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Methods for analysis of the failures in agricultural machinery

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Abstract: *Methods for analysis of the failures in agricultural machinery.* This paper presents examples of practical utilization of the tools and methods for quality management set of instruments in analysis and evaluation of failures that occur in agricultural machinery. There is presented the processing procedure, starting from determination of potential reason for the failure, through decomposition of the technical system, the Event Tree Analysis, the Failure Mode and Effect Analysis and the cause-effect diagram. There are presented possibility of utilization of particular tools for the qualitative and quantitative evaluation of particular product failures and the process of undertaking remedial and preventing actions.

Key words: quality, product, evaluation, agricultural machine

INTRODUCTION

Quality of a product is one of basic elements taken into consideration in the product evaluation. According to Jedliński [2000], quality from the viewpoint of an enterprise means the profit; from the viewpoint of a customer it is usually associated with high value of the product that results from the product properties: exploitation, technological, safety, ease of service, beauty, price or reliability. One of elements used in quality improvement, required by ISO Standards, are tools and methods that are applied to facilitate data collecting and analysis in order to determine the source and causes of qualitative problems. There are known the works connected with utilization of these instruments in enterprise management [Kowalczyk and Maleszka 2010, Buliński et al. 2012, 2013]. In the case of problems connected with qualitative nature of the product (failure, fault, unserviceability etc.), utilization of these instruments facilitates undertaking the rational decisions on remedial and preventing actions, especially since these instruments often use the staff experience [Starzyńska and Hamrol 2009]. In spite of very large set of available methods and techniques in quality management, sometimes they are not appreciated in respect of extra-essential factors [Szkoda and Świderski 2008]. It is evident from investigations of Kuc and Żemigała [2009] that knowledge of the methods and tools in the field of quality management among managerial staff is limited mainly to TQM principles and ISO Standards of 9000 series. Fiodorow [2010] maintains that problems of quality should be solved with the use of simple tools that do not require large financial and time inputs. According to Świderski [2010], the used tools and methods should be adjusted to the potential and scope of enterprise's activity, mentality of employees and their technical and qualitative culture [Świderski 2010].

In subject references there is lack of publications on the ways for utilization of tools and methods for quality set of instruments in the agricultural machinery branch. The failures in this group of machines, that are characterized by a high degree of technical sophistication and work under very unstable and difficult conditions, are especially dangerous [Rybacki and Durczak 2010]. According to these authors, 97.1% of failures in agricultural tractors occurred within the first 1000 engine working hours, while 81.4% of failures between the first and second inspection after tractor breaking-in period.

According to Jósko and Kołodziejski [2008], the failures in power transmission systems in agricultural vehicles and machines, caused by improper utilization and service carried out by the users, constitute over 2% of all failures. The remaining failures are caused by conditions of exploitation and defective parts, including poor quality of materials.

The failure frequency during exploitation period is connected with repair costs. According to Muzalewski [2000], for particular machines and for the entire exploitation period they vary from 40 to 150% of purchase price.

Evaluation of failures can be carried out by various methods. Very often the Failure Mode and Effect Analysis (FMEA) is used. Krishnaraj et al. [2012] regard this method as basic form for supporting actions leading to improvement of product quality. This method includes a general rule: if the level of failure criticality is considerably bigger than 1, a command to proceed to the next stage is issued, thus, to undertake the preventing actions, e.g. by modernization of design or by the changes in technological process [Greber 2010, Wolniak 2011]. The basic premise towards utilization of this method was often the increasing number of claims and the connected increase in guarantee repair costs of the product. Application of FMEA method allowed for a considerable decrease of costs [Badura et al. 2001]. There are also known the works [Skotnicka-Zasadzeń 2013] that present the effects of combining particular tools and methods in pro-quality activity. This approach facilitates determination of the remedial actions.

This paper aims at presenting the method for determination of the reason for sub-assembly failure in technically sophisticated agricultural machine, with the use of several tools of quality set of instruments.

ANALYSIS AND EVALUATION OF DRIVE ENGAGEMENT MECHANISM FAILURE IN AGRICULTURAL MACHINE

The mechanism function is engaging drive of agricultural machine working unit that intakes plant material for further processing. Fault of drive engaging mechanism makes operation of the entire machine impossible; it is regarded as a critical failure. One of the methods that facilitate the failure locating is decomposition of the system (Fig. 1); it enables to determine the scope of carried out analysis. In the considered case it was found that the failure is connected with the following faults: run-out of the belt pulley, difficulties in moving the drive engagement lever and excessive slackness of driving belt.

It is evident from the presented mechanism layout and functional relations, that the problem can be connected with

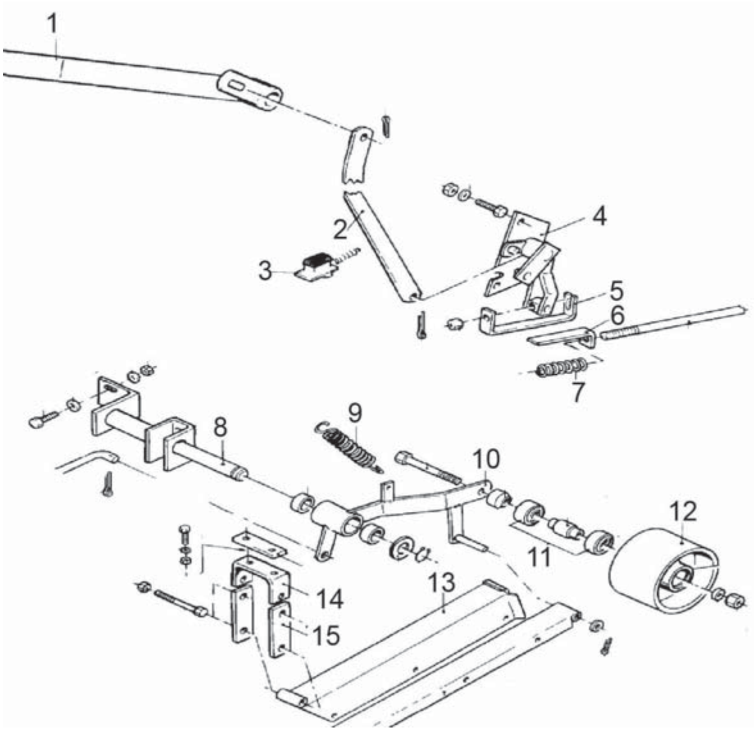

FIGURE 1. Structure of header engaging mechanism: 1 – engagement lever, 2 – connecting link, 3 – switch, 4 – hinge, 5 – bracket, 6 – indicator, 7 – spring, 8 – tightener lever shaft, 9 – tightener spring, 10 – tightener lever, 11 – belt pulley bearing, 12 – belt pulley, 13 – tightener bracket, 14, 15 – brackets

failure of the following elements: hinge (4) of fastening engagement lever (1), tightening spring (7), tightener ever (10), belt pulley (12), tightener bracket (13).

Analysis of dependences between mechanism elements carried out with the use of relation diagram was taken as a basis for determination of potential reasons for failures (Fig. 2). On the diagram there are marked the failure reasons (potential); their occurrence could cause improper operation of particular machine elements and lead to the main failure. The diagram illustrates also faults of the system that enabled occurrence of failures. It is evident from carried out analysis, that majority of inconsistences can be connected with improper quality control or lack of control, as well as inadequate training of employees.

The reason-effect relations presented on the diagram were taken as a basis for execution of FMEA analysis. It allows for evaluation of the risk of failures and faults occurrence, estimation of their importance (consequences), their early detection and making proposals of appropriate preventing and remedial steps, with consideration to degree of criticality of these failures. Taking into account a set of dependences presented on the diagram, the failures of level II (Table 1) were taken as starting point of the analysis.

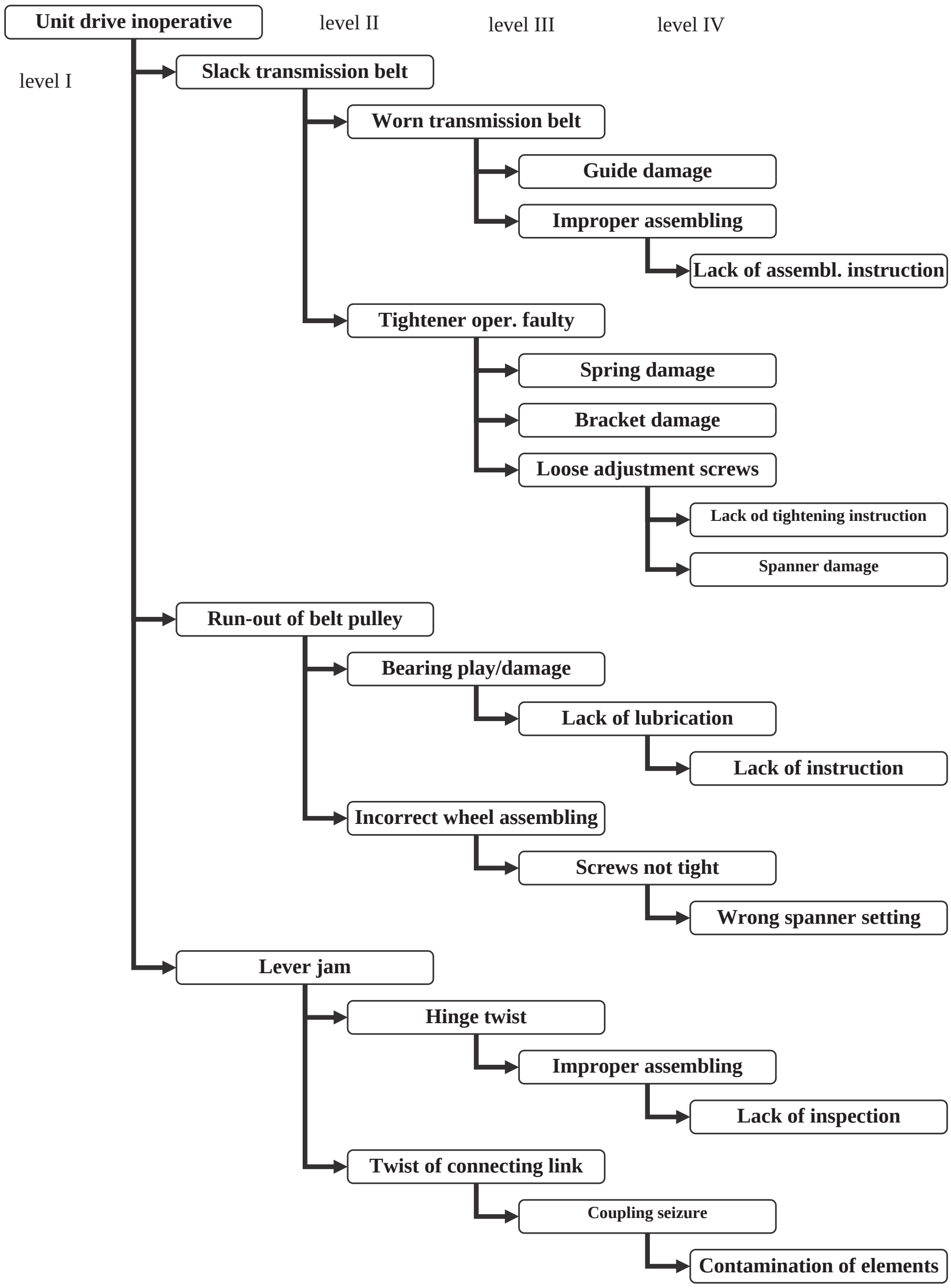

FIGURE 2. Event tree with product failures, reasons and effects

TABLE 1. Product FMEA sheet – problem-system

Element and function	Failure effects	Potential failure	Failure reasons	Control methods	Evaluation			$W_p = R \cdot Z \cdot W$	Remedial steps
					R	Z	W		
Header drive inoperative	Transmission belt slack	Faulty tightener mounting	Careless screw tightening	Control during dealer's inspection	3	8	5	120	Tightening procedure
			Incorrect spanner setting	Stand inspection	2	6	8	86	Subject training
			Spanner damage	Lack	2	6	6	72	Tool inspection procedure
		Transmission belt damaged/worn	Poor quality of belt	Supplier's inspection	2	5	4	40	Supplier's category change
			Incorrect assembling	Lack	4	7	6	168	Instruction + subject training
		Faulty operation of tightener	Tightener spring worn/ /damaged	Lack	4	4	5	80	Inspection/change of spring parameters
			Bracket damage	Stand inspection	2	4	5	40	More accurate inspection
	Belt pulley damage	Bearing damage/ /worn play	Lack of lubrication	Lack	3	8	7	168	Subject training + stand instruction on lubrication
		Wheel balancing incorrect	Balancer damage	Lack	3	8	3	72	Procedure for measuring equipment inspection
	Seizure of drive engagement lever	Hinge twist	Incorrect assembling	Lack	3	7	6	126	Stand inspection
		Twist of connecting link	Coupling seizure	Lack	3	7	4	72	Exploitation inspections, introduction to service manual

In evaluation of reasons for particular failures there were assumed three coefficients (*R* – risk of failure occurrence, *Z* – failure importance, *W* – possibility of failure detection) of values determined according to rules presented in Table 2. Basing on the set evaluation scale it was assumed, that failures of W_p index value that does not exceed 60 points should be observed. The remedial and preventing actions should be quickly undertaken for the failures of W_p index value that varies from 61 to 200 points. The failures of W_p index value above 200 points and regarded as critical ones (they make machine utilization impossible or are dangerous to the user) should be corrected in the first place, as quickly as possible. In determination of *RZW* coefficients (Table 2) one should take advantage of the knowledge and experience of quality department staff, the employees dealing directly with the production process or further stages of "product life", i.e. after-sale maintenance, service etc.

TABLE 2. Values of RZW coefficients for evaluation of product failures

<table>
<tr><th rowspan="2">Value</th><th colspan="3">Coefficient of failure evaluation</th></tr>
<tr><th>R
– risk of failure occurrence or failure reasons</th><th>Z
– failure importance in respect of failure occurrence effects</th><th>W
– possibility of failure detection</th></tr>
<tr><td>1</td><td>Improbable</td><td>Very low, failure does not affect machine exploitation</td><td rowspan="2">Very high, control system assures detection of failure or process disturbances</td></tr>
<tr><td>2</td><td>Almost precluded, very low probability in respect of high process stability</td><td rowspan="2">Low, worsen machine exploitation properties inconsiderably</td></tr>
<tr><td>3</td><td>Rare occurrence of failure, process of high ability to quality (PPM < 63)</td><td rowspan="2">High, used means give high probability of detection of failure or process disturbances</td></tr>
<tr><td>4</td><td rowspan="3">Average risk, failure occurrence probable, process of good ability to quality, but unstable (63 < PPM < 2700)</td><td rowspan="3">Average, causes user's dissatisfaction and makes exploitation difficult, considerably deteriorates product properties</td></tr>
<tr><td>5</td><td rowspan="2">Average, no full control of process</td></tr>
<tr><td>6</td></tr>
<tr><td>7</td><td rowspan="2">Failures occur often, process unstable and of low ability to quality</td><td rowspan="2">High, makes impossible appropriate machine utilization, failure correction involves high costs</td><td rowspan="2">Low, used means probably will not detect failure or process disturbances</td></tr>
<tr><td>8</td></tr>
<tr><td>9</td><td rowspan="2">Very high, almost impossible to avoid</td><td rowspan="2">Very high, product unrepairable, exploitation dangerous for user</td><td rowspan="2">No possibility or means for detection of failure or resulted disturbances</td></tr>
<tr><td>10</td></tr>
</table>

The assumed values of *RZW* coefficients for particular failures and the calculated priority indices (W_p) give the ground for determination of further actions. In the analyzed case the values of W_p indices varied from 40 to 168. This range corresponds to the states – from the level of increased supervision and observations on correctness of system mechanisms' operation (particular components occur on the level that is not dangerous for the user and does not limit seriously the product utilization) to the level that results in machine immobilization, losses for the user and threat to exploitation safety. Particularly high index values resulted from evaluation connected with correctness or accuracy of assembling operations. The undertaken actions that concern the system (trainings, instructions, inspections) should improve considerably product quality and result in achievement of priority indices of the level (W_p < 40).

Within the problem analysis in determination of mutual relations between particular factors, the reason-effect diagram (Ishikawa diagram) can be of great help; it is a graphical analysis of the effect of various factors on the problem, together with their mutual connections (Fig. 3).

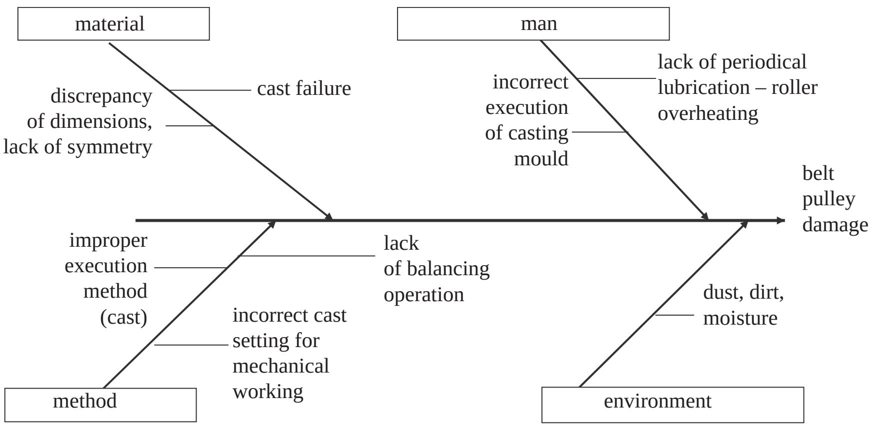

FIGURE 3. Reason-effect diagram (Ishikawa diagram) for belt pulley failure

Proper making out of the diagram (Fig. 3) calls for the efforts of employees team, often including person from outside the enterprise. In solving the complex problems, e.g. in the case of transmission system failure, usually the failure reason can be situated on various stages of production process or can result from deficiency of organizational actions in the enterprise. Correction of failures of that type calls for engagement of learned experts in a given field, focused on detection of the real failure reasons, especially, since they can result from own shortcomings or errors.

SUMMARY

One of the main aims of quality system implementation in the enterprise is making provision for good planning of actions directed to quality stabilization on good level, with effective mechanism for monitoring, evaluation and inspection of products.

The presented way of detection, analysis and evaluation of failures does not exhaust the entire quality set of instruments; however, it is an example of possible combining a series of tools and methods that enable to collect and analyze the information, and also to determine priority of remedial and preventing actions. The presented discrepancy problem approach was worked out on the basis of failure that occurred in agricultural machine. In consideration to utilization of design elements described in the analysis in a wide range of agricultural implements and machines, the presented solution of the problem can be taken into consideration in solving other practical problems, by similar situation and versatility of the used tools and methods. The assumed component values of priority index enable to consider the most important elements from the viewpoint of enterprise activity and possibility of undertaking further actions. This method for evaluation of failure importance facilitates undertaking decisions and monitoring of failure problem.

REFERENCES

BADURA L., GIEMZA M. PREDOŃ B. 2001: Zastosowanie wybranych narzędzi jakości do monitorowania poziomu jakości płytek ceramicznych. Problemy Jakości 5: 45–49.

BULIŃSKI J., WASZKIEWICZ C., BURACZEWSKI A. 2012: Stock management as an element of enterprise strategy Annals of Warsaw University of Life Sciences – SGGW, Agriculture (Agricultural and Forest Engineering) 60: 137–148.

BULIŃSKI J., WASZKIEWICZ C., BURACZEWSKI A. 2013: Utilization of ABC/ /XYZ analysis in stock planning in the enterprise. Annals of Warsaw University of Life Sciences – SGGW, Agriculture (Agricultural and Forest Engineering) 61: 89–96.

FIODOROW A. 2010: Efektywna organizacja projektów w ramach metodyki Six Sigma. Zarządzanie Jakością 3–4: 121–131.

GREBER T. 2010: Analiza skutków niezgodności dla klienta analiza FMEA. Zarządzanie Jakością 2: 118–122.

JEDLIŃSKI M. 2000: Jakość w nowoczesnym zarządzaniu. Wydawnictwo Zachodniopomorskiej Szkoły Biznesu, Szczecin.

JÓSKO M., KOŁODZIEJSKI D. 2008: Wybrane problemy eksploatacyjne pojazdów i maszyn rolniczych w zakresie ich serwisowania. Journal of Research and Applications in Agricultural Engineering 53(2): 5–7.

KOWALCZYK A., MALESZKA A. 2010: Metody i techniki zarządzania jakością w branży motoryzacyjnej. [In:] Zarządzanie jakością – doskonalenie organizacji. Red. T. Sikory. Vol. I. Wydawnictwo Naukowe PTTŻ, Kraków: 524–535.

KRISHNARAJ C., MOHANASUNDRAM K., DEVADASAN S., SIVARAN N. 2012: Total failure mode and effect analysis a powerful technique for overcoming failures. International Journal of Productivity and Quality Management 10, 2: 131–147.

KUC B.R., ŻEMIGAŁA M. 2009: Wykorzystanie wybranych narzędzi zarządzania. Problemy Jakości 6: 23–26.

MUZALEWSKI A. 2000: Koszty eksploatacji maszyn. Wydawnictwo IBMER, Warszawa.

RYBACKI P., DURCZAK K. 2010: Wyniki badań uszkodzeń awaryjnych wybranej grupy ciągników rolniczych. Inżynieria Rolnicza 5(123): 247–252.

STARZYŃSKA B., HAMROL A., NAJLEPSZY Z. 2009: Nowa metoda doboru narzędzi jakości na potrzeby doskonalenia procesów wytwarzania. Zarządzanie Przedsiębiorstwem 2: 65–74.
SZKODA J., ŚWIDERSKI A. 2008: Ocena skuteczności systemów zarządzania jakością. Problemy Jakości 5: 37–40.
SKOTNICKA-ZASADZEŃ B. 2013: Doskonalenie procesu produkcyjnego w przedsiębiorstwie przemysłowym z zastosowaniem metod projektowania jakości. In: Innowacje w zarządzaniu i inżynierii produkcji. Ed. R. Knosali. Oficyna Wydawnicza Polskiego Towarzystwa Zarządzania Produkcją, Opole: 1003–1012.
ŚWIDERSKI A. 2010: Wybrane aspekty doskonalenia jakości usług transportowych. Zarządzanie Jakością 3–4: 43–50.
WOLNIAK R. 2011: Wspomaganie metody FMEA w przedsiębiorstwie produkcyjnym. Problemy Jakości 1: 15–21.

Streszczenie: *Metody analizy wad w maszynach rolniczych.* W artykule przedstawiono wieloelementową metodę analizy wady mechanizmu w maszynie rolniczej. Metoda oparta jest na dekompozycji systemu, analizie relacji funkcjonalnych zachodzących między elementami mechanizmu. Metoda umożliwia zlokalizowanie wady, określenie potencjalnych przyczyn jej występowania i określenia elementów krytycznych. W analizie wykorzystano narzędzia i metody instrumentarium Systemu jakości, takie jak Analiza przyczyn i skutków wad (FMEA), diagram drzewa zdarzeń, diagram przyczynowo-skutkowy. Przyjęte w analizie FMEA wartości współczynników i obliczony na tej podstawie wskaźnik priorytetu umożliwiają określenie granicy między wadami krytycznymi a pozostałymi, wyselekcjonowanie wad krytycznych i podjęcie stosownych działań korygujących i zapobiegawczych. Prezentowane podejście umożliwia rozwiązywanie trudnych problemów jakościowych, występujących w maszynach rolniczych o znacznym stopniu technicznej złożoności.

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