Quality Festival 2019
ISSN 2620-2832

Dobrivoje Ćatić[1]
Milan Vasić
Jasna Glišović

ANALYSIS OF THE FAULT TREE OF THE CROP SPRAYER PUMP

Abstract: *Using the Fault Tree Analysis method - FTA, an analysis of the potential failure modes of the elements of the crop sprayer pump Comet BP 105 was carried out in this paper. In order to conduct a detailed analysis of the causes and failure modes of a pump, it is necessary to know the structure, the way of operating and the interrelationship of the constituent elements. Based on the collected data, the fault tree of the considered object was formed. In this way, the cause-and-effect relationship between failures of structural entities of different levels of affiliation is established. In conclusion of the paper, the importance of applying the fault tree analysis to improve the efficiency of the existing systems and the quality in the development of similar design solutions is pointed out.*

Keywords: *Crop sprayer, Pump, Fault Tree Analysis*

1. Introduction

In successful agricultural production of field crops, chemical protection against unwanted plants (weeds), plant diseases, insects and other pests, as well as foliar feeding, is of key importance for potential yield (Sedlar, 2014). All of this is provided by using crop sprayers. In addition to the selection of the appropriate chemical agent, an important factor for efficient chemical protection of crops is rapid and timely reaction, which among other things depends on the correctness of the used devices. The crop sprayers usually consist of: a working fluid reservoir, pumps, mixing systems, pipes, regulators, spraying wings and sprinklers. The drive pump has the greatest influence on the correct operation of the crop sprinkler. It provides working pressure and flow of working fluid.

Fault Tree Analysis - FTA (Ericson, 1999; Bertsche, 2008) is most often used to analyse failures of technical system elements. The basis of the fault tree analysis is the translation of physical systems into structural logical diagrams. The FTA is implemented according to the appropriate methodology, using symbols for events, logical gates and transfer of parts of the fault tree (Ćatić, 2014a; Ćatić, 2014b).

2. Structure and operation modes of the pump

Based on the available literature, a detailed introduction to the structure and operating modes of the components of the Comet BP 105 crop sprayer pump (Diaphragm pump**s** User Manual, 2016; Diaphragm Pumps BP K Series, 2013) was carried out, which is shown in Figure 1. In this model, a piston diaphragm pump is used (Sedlar, 2014). This pump pushes fluid from the reservoir under pressure through the pipes and the sprayer in the form of a fan-shaped or swirling jet with

[1] Corresponding author: Dobrivoje Ćatić
Email: caticd@kg.ac.rs

small drops. Working pressure ranges from 0 to 20 bars and it is regulated via a special valve, which is an integral part of each crop sprinkler.

Figure 1. Comet BP 105 pump

There is a cardan shaft in the pump housing, as well as three-piece piston rod, cylinders and pistons with oil diaphragms, which are screwed to the forehead of pistons. The pistons are circularly arranged. The piston's axes are in the same plane at an angle of 120 degrees. The movement of pistons and diaphragms allows the suction and suppression of the working fluid through the respective valves. The diaphragms also protect the internal parts of the pump from the effects of the working fluid. The interior of the housing is filled with oil, which reduces the friction of the slipper pairs and allows them to cool.

The pump housing is made of cast aluminium. In order to protect the pump from the chemical effect of the used agents, the exterior of the housing and all other metal elements of the pump are plasticized.

The crankshaft is made of high hardness cement steel. The sliding surfaces of the crankshaft are finely ground, which minimizes wear of this element and bearings. Nevertheless, over time, the sliding surfaces of the crankshaft and bearings can be damaged (Figure 2), which leads to increased friction, heating of elements and reduced efficiency of operation.

Figure 2. Damage due to wear of the crankshaft and sliding bearing

The oil diaphragms are made of perbunan. Figure 3 shows the most common type of oil diaphragm damage caused by the combined effect of cyclic deformations, working pressure and chemical effect of the used agents.

Figure 3. Rupture of the oil diaphragm

The pump valves are made of polyamide resistant to various chemicals used in agriculture.

The air chamber consists of two aluminium castings between which the air diaphragm is located. On the underside of the air chamber, there is a valve with a cap for blowing the chamber for the purpose of depreciation of hydraulic strikes, and the air chamber itself is protected by a polyamide powder.

3. Fault tree of crop sprayer pump

A functional approach was used to create the Comet BP 105 crop sprayer pump fault tree, intended for devices ranging from 12 to 14

m. The top event in the fault tree is defined as "Failure of the crop sprayer pump," whereby it implies a complete or partial loss of operating capacity of the system under consideration. Indirect events are defined in the way that a pump failure occurs, i.e. over the mark of the cancellation. It should be emphasized that a specific number of indirect events in the fault tree are common for other relevant structural components of the crop sprayers. For the purpose of forming the fault tree of the object in question, for practical reasons, modified symbols for the primary basic event (circle) and the secondary basic event (rhombus) were used.

In order to record the potential ways of failure of the elements of the crop sprayer pump, the manufacturer's instructions for handling and maintenance have been used (Instruction Manual, 2006; Diaphragm pump**s** User Manual, 2016). Considering the individual failure ways of the crop sprayer pump elements, it can be determined that all causal events that lead to the top event can be classified into 6 subordinate indirect events (Figure 4): complete failure of the pump, the pump does not suck up the fluid, the pump suppresses a little fluid, mixture of water and oil comes out of oil meter, oscillations of the spray nozzle’s jets and lack of oil in the pump housing.

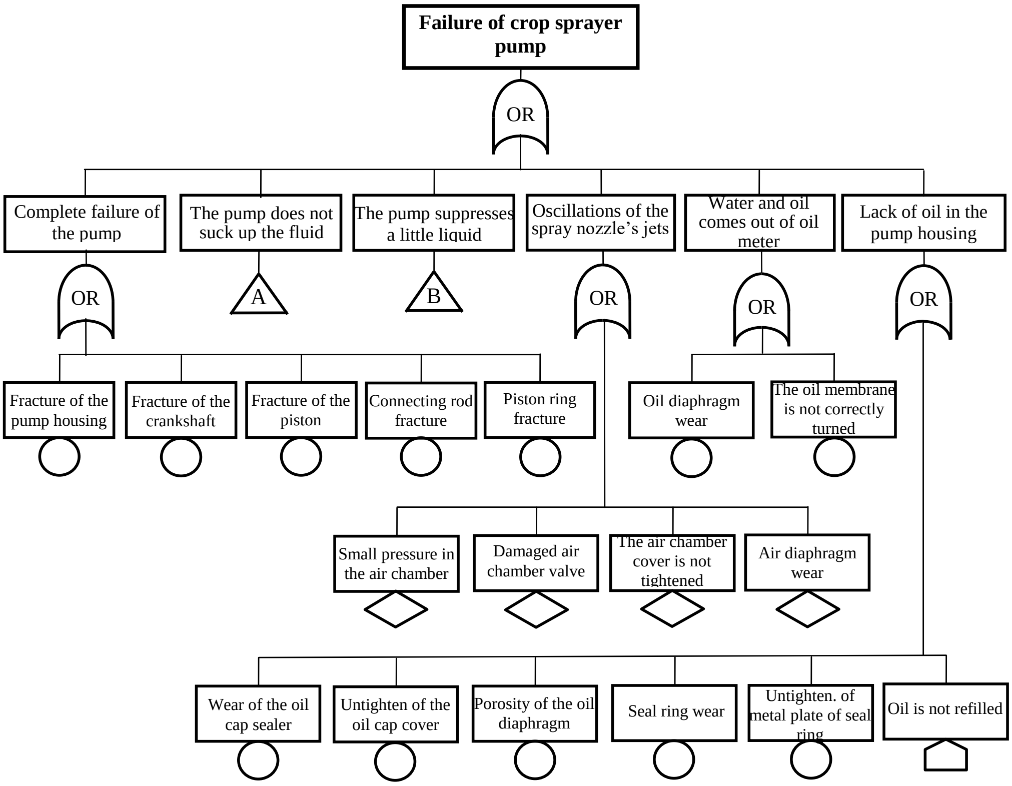

Figure 4. Fault tree of the crop sprayer pump

Complementing the structure of the fault tree with the causes leading to them in the form of a branch of the fault tree was done by a deductive analysis of indirect events. In this way, in addition to identifying and registration of the potential failure modes of the elements of the crop sprinkler pump, the cause-and-effect relationship between basic, indirect and top events has been established.

The indirect event, "Complete failure of the pump" means the complete loss of the pump's operating ability, or the termination of the function of the crop sprinkler. The causes of the occurrence of this event are usually the primary failures (fracture) of the elements: pump housing, crankshaft, piston, connecting rod or crankshaft rings. Fractures of these elements can occur due to impact loads, overload caused by an irregular operating mode or due to fatigue of the material of elements. It should be said that the probability of these events is very small.

The indirect event "Pump does not suck up liquid" has been developed from basic events in the form of an independent sub-tree given in Figure 5. This event can occur if the suction hose is folded or there is a compromised tightness of the supply section of the pump installation or a clog inlet has occurred. Compromised tightness of the working fluid supply can occur due to the occurrence of cracks on the hose shank, loose connections of the shank nut, damage to the rubber "O" gasket, loose connections of the hose clamp or damage to the hose. The clogged fluid supply may occur if there is no filter for cleaning or there is a filter strain, so that the shavings, impurities and residue from the fluid reservoir flow smoothly and reduce the flow of the suction line.

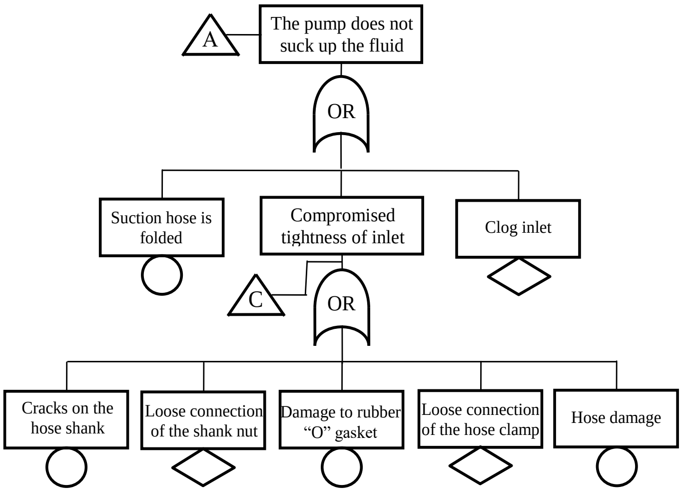

Figure 5. Independent fault sub-tree for the event "Pump does not suck up the fluid"

The "Pumps suppress a little fluid" event, which can also be defined as reduced efficiency of the pump, may results from an incorrect position of the flow valve or damage to the flow valve or damage to the inlet tightness. Damage to the flow valve may occur due to: fracture of the spring or wear down of the valve basket, spring seat or the valve disc. The damage to the inlet tightness has already been considered within the framework of the sup-tree shown in Figure 6.

Indirect event "The mixture of water and oil coming out of the oil meter" occurs as a result of the oil diaphragm damage or if the oil diaphragm is incorrectly reversed during assembly or maintenance, and the working fluid passes from the chamber into the housing.

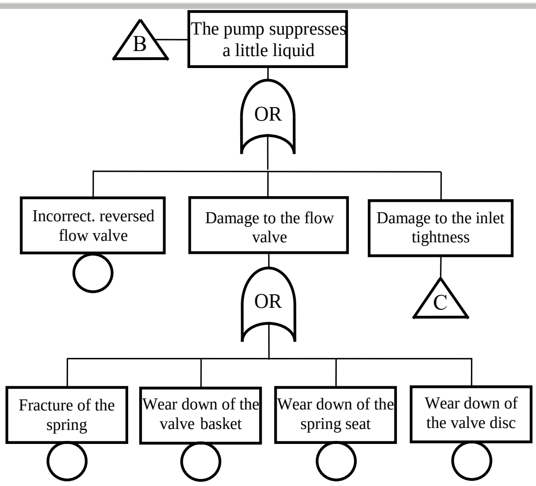

Figure 6. Independent fault sub-tree for the event "The pump suppresses a little fluid"

"Oscillations of the spray nozzle's jets" can occur as a result of: low pressure in the air chamber, which must be adapted to the technical characteristics of the sprayer-nozzles, damage to the valve of air chamber which does not hold the air, the looseness of the cover of air chamber or the wear down of the air diaphragm must be adapted to the technical characteristics of the sprayer-nozzles, damage to the air chamber valve which does not hold the air, the looseness of the cover of air chamber or the wear down of the air diaphragm.

"Lack of oil in the pump housing" can occur if oil leakage occurs or if the oil is not controlled and refilled for a long period. A slight oil leakage occurs as a result of: wear down of the oil cup gasket, the looseness of the cover of oil cap, the porosity of the oil diaphragm, wear down of the sealing ring, or the looseness of the metal plate that presses the sealing ring on the pump housing. The fault tree of the crop sprayer pump (Figure 4) shows the implementation of the symbol "house" for events. The event "Oil is not refilled" is not really a cancellation event. This is an event that is normally expected to happen. The reason for this event to be included in the consideration is to take into account all events that could lead to a top event. The people involved in this field should get used to closely monitor the oil level in the crop sprayer pump, such as for the oil level in the tractor's engine or for the water level in the refrigerator.

The developed fault tree should not be considered complete. In the specific case, it can be supplemented with other events with less probability of occurrence. Grouping original events, as well as defining indirect events, can be done in a different way.

By adopting a sufficiently general top event in the fault tree of the crop sprayer pump and its development to basic events, it is possible to record most of the potential failure modes of constituent components, which can be used, among other things, as a basis for analysing the modes and consequences of failure.

4. Conclusion

The durability and reliability of the crop sprayer pump depend to a large extent on proper exploitation and maintenance. Monitoring and measuring of performance parameters are crucial for timely detection of defects. The causal defining of the state of the system in the form of a fault tree, at the exploitation phase, can also serve as a diagnostic tool for determining the most probable causes of the resulting failure. Furthermore, the results of the FTA analysis can be used to assess the benefits of maintaining and developing a maintenance plan for the considered technical systems.

The long-term systematic collection of data on the specific pump, the results of the control of the production process, the testing results, user complaints, etc. can serve as a basis for developing undeveloped events in the fault tree to their own basic events.

In addition to a detailed analysis of the considered system from the point of view of the failure, the formed fault tree of the crop sprayer piston-diaphragm pump can also be used for the analysis of the failure of other variants of the construction of pumps for crop sprayers.

References:

Bertsche, B. (2008). *Reliability in automotive and mechanical engineering.* Berlin Heidelberg: VDI-Buch, Springer-Verlag.

Ćatić, D., Gašić, M., Savković, M., & Glišović, J. (2014a). Fault tree analysis of hydraulic power-steering system. *International Journal of Vehicle Design*, 64(1), 26-45. doi 10.1504/IJVD.2014.057774

Ćatić, D., Glišović, J., Miković, J., & Veličković, S. (2014b). Analysis of failure causes and the criticality degree of elements of motor vehicle's drum brakes. *Tribology in Industry*, 36(3), 316-325.

Diaphragm Pumps BP K Series, BP 105 K – BP 125 K (2013). Comet, Agricultural division, Retrieved fromhttps://www.comet-spa.com/downloads/agriculture/1_BASSA%20PRESSIONE/1%20POMPE%20A%20MEMBRANA/1%20BP%20SERIES/5%20BP%20105_125%20K/Esploso%20BP%20105%20K%20-125K.pdf

Diaphragm pumps, User Manual (2016). Comet, Agricultural division, Retrieved fromhttps://www.comet-spa.com/downloads/agriculture/1_BASSA%20PRESSIONE/1%20POMPE%20A%20MEMBRANA/1%20BP%20SERIES/5%20BP%20105_125%20K/Manuale%20pompe%20BP.pdf

Ericson, C. (1999). *Fault Tree Analysis – A History*, in: Proceeding of the 17th International System Safety Conference, Retrieved from http://www.fault-tree.net/papers/ericson-fta-history.pdf.

Instruction Manual (2006). Agrifac trailed sprayer GN/GS-3200/4200, Agrifac,Retrieved fromhttps://www.agrifac.com/_library/15684

Sedlar, A., Bugarin, R. & Đukić,. N. (2014). *Pesticide Application Technique*, Novi Sad: Faculty of Agriculture.

Instructions manual for use and maintenance of carried tractor sprayer MT-350S / 400S M-400/600-Factory for the production of plant protection machinery MORAVA AD from Pozarevac.

Dobrivoje Ćatić
Faculty of Engineering,
Kragujevac,
Serbia
caticd@kg.ac.rs

Milan Vasić
DR100IĆ,
Kostolac,
Serbia
milanpvasic@gmail.com

Jasna Glišović
Faculty of Engineering,
Kragujevac,
Serbia
jaca@kg.ac.rs