Approaches of the Best Maintenance Strategies Applied to Hydraulic Drive Systems

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Abstract: *As a consequence of global competition priority measures are necessary for a total elimination of losses and failures of hydraulic drive systems. This is the reason why the maintenance activity must be continuously improved. So, the maintenance activity must be understood more than a periodic revision to remove the damages that may occur. Many companies are not underestimating the maintenance activity and large amounts of funds are invested in maintenance management. The research activity is encouraged to develop new design methods in the reliability of hydraulic systems and in preventive and predictive maintenance. The paper extends a careful review of all maintenance strategies capable of ensuring the smooth running of hydraulic drive systems with a case study applied to an agricultural tractor.*

Keywords: *Maintenance, hydraulic system, equipment importance, total productive maintenance, environment, European directives*

1. Introduction

A hydraulic drive system can be analyzed as a black box, without knowing what it is inside but knowing who are the inputs and the outputs. Any change in the system operation is observed as a change of output parameters or the occurrence of other undesirable sizes which will oblige us to check firstly the input parameters. If the inputs do not register deviations from the operation rules of the system then the causes of mal functioning must be search in the structure of the black box system. Because a hydraulic system has a structural integrity, the system reliability is dependent on the each element reliability. These considerations must take into account when we want to manage the maintenance activity of a hydraulic system.
In our days maintenance is not a simple troubleshooting activity.
Maintenance is the act of maintaining the technical integrity and the functionality of a system as long as possible, [1, 2, and 3]. For a hydraulic system, maintenance is as an act of defence which prevents component failure and improves system reliability, [1].
There are two basic maintenance approaches: a corrective maintenance (or reactive maintenance, the mostly used to minimize the troubleshooting time response) and a preventive maintenance (or proactive maintenance suitable the best maintenance practice for hydraulic systems), [1]. The corrective maintenance performed the tasks of identification, isolation and rectification of a fault so that the failed hydraulic system can be restored to its normal operable state. The preventive maintenance is oriented to performance in order to prevent all hydraulic system failure before it occurs.
In practice there are some combinations of basic approaches that it will be discussed in the paper as a case study of the hydraulic driving mechanisms of a 90 HP agricultural tractor having the hydraulic block diagram plotted in Figure 1, [4].
The hydraulic system contains an A1VO axial piston pump with variable capacity, a steering, a steering cylinder, a priority valve, a battery of directional valves (working hydraulics) and two hydraulic cylinders. Other components are: a hitch control, a 3 point hitch, a controller, a draft sensor, a position sensor, and a control panel.

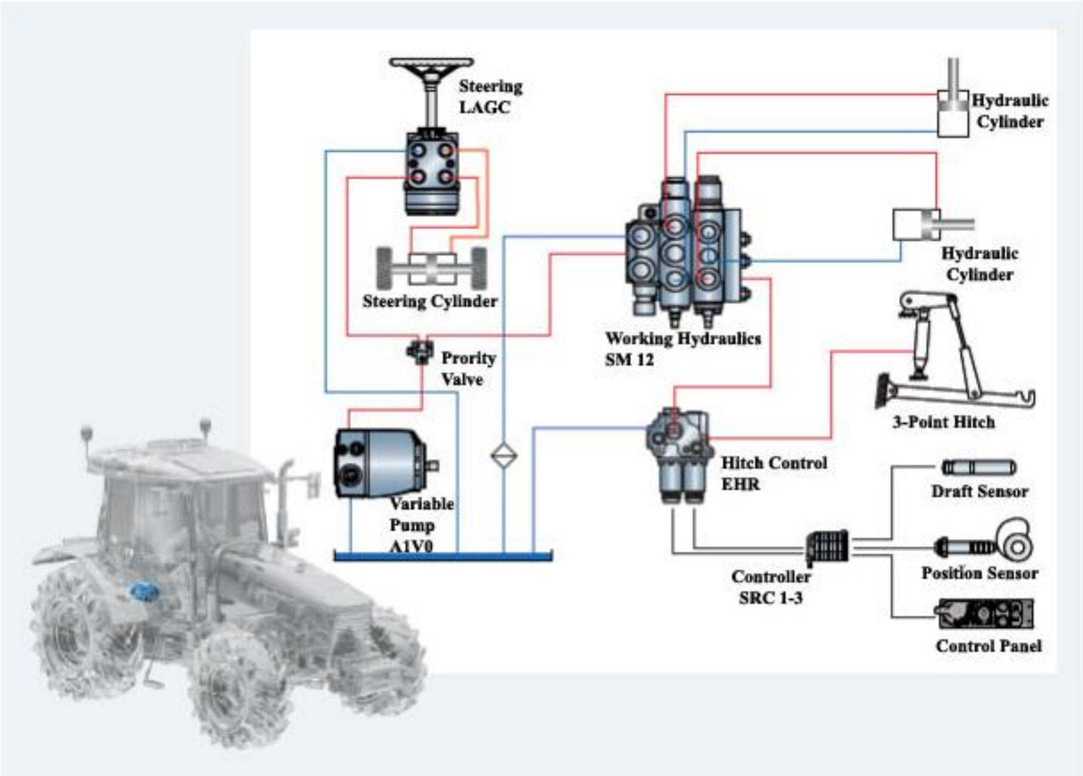

Fig. 1. Block diagram of a 90 HP agricultural tractor, [4]

In the paper maintenance types and how to choose the proper type of maintenance is presented for the 90 HP agricultural tractors. A decision tree for the maintenance strategy is presented, too, in correlation with the equipment importance factor, I.

2. Maintenance types

In Figure 2 are presented a simplified classification of maintenance types, [5]. The scheduled and unscheduled maintenance activities are the core of this classification. It is observed that even the corrective maintenance is a scheduled activity.

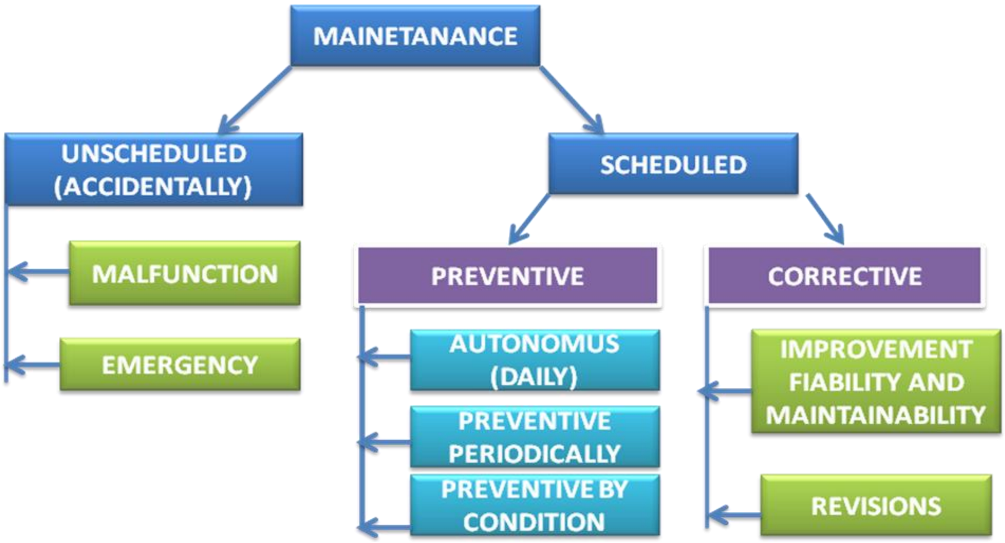

Fig. 2. Maintenance types, [5].

The unscheduled - (accidentally) maintenance are at fault, or in emergency case. The operators begin repairs after an unforeseen defect and shall restore the facility or its components in acceptable working conditions. Accidentally maintenance may be required as a result of a specific choice of the company or unscheduled, as attitude like "wait and see", [5].

The scheduled maintenance is preventive or corrective.

Preventive maintenance should be performed after predetermined criteria covering the following issues:

- ✓ defect prevention by the identification and measurement of one or more parameters;
- ✓ extrapolating the remaining time before failure, using appropriate models. The probability that the hydraulic system or a part of the system is not in acceptable operational conditions is reduced. Preventive maintenance can be done at different time periods: at regular intervals, at safe intervals, at irregular intervals, at constant time intervals, at a constant date, as a routine operation or an extraordinary one, [5].

From this point of view, ***the predictive maintenance (also called conditional maintenance)*** is performed as routine checks or continuous checks and is based on the following concepts:

- ✓ many defects do not occur instantly proper functioning;
- ✓ it is possible to identify the emergence and the evolution of defects.

In other words the plants give some warning signals before the crash. These warning signals can be defined as a potential faults. Knowing the real state of the system components, the operator will proceed by applying a rational preventive action, [5].

Corrective maintenance is a concept based by intervention on equipment after it has crashed (for example repair, partial or total change of defective equipment). Corrective maintenance is "all actions taken after the failure of equipment or after his office degradation unexpectedly", [4].

Reliability centered maintenance can be defined as a process used to determine the steps to be taken to make sure the equipment performs its function in its operational context. This maintenance concept appeals to effective methods of maintenance that helps to prevent critical failures appearance, [4].

3. The choice of maintenance type

A careful review of all maintenance strategies applied to hydraulic drive systems will follow a decision tree like in Figure 3, [4].

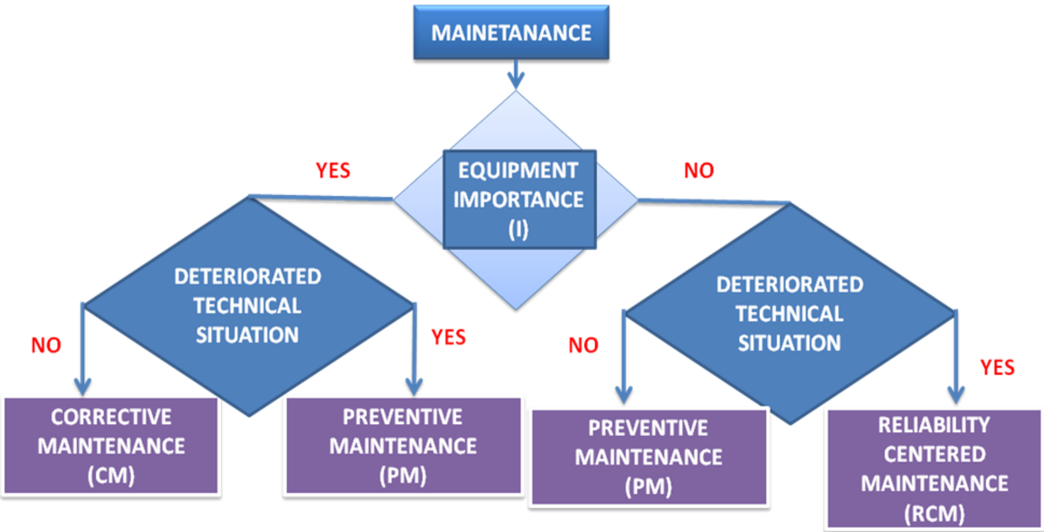

Fig. 3. Decision tree for election of the maintenace strategies

From this perspective, for the hydraulic equipment of 90 HP agricultural tractor, shown in Figure 1, the following choices are available, as in Table 1.

TABLE 1: Maintenance choices

Apparatus class	Apparatus	Equipment Importance I		Applied type of maintenance
		%	Qtr (see fig. 4)	
Execution	**Steering cylinder**	**10**	**1st**	PM, RCM
Command	**Steering**	**10**	**2nd**	PM, RCM
Execution	**Hydraulic cylinders**	**5**	**3rd**	PM, RCM
Power	**Axial piston pump with variable capacity**	**60**	**4th**	CM, PrM
Safety and distribution	**Battery of directional valves**	**10**	**5th**	PM, RCM
Safety and distribution	**Priority valve**	**5**	**6th**	PM, RCM

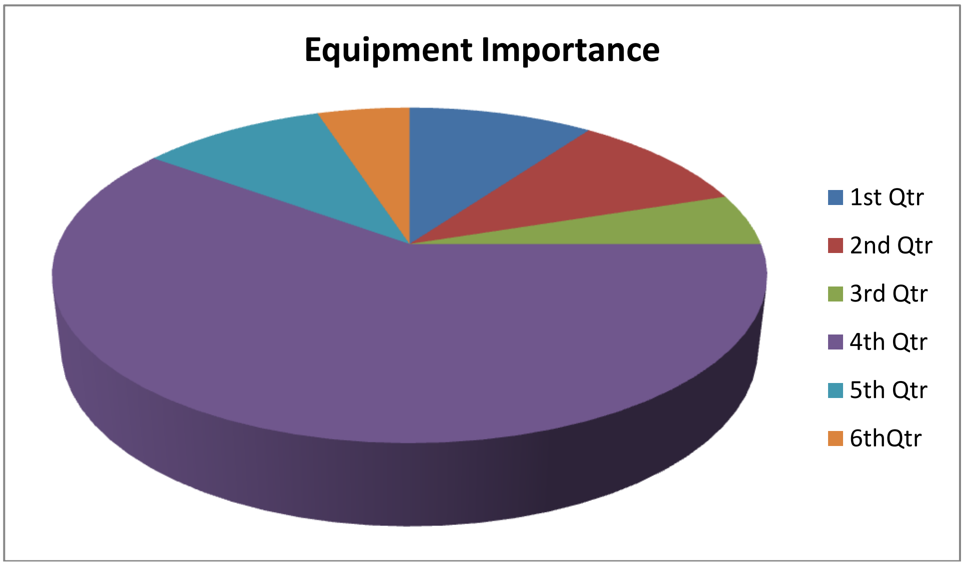

Fig. 4. Equipment importance

Each element of the hydraulic system is quantifying as function of the equipment importance (I) in the maintenance scheme and operation rules. In Figure 4 is plotted the equipment importance as percent average from the whole.

4. Total productive maintenance, an innovative concept

Total productive maintenance, TPM, is an innovative Japanese concept. The origin of TPM can be traced back to 1951 when preventive maintenance was introduced in Japan, [6].
The hydraulic drive installations are component part of many technological systems from different industries of production. Therefore, the total productive maintenance model can be successfully applied in this case.
Total productive maintenance is based on the "5S" (Sort, Set, Shine, Standardize, Sustain), [2]. The support activities of this maintenance model, and recognized as the eight pillars of total productive maintenance, "eight pillars of TPM" are presented in Figure 5 [TPM].

Fig. 5. The eight pillars of TPM, [1]

The total productive maintenance targets are available not only in machines manufactured production, [1, 7] but in hydraulic system, too. The TPM targets are, [7]:

- ✓ to obtain minimum 80% OPE, (Overall Process Effectiveness);
- ✓ to obtain minimum 90% OEE (Overall Equipment Efficiency);
- ✓ to run the machines even during lunch;
- ✓ to operate in a manner, so that there are no customer complaints;
- ✓ to reduce the manufacturing cost by 30%;
- ✓ to achieve 100% success in delivering the goods as required by the customer;
- ✓ to maintain an accident free environment;
- ✓ to develop multi-skilled and flexible workers.

5. Maintenance of work fluid and environmental protection

The maintenance of hydraulic systems of different machineries means not only the maintenance of relevant apparatus but also the maintenance of hydraulic oil, the working fluid in the system. It is estimated that about 70% of the breakdown of hydrostatic drive systems have as main cause the used hydraulic oil. The working fluid maintenance means firstly to monitor the contamination of the hydraulic used oil and the fluid leakage control, too. The importance of this maintenance transcends its purely technical aspect, it having too by produced effects a strong environmentally character. The oil leaks of fluid are not only unsightly, they are hazardous. It makes workplace floors slippery and dangerous and can also contaminate the environment. In fact, as little as a quart of oil can pollute up to 250,000 gallons of water, and it is estimated that 100 million gallons of oil are leaking annually from hydraulic systems, [8]. For this reason oil leakage occurring in plants must be removed as quickly as possible by gathering connections and/or replacing the defective seals.

Because of the work environment conditions and additives used in the hydraulic oil, after an operation period of time, any hydraulic oil loses its purity through contamination with small solid particles. Because of the hydraulic oil contamination the hydraulic system performance will decrease.

Used oil must be carefully replaced from the system and stored in special containers for recycling, compliance with environmental standards. Solid particles are highlighted with specific laboratory equipment. At INOE 2000 – IHP Bucharest, there are concerns in this regard since 2005, through the purchase of a machine type CM Laser, manufactured by Parker Company. Tests made on samples of oil may indicate the existence of impurities solid particles of different diameters.

6. European Directives and international standard protection

The maintenance activity brings together elements concerning to safety and health at work (see the last TPM pillar). For this reason, Framework Directive 89/391 /EEC, take into account the introduction of measures for the safety and health of workers at work improvement promotion. Directive 89/391/EEC fixes the basic legal and legislative framework for the adoption of special directives on minimum health and safety requirements at using by operators of protective equipment at work place, and is republished in consolidated text by Directive 2009/104/EC.
In the field of Hydraulics, we can mention "Machinery Directive 2006/42/EC", "Electromagnetic Compatibility Directive EMC 2004/108/EC", "Low Voltage Directive - 2006/95/EC", "Guidelines for explosive atmospheres ATEX 94/9/EC and IECEx Certification Scheme for Explosive atmospheres", "Pressure Equipment Directive PED 97/23 / EC ", [1]. For waste oils it was been adopted Directive 75/439/EEC.
In the year, 2007 once Romania joined to European Union, it was passed to implement the international quality standards from ISO 9000 to ISO 9004. The Romanian harmonized version ISO 9000 can be found in the standards SR EN ISO 9000.

7. Conclusions

Establishing the correct maintenance strategies are imperative when it is desired an optimal functioning of a technical system. For hydraulic drive systems, the type of maintenance can be determined depending of the component equipments importance. Besides a good knowledge of support and repair techniques by multi-skilled and flexible workers for these activities, is recommended the implementation of EU directives and international standards in the field. The direct benefits arising here are those relating to environmental protection and health of workers by ensuring the safety and reducing the number of accidents at work.

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