in a sense, add life to machinery. When those root causes could be, as possible, removed or eliminated the result is an extended machinery life [6]. While the root causes of failure are many, or at least presumed to be, it is generally accepted that 10% of the causes of failure are responsible for 90% of the occurrences. Most often, the symptoms of failure mask the root causes or they are presumed themselves to be the cause [7]. PAM is an important means to cure failure root causes and extend machine life. PAM (or Prevention /based Maintenance) programs utilize predictive , preventive maintenance techniques with root cause failure analysis to detect and pinpoint the precise problems combined with advanced installation and repair techniques including potential equipment redesign or modification to avoid or eliminate problem from occurring [8]. An alternative of existing design should be under consideration as an option generally allows the design effort to be more productive and economical. Many times it is not possible to implement design changes due to complexities and cost considerations. In such situations operational reliability is intended to be assured through effective maintenance actions. Knowledge of the technical condition of the components is crucial to decide upon the type and frequency of maintenance actions required [9]. The advantage of PAM over other maintenance approaches is ability to pinpoint and eliminate a problem before any symptoms occur in the machine and that would save money and keep the machine out of the overhaul in the long run. PAM commissions corrective actions aimed at the sources of failure (Failure Root Causes, not just Symptoms). It is designed (and that is its central theme) to extend the life of machinery as opposed to : (1) making repairs when often nothing is broken (2) accommodating failure as routine and normal , and / or (3) preempting crises failure maintenance in favor of scheduled failure maintenance [5, 7].

IMPLEMENT THE AMELIORATIC TECHNIQUE

The present work attains an attempt to implement PAM approach through particular emphasis on some dynamic mechanical components of carrying idler assembly for troughed belt conveyor equipment in an industrial sand conveying system for a casting unit as an applied case in practice. The troughed belt conveyor had the following features; length between inlet and discharge: 9m; Angle of inclination: 20□; belt width: 650 mm; capacity: 5 ton/hr.

The ameliorative technique applied in this paper is characterized by comprehending the contents of the mechanical design regards associated with the maintenance function aspects, and by pursuing of a process for continual improvement [10]. That process comprises of detecting, analysis, and evaluating the existing situation, diagnosing reason for the amelioration action that should be undertaken for the system under research in the present work. The corner point is identifying possible solutions, evaluating the effects, and then implementation of the new solution. It is important to assess the effectiveness and efficiency of the process with the action of the ameliorative approach completed.

An active pursuing of (SAQCEADS^{+}) (Site Applications of Quality Characteristics Evaluation And Activating Design Standardization) approach [11,12] and pro-active Maintenance (PAM) approach [13, 14] had been performed in the implementing of an (Engineered Amelioration and Sustainability Enhancement (EASE) technique adopted in the present work .The work depends upon visual inspection of the above mentioned mechanical components (Elements), in addition to what had been facilitated to carry out some tests for the sake of assessment of the worn parts of those elements. Some adjusting procedures, primary routine maintenance, and sometimes replacements of some mechanical parts and elements of the equipment concerned with in the present work had been conducted previously and before proceeding the present work, but those actions don't prove reliability in the performance of those elements. This can be deduced from several faults, troubles, shutdowns and replacements that had been happened in the system causing major problems that could not be corrected with regular in–service actions. Performance is a dimension of quality that refers to the efficiency in which a part or an element performs its intended purpose [15]. Unsatisfactory functional performance represents a sign of asset failure [16]. A lack of accurate and dependable historical data about those events had been pointed out and that represents one of the main limiting factors in applying PAM approach. Downtime prompts upgrading of the equipment for enhancing performance. An analysis which is one of the maintenance performance measures (Metrics) had been made by analyzing number of failures per period per category of the system under study in the present work. Those failures are due to: defects of some mechanical parts and elements, mechanical design deficiencies and process upsets. The analysis of failed components can indicate the need for the present ameliorative approach. The analysis is performed to review several condition – based maintenance for detected and investigated failures. The implemented amelioration and sustainability enhancement (EASE) technique in the present work encompasses: identifying and documenting available data as a history of the equipment that had been gained from the unit site concerning the equipment dealt with herein (there is a noticed lack in that issue); determining the cause and effect factors as they become apparent and making changes in the operation and maintenance functions as they affect the overall uptime.

The important functions (of a piece of equipment) to preserve with routine maintenance were identified, their dominant failure modes and causes determined, and the consequences of failure ascertained. A combination of operation and maintenance, as well as design, and purchasing (of some standard items in the above mentioned mechanical assembly according to the reliable standard specifications), manufacturing of the mechanical elements due to their updated designs were required in order to truly address the implicated problems.

RESULTS

After Studying, analyzing, and evaluating the factual findings of the equipment under study in the present work, it is a must to change the designs of the equipment defected parts so as to comply with the requirements of the detailed mechanical and process designs and also the required performance of it in the system . That can be considered as an engineering judgment based upon what have been previously mentioned above. Equipment redesign had been considered where no predictive or preventive task is available to avoid failure happened in the existing equipment. Design modification is an alteration (to the configuration of carrying idler of the troughed belt conveyor in the applied case within the present work) driven by the ameliorative technique to improve reliability, safety margin, and operational performance. Application of design changes for improvement of system reliability had been dealt with in several efforts such as that cited in [17].

A design process for equipment upgrading and reliability improvement had been conducted, and improved new designs for the carrying idler of the troughed belt conveyor had been accomplished as shown in "Fig. (1)" as a more constructive solution and a more proactive approach. In those designs some important considerations of the ameliorative approach had been carefully taken into account after manifesting what it comprises of conceptual regards. An analysis and assessment of those elements performance due to mechanical design point of view had been made. The considered mechanical assembly had been modified by a redesign effort work which succeeded to significantly improve maintenance and equipment performance. Design updating and improvements conducted

on the existing parts which were driven by the ameliorative approach fulfill the requirements for the application under study, significantly result in maintenance effectiveness promotion, increasing its efficiency, enhancing quality and reliability of those elements and components involved , and upgrading performance of the equipment of the system concerned with. Mechanical design point of view should be given proper considerations for manufacturing above mentioned parts and elements .Greater challenges arise when the design must meet two or more conflicting objectives (such as minimizing mass , volume , cost , and environmental impact [18]. Other specialized maintenance engineering efforts through some adjusting and improving procedures had been carried out to the equipment in order to boost its performance and improve system reliability.

Condition – based monitoring of the subsystem dealt with in the present work and the analysis that had been undertaken rather than turning wrenches as in conventional maintenance practices had well impacted the system of the unit. The implemented PAM approach in the present work to enhance reliability and improve performance of the equipment concerned with revolves around three principal maintenance techniques or activities: predictive, condition – based and reliability – centered.

Pursuing of the ameliorative technique adopted and conducted herein returns several outputs for the system dealt with such as:

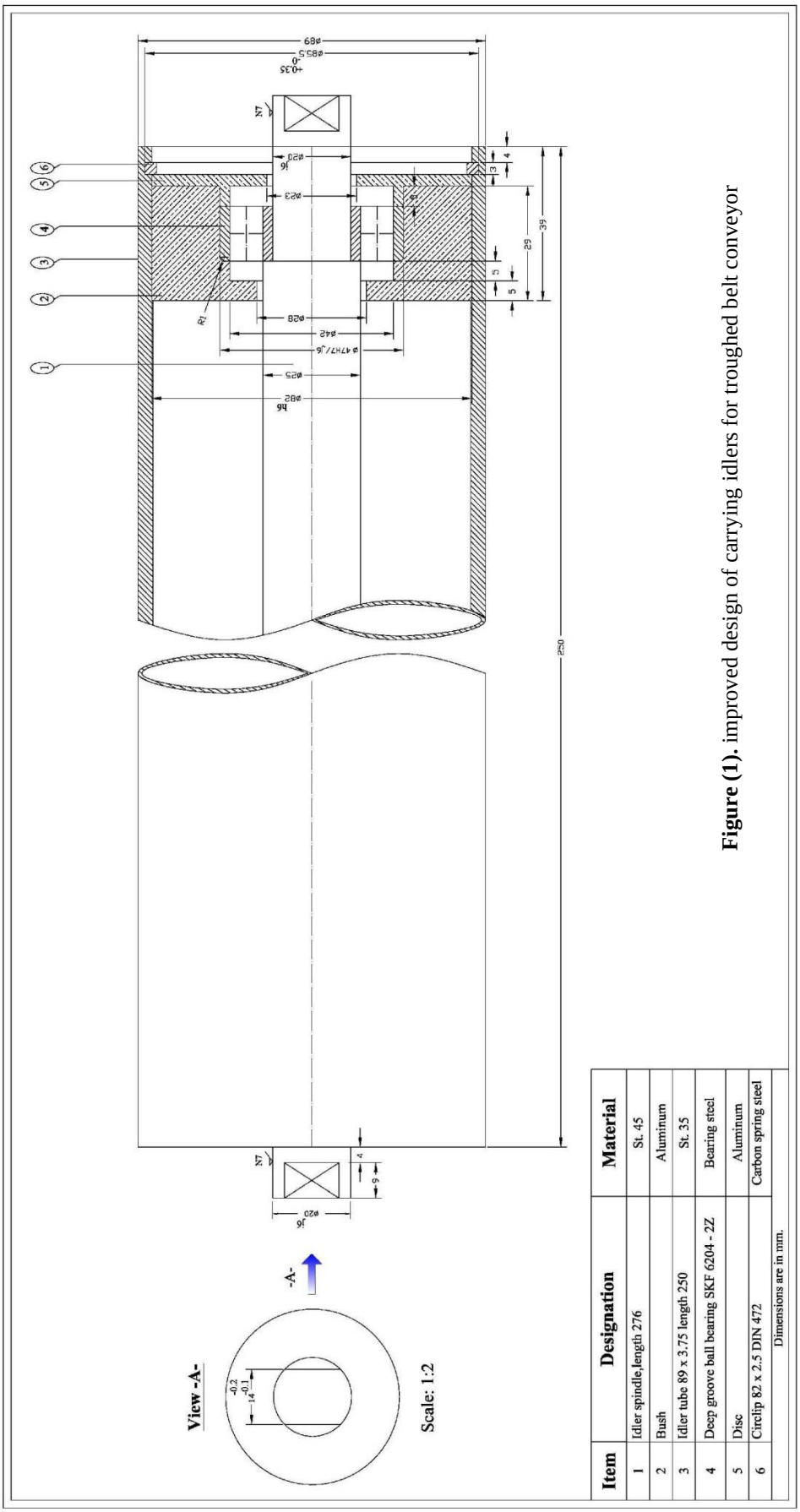
1- Minimizing unplanned downtime while maximizing safety and operational availability.

2- Minimizing inspection overhauls.

3- Reduced maintenance costs through minimizing requirements for time directed maintenance.

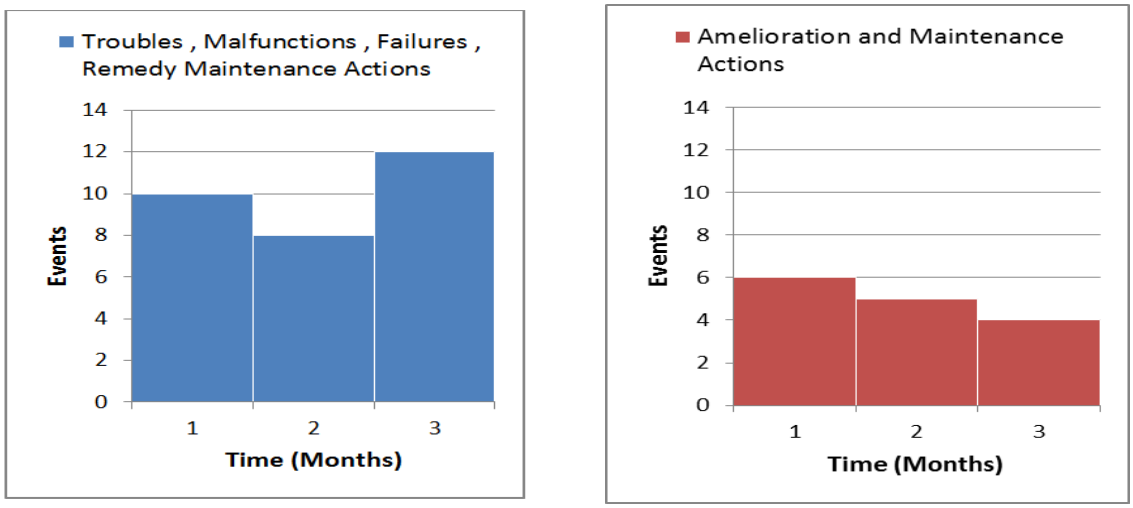
4- Improving system operational flexibility and being able to tune the maintenance with other process factors.

A Comparison of events that had been occurred in the system dealt with before implementing of the present work technique and during its investigations, and after implementing of it was showed in Fig. (2) – A and B respectively within three months for each case. Case B didn't involve serious and affecting events (such as that stated in case A), but it included amelioration and maintenance actions according to the present work approach which resulted in an enhancement of performance of what had been dealt with by a ratio of about 50%. Additional savings over conventional maintenance programs could be yielded by implementing such a technique.



Item	Designation	Material
1	Idler spindle,length 276	St. 45
2	Bush	Aluminum
3	Idler tube 89 x 3.75 length 250	St. 35
4	Deep groove ball bearing SKF 6204 - 2Z	Bearing steel
5	Disc	Aluminum
6	Circlip 82 x 2.5 DIN 472	Carbon spring steel

Figure (1). improved design of carrying idlers for troughed belt conveyor



A

Before Implementing of Present Work Technique and During its Investigations

B

After Implementing of Present Work Technique

Figure (2). comparison of events before and after implementing of the present work technique

DISCUSSION AND CONCLUSIONS

1- Performance upgrading, improving system availability, and enhancing reliability through anticipating to eliminating failures by an active adopting and implementing the ameliorative technique in the present work as its main targets had been satisfied.

2- Applying the ameliorative technique in the present work had led to an improved process for facilitating maintenance function by avoiding unnecessary preventive maintenance through condition knowledge; and by constantly being pro-active in seeking to improve reliability and uptime. It summed up the case for quality, sound engineering and good design.

3- Understanding and implementing the present work technique and sustainability related practices is essential. That endeavor could promise to advance maintenance programs to higher levels of achievement and prompts the mechanical group in the related maintenance department and management to re-evaluate their current maintenance practices.

4- Equipment history must be documented accurately to be useful and effective in the maintenance that would lead to a better implementing of the action of plan.

5- PAM approach is a valuable tool which can yield substantial improvements in equipment performance. PAM approach implementation should emphasize elimination of failures that require maintenance in away pertaining to pre-act instead of react. What the successful facilities accomplished didn't come without considerable effort and change of attitude, focus and commitment to a future where they are able to be proactive rather than reactive. That might be considered as "mastering the maintenance process" [19].

6- Some developing considerations for the implemented technique in the present work concerning its scope and suggestions for future research directions and improvements in the followings appear to be worthy:

   a) Establishing and enhancing implementation and promoting sustainability of a more struggling and a properly developed and managed program to be as a PAM tool introduced at the unit or facility and would help the unit in the long run for the system dealt with in the present work is significant. Also, widening the case studied herein by considering other equipment of that system is worthy to develop asset management strategy for its activities and components.

b) Getting use of a technological system that enables a better manufacturing of dome-end idlers and rollers for the troughed belt conveyor which produces superior dome-end form is considerable.

c) It is an important responsibility to update the maintenance and reliability engineering practices and programs by considering several aspects of PAM as a radically innovative approach and a breakthrough strategy in maintenance improvement to meet utilities and infrastructure sector needs. That could prompt technical excellence in maintenance, moving from a reactive to a pro-active culture.

d) It might be considerable to entrench continuous improvement beyond PAM. New directions in the 21st century (the evolution of maintenance organization) are to move from maintenance management to physical asset management [20]. A strategic approach to achieve maintenance excellence is to get the technology, process, and people mix right.

e) It is an important need to transfer knowledge and technologies for machinery diagnosis and prognosis in terms of failure prevention strategies and condition monitoring approaches, to provide an advanced methodology through technology convergence. Machinery health monitoring and management is developing in the recent and advanced maintenance engineering practices. Sustainable asset management links assets, people, and processes for results, and presents new ways of maintaining and improving assets in utilities.

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