Quality build plans significance to guaranteeing physical assets reliability

Peter Muganyi

Department of Engineering Management
University of Johannesburg
Johannesburg, South Africa
peter777.muganyi@gmail.com

Charles Mbohwa

Faculty of Engineering and the Built Environment
University of Johannesburg
Johannesburg, South Africa
cmbohwa@uj.ac.za

Abstract

The study was undertaken to examine how documented systems are used to aid the activities that were applied to ameliorate physical assets reliability. A documented system referred to as a quality build plan was applied in a re-build workshop to give guidance to repair and assembly procedures in a workshop set up. The equipment that were included in the workshop comprised of gearboxes and pumps, of which detailed steps of repair or assembly had to be followed in order to ascertain correct functionality and reliability. The study sought to unveil the effect of the composition of the documented quality build plan and how significant the impact was, on the ensuing physical assets reliability in the occasion of full compliance or deviation from the specified actions. The specified actions of the quality build plans were assessed to reveal their impacts on the resultant physical assets reliability.

Keywords

Quality build plan; documented system; reliability; physical asset; assembly procedures.

1. Introduction

The repairing of hardware breakdowns and restoration of functionality requires the performance of maintenance procedures which follow a sequence of tasks (Zhang et al., 2017:150). Procedures are used on different categories of equipment and applied in numerous industrial applications, to give repeatable results on findings or performance (Bianchini et al., 2018:1). A documented maintenance procedure is designed in such a way that it specifies an arrangement of activities for detecting failures, refurbishing a component, re-establishing reliability or modifying a particular piece of equipment (Reed and Lofstrand, 2016:478). A procedure may be intricate if it features multi-probable mission consequences, synchronized mission accomplishments and application to multi-component multi-state arrangements (Reed and Lofstrand, 2016:478). A procedure should ensure that it is fully detailed and optimized for effective performance in regard to attaining expected results, planned execution period, resources utilization and safety/environmental aspects (Reed and Lofstrand, 2016:478).

The inspections and maintenance of production and infrastructural assets mostly culminate in repairs which assume perfect or imperfect outcomes, which require maintenance procedures in one way or another (Özgür-Ünlüak and Bilgiç, 2017:652). The participation of maintenance engineers, allocation of adequate resources, documented maintenance procedures, effective maintenance plans as well as skilled artisans, were cited as the principal factors for the maintainability and reliability of workshop refurbished equipment (Tsarouhas and Makrygianni, 2017:1895).

2. Limiting factors on maintenance procedures effectiveness

Maintenance diminishes the quantity of incidents, expands the efficiency of, and raises the lifespan of the physical asset, thwarts massive repairs expenses and unanticipated failures, improves asset availability, and heightens the safety and reliability of manufacturing assets (Islam et al., 2017:418). As a move to improve the effectiveness of equipment repairs, it is essential to appraise and compute humanoid performance in maintenance procedures, and techniques such as the human reliability assessment technique that has been applied before in this regard (Islam et al., 2017:418).

Human error is the prevalent aspect that affects the effectiveness of the maintenance tasks during maintenance procedures (Islam et al., 2017:416). The dominant causes of the human errors comprise: insufficient training and skills, ineffective communication, poor clarity of tasks requirements, insufficient maintenance process monitoring, worker fatigue, stress and failure to concentrate on task (Islam et al., 2017:416). Also, internal and external aspects influence the artisans' performance while executing maintenance procedures such as weather conditions, workplace temperatures, noise levels and vibrations, over and under workload/stress (Islam et al., 2017:416). If it were not because of prevalent human errors, which are regarded as a component of daily function for industrial employees, then there would be no need to establish procedures for maintenance tasks (Noroozi, et al., 2013:252). Errors are undesirable as part of work life, but they constitute some intentional and unintentional aspects of human behaviour which can sometimes be attributed to lack of attention to the task at hand (Noroozi, et al., 2013:252). Various reasons are attributed to maintenance errors occurring and they encompass poorly designed work layout, improperly documented maintenance procedures/work instructions, unsuitable working tools/equipment, complicated maintenance duties, intolerable environments (such as very hot or cold temperatures, high humidity and high noise), fatigue, obsolete maintenance instructions and insufficient training and experience (Noroozi, et al., 2013:252). Highly experienced maintenance repairmen with higher emotional stability, less incidents of fatigue, and greater work motivation have higher probabilities of not committing errors during maintenance activities (Noroozi, et al., 2013:252). The errors in maintenance activities and the delay of tasks completion are both undesirable factors and techniques such as simulation are usually applied to evaluate maintenance procedures for effectiveness (Zhang et al., 2017:150).

3. The need for documented maintenance procedures

Without the use of a maintenance procedure which is documented, it is highly probable to perform tasks erroneously or for tasks to take much longer to accomplish than expected (Zhang et al., 2017:150). Complex repair processes may require procedures that call for the likes of techniques that apply Genetic Algorithms to find fitting solutions within reasonable times and computational effort (Zhang et al., 2017:150).

When machines are fabricated or refurbished NOT according to a standard specification, their ensuing performance will be greatly compromised and the resultant reliability is not guaranteed (Tarefder et al., 2016:20). When maintenance activities are done according to experience only, it is probable that the procedure will disappear in the advent of the departure of the experienced workman, so documentation of crucial maintenance procedures is imperative for repeatability in maintenance outcomes (Tarefder et al., 2016:20). Therefore documented maintenance procedures are essential to maintain the best practices of carrying out specific maintenance tasks and to ensure repeatable performance of maintenance activities is upheld.

The risk-based inspection traits and human error traits should be incorporated in the development of maintenance inspection focused procedures (Noroozi et al., 2014:131). The risk rating takes the form of the table displayed below.

Table 1: Risk rating table (Noroozi et al., 2014:140)

Category	HEP	Consequence severity				
		Critical (C)	High (H)	Medium (M)	Low (L)	Warning (W)
A	0.10 – 1.0	1A	2A	3A	4A	5A
B	0.01 – 0.10	1B	2B	3B	4B	5B
C	0.001 – 0.01	1C	2C	3C	4C	5C
D	0.0001 – 0.001	1D	2D	3D	4D	5D

Some researchers have vouched for various quantitative techniques for human errors probabilities in maintenance procedures, and these include the likes of SLIM, HEART, and TTHERP (Noroozi et al., 2014:132). The HEART technique is used for evaluating human errors centred on the tasks demands, the dominant risks pertaining to the task and the prospects of recovering from the error(s), and it generates reliability and risk equations, which take into account the ergonomic factors that have significant bearing on performance (Noroozi et al., 2014:133).

Training on the developed maintenance procedures is one crucial element that need to be effectively carried out if the application of documented procedures has to be successful. Training on maintenance procedures can take any format, and these days, the computerized training applications are prevalent in the engineering field for the training of maintenance personnel (Borsci et al., 2016:41). The computerized training applications are these days mostly carried out in virtual reality 3-D scenarios to afford training participants to experience the training content in a virtual world where real items, settings, apparatuses, and movements can be simulated and interact with the participants (Borsci et al., 2016:41).

4. A practical application of Quality build plans in a chemical manufacturing industry

The application of quality build plans was reviewed in a chemical manufacturing industry in South Africa, where the maintenance workshop personnel developed documented maintenance procedures which they termed quality build plans. The documented procedures were applied to ensure that any workshop installation, repair, refurbishment or critical machine repairs in the field were done systematically within proven time frames and maintenance standards. The machines covered in the workshop included pumps, gearboxes and tank installations and repairs. The table below shows an extract from a documented maintenance procedure that dealt with the guided selection and installation of chemical gaskets in a flanged joint.

Table 2: Gasket selection table

Duty	Caustic soda 50%, Caustic Filtrates	Sulphuric Acid 98%, Acidic Filtrates	HP Air LP Air	Sasol Gas, Vacuum Air, HP Air, LP Air	Fuel oil Oil (hot/ cold)	Liquor, Pulp, Acidic Filtrates, Effluent 30% Acid	Water	Steam Joints – rough flange faces	Steam LP HP
Gasket	Hygrade LS	TopChem 2003	CRIR Spiral Wound gasket	C4430	CRIR Spiral Wound gasket	Hygrade LS	Neoprene	Hochdruck	CRIR Spiral wound gasket
Colour	*White*	*Creamy White*	*Green /yellow*	*Creamish white*	*Green/ yellow*	*White*	*Black/red/purple*	*Grey*	*Green/ yellow*

				top/ green back			*rubber*		
Flange type	*Weld Neck, Flat Face*	*Weld Neck, Flat Face*	***Weld Neck, Raised Face***	*Weld Neck, Flat Face*	***Weld Neck, Raised Face***	*Weld Neck, Flat Face*	*Weld Neck, Flat Face*	*Weld Neck, Flat Face, Class 300*	***Weld Neck, Raised Face***

The documented quality build plan had specific instructions on how the maintenance tasks had to be carried out and detailed the tools that had to be used for each and every step. The values to be attained during the maintenance activities were also documented to ensure that there was full compliance to desired maintenance specifications. The table below shows the instructions that were included in the quality build plan.

Table 3: Maintenance tasks description (Extract)

Task #	Activity description
1	Select correct gasket, refer to table above · check the condition of the new gasket by inspecting the following: Inspect the gasket material for possible defects such as bends or creases
2	Select correct bolts / studs / nuts / washers. Only Grade 8.8 bolts. · Bolts/studs should be free of dirt and corrosion . The studs should be straight and the threads free from nicks, burrs and chips. · If re-using old ones then make sure they are in good condition - clean them and make sure nuts turn freely. . If making a high pressure joint, e.g. HP Steam, use studs and nuts instead of bolts and nuts. · If the joint had been injection sealed, all the bolts and nuts will be renewed. · Bolts/studs must be long enough to allow two threads to protrude from the nut after fastening.
3	Check condition of flange faces · inspect the mating flanges for dirt, mechanical damage and corrosion . The contact area of the flanges should be free from excessive pitting, radial tool marks and scratches . Clean away any old gasket material . Be certain that solvent for cleaning stainless steel items does not contain chloride · Make sure that the concentric grooves are in good condition – no radial scores / damage to grooves. · Make sure that flanges are not distorted
4	Lubricate the bolts / studs and washer / nut bearing surfaces with Nickel anti-seize lubricant. · Use only approved thread lubricants, prevent lubricant from entering the pipe
5	Locate new gasket centrally · Do not use jointing pastes on any gasket.
6	Align flanges properly without the need for excessive force. . The holes should be lined up so the studs can be inserted freely. . Look for any special markings that may indicate a specific alignment is required · (From ANSI B 31.3): Angular less than 0.3 Degrees (1 mm in 200 mm) Parallel less than 3 mm.
7	Insert bolts/studs, washers & nuts, and tighten by hand. . The gasket shall be properly handled to avoid damage . Check that alignment of the flanges is OK · Angular alignment and parallel alignment . Tighten all bolts / studs in a cross-tightening pattern (see Appendix B for tightening sequence). It is recommended that if there are more than twelve bolts, they should be numbered to aid identification.
8	------------------
9	------------------
10	------------------

Further to the documented instructions in the quality build plan, graphical illustrations were also added in the quality build plan, such as the figure shown below.

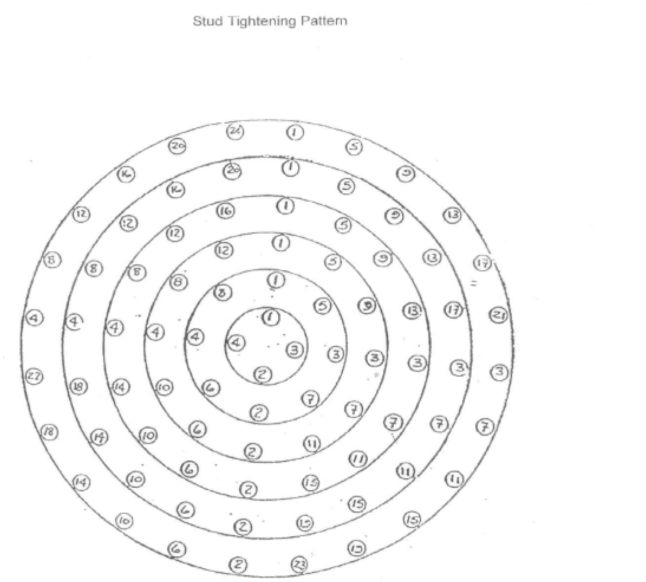

Figure 1: Stud tightening pattern in quality build plan

In terms of training on the documented quality build plans, it was imperative that the maintenance artisans were competent enough to carry out the required tasks as the following training and competence requirements were specified in the documented procedure:

1. Only validated joint makers shall be permitted to make gasketted joints.
2. All joint makers shall undergo formal training by nominated validators to ensure that the principles specified in this procedure are understood and complied with.
3. Upon satisfactory completion of training the joint makers shall complete a Validation Questionnaire.
4. Only after successfully completing the Validation Questionnaire shall the joint maker be deemed validated and have his/her name entered onto the validation register maintained by the Training Department.
5. A register of all joint makers will be maintained.
6. A register of all joint validators will be maintained.
7. All joint makers' validations shall be reviewed on a bi-annual basis by completion of the Validation Questionnaire.

A supervision or quality checking protocol was also put in place according to a checklist which needed to be completed every time when the maintenance task was completed. Table 4 below displays the checklist that was used for checking the quality of workmanship after task completion.

Table 4: Task completion checklist

ITEM	**Artisan**	**Foreman**	**Task Leader**	**Inspection Method/Tool**
CLEANLINESS OF FLANGE FACES				
CORRECT GASKET INSTALLED				
CORRECT SIZE OF BOLTS				

FLANGE SQUARENESS CORRECT				
JOINT FREE OF STRESS				
TIGHTNESS OF BOLTS CORRECTLY TORQUED				
TRUENESS/DEPTH OF SPIGOTS CORRECT				
NUMBER OF THREADS PROTRUDING				

5. Discussion

The developed quality build plans or maintenance procedures showed that the documented systems guaranteed repeatability of maintenance outcomes such as repair times and reliability levels. Documented systems prevented variability in the procedures used for the specific maintenance tasks. It was shown that the requisite training and competency had to accompany each and every developed and documented quality build plan, along with the necessary quality checks and supervision during execution. The major factors to be considered for the documented quality build plans to be effective in attaining guaranteed equipment reliability were found to be:

- The relevant training, competence level and experience are necessary to ensure that relevant skills are applied on the maintenance tasks. The training methods however, need to be quantified for cost effectiveness as aspects such as the expenses, complexity and geographical spacing of training participants need to be taken into consideration
- A checking or supervisory mechanism to confirm compliance during each job is essential to ensure compliance to documented specifications
- Before a documented procedure is launched, it is supposed to go through a validation process to confirm its viability, applicability and simplicity
- The documented procedures need to be comprehensible and easy to understand procedures to all users of the procedures
- The documented procedures need to be kept updated with the prevailing circumstances and technologies
- The documented procedures need to be well communicated and easily accessible to all users
- The right environments/ ergonomics need to be available always to enable maintenance workers to effectively carry out their duties
- The correct maintenance tools and equipment need to be available always to enable the effective carrying out of maintenance tasks

6. Conclusion

Documented quality build plans are essential for eliminating human errors and to ensure that the performance of maintenance crews is repeatable. The reliability of equipment is guaranteed if the maintenance team uses documented quality build plans or procedures for their equipment repairs, overhauls and refurbishments. The main reason for applying documented procedures is to prevent human errors and avoiding maintenance crews to use unoptimized methods of task completion which may result in unnecessary delays and expenses. The issue is not just about documenting the maintenance procedures, but it is about ensuring that the procedures are made available and trained on the relevant personnel that are going to use the procedures in their task execution. The relevant and effective training methodology need to be applied to ensure the right competence is imparted to the users of the documented procedures. Thus, when applied correctly, the documented quality build plans are an assurance of physical assets reliability after maintenance actions have been taken on a piece or assembly of equipment.

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Biographies

Peter Muganyi is a doctoral candidate in Engineering Management at the University of Johannesburg, South Africa and he is an Engineering Manager at Gyproc. His research interest covers the areas of Lean Six Sigma effectiveness, Strategic Maintenance Systems deployment and Business Process Modelling.

Professor Charles Mbohwa is the Vice-Dean Postgraduate Studies, Research and Innovation at the University of Johannesburg's (UJ) Faculty of Engineering and the Built Environment (FEBE). As an established researcher and professor in the field of sustainability engineering and energy, his specializations include sustainable engineering, energy systems, life cycle assessment and bio-energy/fuel feasibility and sustainability with general research interests in renewable energies and sustainability issues.