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Bangladesh J. Sci. Ind. Res. **44(3)**, 319-326, 2009

BANGLADESH JOURNAL OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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Maintenance Integration in Equipment Design Process for Africa

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Abstract

The integration of the maintenance as soon as possible in the design allows reducing the possession cost of equipment. This factor being major for the users of agricultural and food processing equipments in Africa, the objective of this study was to answer this requirement. In order to satisfy this need, a critical approach of the tools developed in the industrialized countries and an analysis of the maintenance practices in developing countries permit to suggest several tools and recommendations for integration of the maintenance in the design.

Key words: Africa, Design, Equipment, Integrated maintenance

Introduction

When using agricultural and food processing equipments for small scale agricultural products transformation in Africa, the maintenance shortcomings often affects the users. Among the factors generally raised to explain these equipments unreliability, one specifically notes the lack of quality of the work materials, which may come from the scrap materials at the end of their life cycle, the insufficient mastery of the rules of art at manufacturing level, the inappropriate use by the users who turn the equipment away from his normal conditions of use, the remoteness of the actors enable to ensure the after-sales and repairing service. The maintenance is most of the time undergone by the user, knowing that the maintainability and reliability of the equipment have not been really taken into account by the equipment manufacturer at the steps of design and manufacturing (Azouma, 2005; Giroux and Marouzé, 2006; Bationo, 2007). In this context, it appears important to integrate maintenance as early as possible in the coming equipment design first steps. From the statement that integrating maintenance in the design requires a feed back of experience and a capitalization process of the use, the present study will first analyze the relevance of the main tools and methods of maintenance developed in design by manufacturing industries of Northern countries where the working availability and safety constitute a major competitive advantages, in regard of technico-economic and social context of developing countries. An analysis of the local practices of maintenance in Western Africa, achieved from a survey will allow to catch the constraints and the factors to be taken into account in the design. This work was also enriched by an experimentation achieved on the design of an animal-drawn manure spreader for small farms in Africa (Azouma *et al.* 2007). Finally, from all these factors, some recommendations will be proposed to inventors in order to facilitate, thereafter, maintenance at the use period of the equipments.

Materials and Method

After an overall state-of-the-art of equipment maintenance in developing countries (Starkey, 1994; De Groote, 1995; Diallo, 2000; Tchinda, 2000; Haque *et al*. 2001; Baryeh and Raikane, 2003; Patric et al. 2005) and an analysis of maintenance methods in industrialized countries (Monchy, 2000; Treillon *et al.* 2004), an inquiry has been performed on 12 equipment manufacturers and 47 equipment users in Benin, Burkina and Togo (Figure 1). After a brainstorming on maintenance issues in the savanna region of Togo with 19 peasants, an investigation has been conducted on 28 users owing globally 71 machines comprised of 21 types including 7 agricultural and 14 food processing equipments. These investigations are carried out with the method of the Professor Shiba (1995) which allows, with the interrogation of a dozen people only, to collect at least 70% of the useful information. We visited and essentially interrogated peas-

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ants, food processing equipment users, and Small and medium enterprises (SME) in Togo and Burkina Faso. The data have been treated on Excel software and manually for open questions.

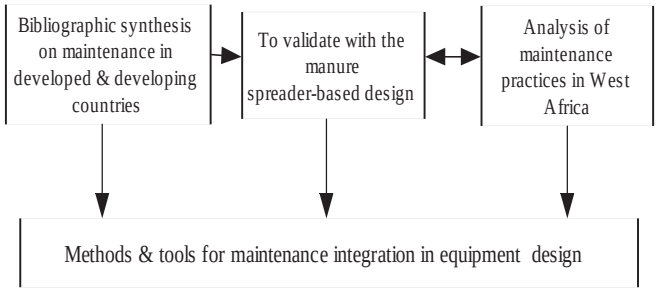

Fig. 1. Research process for the integration of the maintenance in the equipment design

Results and Discussion

The aim of this paragraph is to summarize and put on discussion the results of the analysis of maintenance tools and concepts developed in industrialized countries and maintenance practice in developing countries a design team could use in an African country.

In that narrow environment of developing countries the design teams according to their level of expertise can appropriate concepts (**) analyzed in Table I but their setting remains especially the Mean time between failure (MTBF) and Mean time to repair (MTTR) difficult (*) because of the lack of basic information on experience feed back. These concepts do not aim at health and security rules observance related to equipment users, and consumers of products coming from food processing equipments (*) whereas Preliminary hazard analysis (PHA) easy to be appropriated and executed (**** or ***) by a design team can meet this need (****). In the context of single item or small scale agricultural and food processing equipments manufacturing, Single minute exchange of die (SMED) is unsuitable (*) as the down times are prejudicial neither for the equipment manufacturer nor for fresh food producer. From this bibliographic study of maintenance, issues in developing countries are classified in Table II. Generally, we note that there are more operational availability issues than machines intrinsic availability issues that is to say the logistic support is important. The user is particularly interested in the industrial system life term he has to capitalize, to redeem, and to renew his investment in order to continue the production.

Table I. Concepts and tools maintenance relevancy used for design in developed countries with regard to developing countries conditions and users expectations

Concepts & Tools	Relevant criteria with regard to design in developing countries					
	Design team Appropriation ease	Design team work execution ease	Product quality mastery	Repairing cost mastery	Repairing delay mastery	Security & health rule observance
Reliability concept (MTBF)	**	*	***	***	***	*
Maintainability concept (MTTR)	**	*	***	***	***	*
Intrinsic availability concept	***	**	*	**	**	*
Operational availability concept	***	**	*	**	**	*
Dependability concept (RAMS)	***	***	***	***	*	***
Pareto law & ABC curves	****	****	*	***	***	*
PHA	****	***	*	*	*	****
FMECA	***	***	****	***	***	**
SMED	*	*	*	***	*	*
Poka-Yoké	****	***	***	***	*	*
Integrated logistics support	****	***	*	***	***	**
Operator maintenance: 5 S	****	***	***	*	*	***
Ishikawa Diagram	****	***	*	***	***	*
Overall equipment effectiveness (OEE)	**	**	****	*	***	*
Capability & 6 Sigma	**	**	***	*	*	*

* * * *: Very relevant; * * *: Relevant; * *: Less relevant; …. *: Not relevant

Sources: Monchy, 2000; Treillon *et al*. 2004; Azouma, 2005

Table II. Maintenance difficulties in developing countries classified by importance order

No.	Maintenance difficulties classified by decreased order	Causes
1	Lack of Integrated logistical support for tractors and food equipments	Abroad made design: couple "Environment-Equipment" not taken into account in design process
2	Lack of application efficient maintenance related to the productivity	Ignorance - Cultural obstacles Lack of planning and control
3	Engine failures and spare parts wear	Lack of maintenance and quality of the materials - Human mistakes
4	Insufficient financial means	Low income - High taxes and charges
5	Equipments bad use	Lack of training - Carelessness Turn away use
6	Lack of information record for maintenance analysis	Ignorance - Lack of technical programs or assistance

Sources: de Groote, 1990; Fall, 1990; Trouve, 1990; Merlin, 1991; Starkey, 1994; de Groote, 1995; FAKT, 1996; N'Daw, 1998; DPV, 1999; Diallo, 2000; Azouma, 2005, Bationo, 2007

Table III. Life term, cost of repair and maintenance of the equipments

New equipments	Life term		Repairing and spare parts cost converted in equipment purchase cost (by per cent)
	per year	per hour	
Tractor	8 à 10	10000 à 12000	130
Motocultor	6 à 8	3000 à 4800	130
Tools for tillage and ploughing	5 à 10	2500 à 5000	350 à 400
Implements for seedbeds and inter-cultivation	5 à 8	4000 à 4500	250
Equipments for sowing and planting	5 à 8	2500 à 3200	150
Manure spreaders	5 à 8	1000 à 1800	200
Equipments for crop protection	5 à 12	1000 à 2400	200
Equipments for forage harvesting	5 à 12	1600 à 3500	150 à 300
Combine harvesters	5 à 7	4800 à 5600	120 à 150
Trailers (plate-forme)		4000 à 4500	250
Maize shellers		4000	200
Sorters, Cleaners-Separators		2000 à 4000	50 à 100
Hammer mills		2000	250
Motors		3000 à 8000	150
Water pumps		6000	100

Sources: Ministère français de la coopération et du développement, 1991; FAO, 1992; Gay, 1993

The Table III lets us declare that agricultural equipments life term in developing countries is known and the maintenance cost valuation is no more a problem. On the other hand, it is fair to initiate research works in order to value the food processing equipments life term from the experience feed back and tests in laboratory or from the comparative analysis. Before getting results from suitable studies and in case of a well conceived product, we assume that the working term for food equipments in developing countries is between 8 and 12 years. Otherwise, food processing equipments minimal life term could be assimilated to that of its thermal and electric motors: from 3000 to 8000 hours. Repairing and mainte-

nance cost fluctuates between 75 and 250% of food processing equipment purchase cost. In case of breakdown, peasants and food producers get in touch more usually with a mechanic than with an equipment manufacturer who made the machine (Figure 2). All users consider expertise as the essential ground in choosing the equipment repairer (Figure 3).

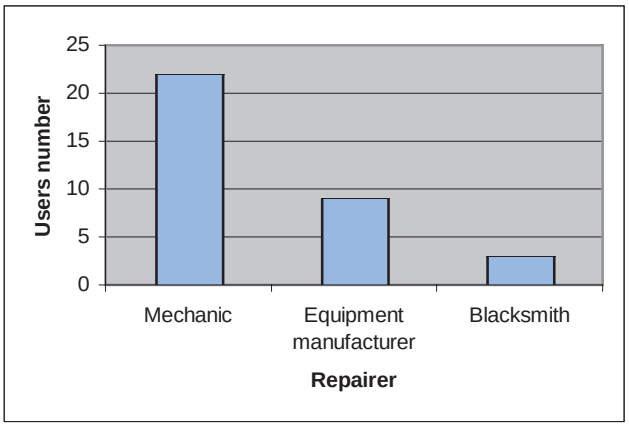

Fig. 2: Choice of the type of repairer by equipment users

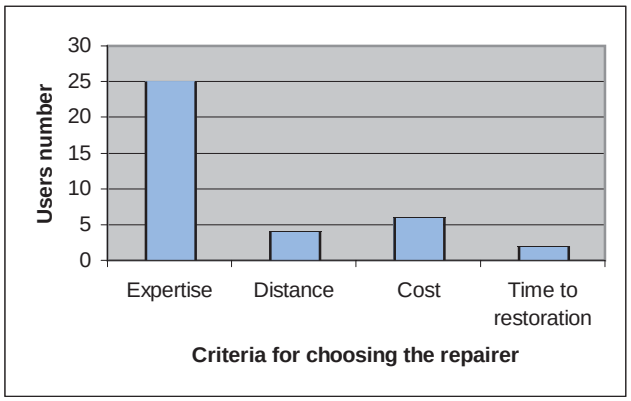

Fig 3: Users criteria for choosing the repairer

Although users generally buy very new equipments, agricultural equipments do not have a formal guarantee (un-formal agreement and fair resolution of disputes) (Figure 4). No valid reason, no distance or purchase costs dispense the equipment manufacturers from guarantee and after-sales service.

State-of-the-art of maintenance in developing countries, results of investigations achieved in Benin, in Burkina and Togo and participatory design experimentation of a manure spreader for solid organic manures (Azouma *et al.* 2007) allow to propose tools for maintenance integration in equipment design process for Africa.

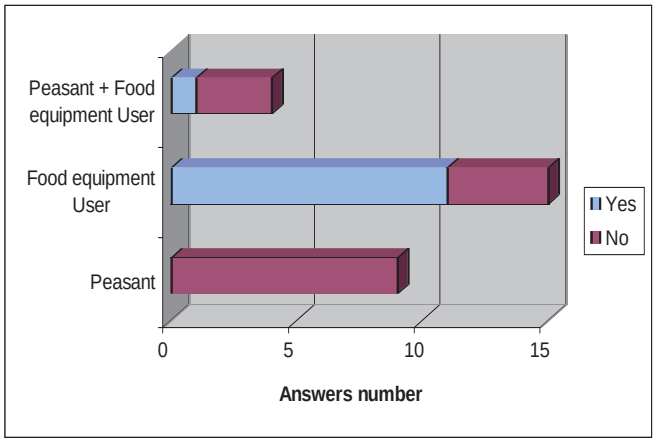

Fig. 4: User answers on the after -sales service and guarantee

3. Tools and methods for maintenance integration in the design process

Referring to an organized design process a research team could adopt the approach illustrated in Figure 5 from definition step of the future equipment, completed by explanations necessary to execution.

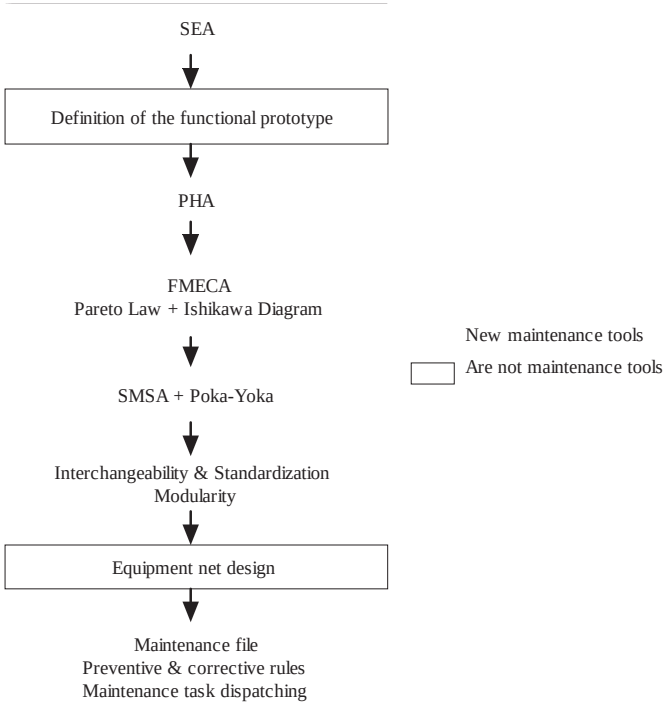

Fig. 5. Maintenance integration in design process for Africa

1. Define a Specification Equipment Availability (SEA) during the need analysis and the state-of-the-art; it aims at characterizing in relationship with the machine manufacturer and the equipment users, the reliability and maintainability criteria expected: questions will be on components and subsets resistance, quality rate of equipments and of products from food equipments, yearly load of effective work, manual, motorized or automatized work, usual breakdowns of equipments, the average repair cost; defining maintainability criteria compare with technological environment: normalization and standardization in comparison to the components of home-made equipments and materials available, fixing systems reduction, expertise in maintenance in the region of use, maintenance tasks generally executed by equipment users, repairing delay and repairing average time, non maintenance experienced consequences.

2. Apply PHA to functional prototype of the equipment in order to identify zones and dangerous elements (components or produced food toxicity) and to look for preventive measures in design period.

3. Execute the FMECA on the adopted functional prototype: determination of equipment critical points, a preventive maintenance plan simulation, quality seek, treatment of real and foreseeable breakdowns list using Pareto law to determine 20% of breakdowns causing 80% of equipment unavailability cases and to which will be applied the Ishikawa diagram principle so as to find default causes. Checking causes will essentially be done from the 3 M that characterizes operational availability: Methods, Men and Means for the work.

4. Apply the Poka-Yoké: introduction mistake prevention devices and detection devices in order to alert the equipment user: symmetry reduction and shape changes on a same component, marking components, use of sensors and resonant or luminous alert systems. Here, it will be necessary to take into account the elements of the Specification of Materials and Spare parts Availability (SMSA) that constitutes a new tool for local manufacture design integration (Azouma *et al.* 2005).

5. From equipments already used in the region and equipment manufacturers' components stock, define the interchangeability, components standardization and the equipment modularity compare to users needs.

6. After having completely defined the coming equipment, make up a maintenance file and propose an equipment logistics support strategy leaning on the steps illustrated on Figures 6 and 7. This file also integrates Distributed Maintenance for Africa (DMA) defined in the recommendations to ensure equipment operational availability. The two major handicaps of the logistics support chain concern repairers and suppliers concentration in cities or in the capitals and communication difficulties.

7. After manufacturing prototype and his experimentation in laboratory, value the number of breakdowns (N) and the rate of occurence of failure (λ) in full capacity work during 6 to 12 months period time in enterprise context in order to improve the availability of the equipment.

4. Principles for local maintenance integration in the design

From the state-of-the-art on the maintenance both in developed and developing countries thereafter analysis of the

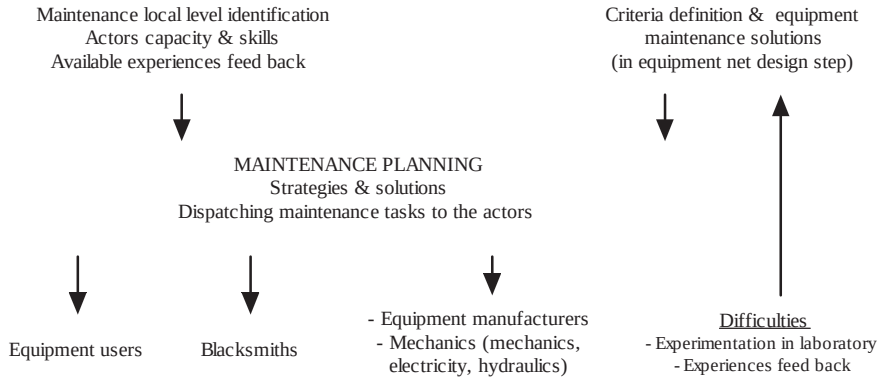

Fig. 6. Process of planning equipment maintenance for Africa

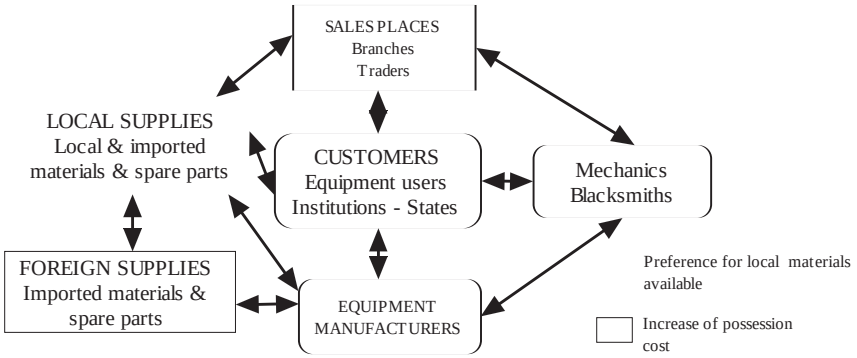

Fig. 7. Logistics support chain users centred for Africa

practices in West Africa, in Benin, Burkina and Togo, we will make several recommendations concerning: intrinsic availability of the equipment to be designed and operational maintenance.

4.1. Recommendations for the intrinsic availability of the equipment

- Choose components fixing systems and subsets in existing equipment range
- Determine expected life term of manufactured equipment compared to the existing equipments in the region or taking into account motor life term, source of energy for the equipments, as reference. Experience feed back will improve these first approaches of solution.
- Calculate in a more rigorous way the main torque between the motor and the tool in order to reduce components wear.
- Choose the thermal motors that tolerate fuels of mediocre quality or foresee complementary filtering devices.
- Use materials enough resistant to agro-climatic conditions and to using constraints: gaps of temperature, hygrometry, hard or delicate work, frequent manipulations of a device in order to ensure equipment reliability.
- Reduce fixing systems number in order to decrease Time to repair.
- Integrate notion of portability in design in order to facilitate equipment handling.

4.2. Recommendations to ensure the operational availability of the equipment

From the analysis of SOSEA tractors "Agrimex" export experience toward Africa and from analysis results of practices (Azouma, 2005), an approach of distributed maintenance of motorized agricultural and food equipments centred on maintenance operator but not on the tasks, Distributed Maintenance for Africa (DMA) has been defined. This tool includes 3 levels with levels 1 and 2 referring to FD X 60-000 norm (AFNOR, 2002).

Level 1. Users

Daily maintenance are devoted to equipment users: full reservoir with fuel at the end of works; tighten bolts, to clean the equipment, radiators (grids); verify the level of water, oil, air, and full if necessary. Check electric connection systems and if there are not flights of the inputs.

Level 2. Traditional blacksmiths: modern blacksmiths and welders

Draining motor, replacing wear components on agricultural equipment thereafter repairing and manufacturing simple components: weldering and loading components, reproduction of a hopper.

Level 3. Mechanics of levels 3, 4 and 5 referring to FD X 60-000 norm

They will do the heavy repairs: the motor, the electric system, the hydraulic system, the system of cooling and the transmission: propeller shaft, box-gear, steering shaft.

The MDA is completed by other recommendations that will improve the operational availability of equipment in Africa.

- Take into account for the design an accessible possession cost to potential equipment users through criteria such as availability and the proximity of work materials provision points (materials and components), the durability, manufacturing and maintenance costs reduction.

- Provide an after-sales service and a guarantee for equipments.
- Write a notice of use adapted to developing countries users: use maximum of pictograms, alphabetisation if necessary for an efficient use of the notice and the symbols.
- Train users at least to maintenance level 1 then assign the other tasks according to their complexity to blacksmiths or to mechanics or equipment manufacturers.
- Couple use to the maintenance within the enterprises to constitute reliable data bases from experience feed back; this can be done by setting a team in charge of quality, two qualified workers and a workshop chief or a technical Director, who records information on equipments and machines maintenance and bring up some solutions to the industrial systems default.
- Advise equipment users to use only standard spare parts or artisanal components only for temporary repair.
- Train users on the economical interest of relationship between quality and cost of an equipment and the preventive maintenance (to put the accent on unavailability costs) that constitute factors of gain and no of loss of money for the agricultural and food production systems.
- Incite state institutions to write some machine and social instructions to regulate equipment design and use in secure condition.
- Train the Small and medium enterprise or industry (SME or SMI) to maintenance organization and management: structure, levels of intervention, programs and budget, report writing (historic, statistical parameters, etc.), spare parts stock management.
- Create index or catalog of sub-regional and international enterprises and local workshops, in order to have a book that permit to widen the choice of services suppliers in the field of subcontract and work materials.
- Apply an operator maintenance system based on the 5 S with bonus settled and organized in a concerted way with the SME or the agricultural and food producing cooperatives staff
- Settle a documentary fund on maintenance organization and management and a bank of data on equipment breakdowns and solutions brought to each set: motors, tillage tools, post-harvest and food processing equipments.
- Always require a use notice when purchasing or acquiring new or second-hand machines

Conclusion

This study confirms the interest of a maintenance centred on the user and the set "environment-equipment". In developing countries context the difficulty to set such a process is formalizing very limited experience feed back. This question could be treated in two ways, on the one hand collecting information on experience feed back by a team constituted within the enterprises and on the other hand, by setting up information collecting system piloted by teams from universities and research centers.

Acknowledgements

The authors are grateful to the French Government, the Laboratoire de Mécanique Appliquée R. Chaléat of Université de Franche-Comté (LMARC - Besançon) and the Université de Lomé (UL) for its technical and financial support. We would like to thank the equipment manufacturers and users from Benin, Burkina Faso and Togo for providing the raw data without which this paper would not been possible. We thank Daniel Varchon (retired), Professor at the Université de Franche-Comté, for valuable comments, advice and financial support.

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Received : September 18, 2008;
Accepted : February 11, 2009