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COMPARISON ANALYSIS OF TWO WINDER HYDRAULIC DISC BRAKE SYSTEMS WITH RESERVE

Summary. The paper deals with a certain properties of two hydraulic disc brake systems with reserve used for mining winders. Values of essential reliability factors has been compared for two different constructional solutions. The first one consists of two independent pump units which have one common cold reserve. The second solution consists of two independent pump units, each has its cold reserve. As values of the reliability factors estimations obtained from exploitation investigation for ASEA type hydraulic disc brakes are used. It is shown that reliability decrement due to application in the first solution one common reserve only is negligible from practical point of view.

1. INTRODUCTION

The above paper is one out of the series works (see for example [2-4]) concerning reliability of safety problems of mining winders which came into being during realisation of the research work [1].

The subject of consideration of this paper is theoretical problem which solution shows the possible way to start further investigations, constructional one, for obtaining a solution the more economical than used to now.

In nowadays mining winders of medium and high power one can meet hydraulic disc brakes more frequently. In Poland new winders for main haulage shafts have this brake only.

Hydraulic disc brake is a system which consists of two assemblies, taking into consideration their functions, namely:

- executo-driving assembly,
- supply and control assembly.

A pump unit is a significat subsystem of the brake. In several countries the unit is not reserved. In Poland, in turn, a principle of reservation of the unit is exploitation practice. One can assume that the reserve is cold one from the reliability point of view. Correctness of the reservation principle or - saying more precisely, increment of the reliability of system due to application of the reserve pump unit in comparsion with the brake without redundancy was analysed in the paper [3].

This paper is a further stage of consideration dealing with a problem of exploitation of two hydraulic brakes being subsystems of two independly operating mining winders in one haulage shaft. Considering the high cost of the pump unit conception of two hydraulic disc brakes equipped in one reserve only, came into being. The idea is purly theoretical one - yet. A problem: how reliability will change for system of two hydraulic disc brakes possessing one common reserve in relation to system of two hydraulic disc brakes where each one has its own reserve pump unit (nowadays practice), is the point of consideration of this work.

2. RELIABILITY ANALYSIS

According to what was stated in the introduction the subject of reliability analysis are two constructional solutions.

Solution I. There are given two hydraulic disc brakes with one common reserve pump unit. Let us assume, for obtaining a clear solution and for hudge simplification of computational procedure that all pump units are of the same reliability. Stipulated assumption will not be far from the possible real exploitation conditions. The above system is illustrated in fig. 1.

Solution II. There are given two hydraulic disc brakes. Each one has its own reserve. It is assumed, for comparsion possibility of the obtained results that brakes and pump units are of the same reliability. This system is shown in fig. 2.

In order to get analysis connected with real practice, the data obtained from the reliability investigations concerning hydraulic disc brakes Sweedish made ASEA type exploitated in Poland were taken into account.

In compliance with the results of research work [1], reliability of particular units A (pump) and B in brake systems are as it is shown in table 1.

Let us find now, the values of reliability factors for both considered systems: solution I and II.

Let us consider the first solution. Here we have five elements. Elements A and B can be in work or repair state. Reserve unit can be in three states: work, repair and reserve. Elements A and B can be in a standstill state as well, as in extortion state due to occurance of repair state of

Table 1

Reliability factors of units of ASEA type hydraulic disc brakes operated in Poland

Name of factor	Symbol	Value	Unit
Intensity of failures	A	4.26×10^{-4}	h^{-1}
	B	6.61×10^{-4}	h^{-1}
Intensity of repair	A	0.82	h^{-1}
	B	0.64	h^{-1}
Mean work time between two neighbouring failures	$MTBF_A$	2348	h
	$MTBF_B$	1513	h
Mean repair time	$MTTF_A$	1.2	h
	$MTTF_B$	1.6	h
Repair factor	A	5.19×10^{-4}	
	B	10.33×10^{-4}	
Availability	A_A	0.99948	
	A_B	0.99896	

element connected in a series way with it. Number of theoretically possible states is [5]:

$$L = 2^4 \times 3 = 48.$$

Analysing the set of all theoretically possible states and rejecting the subset of technically unfeasible states one can get an exploitation repertoire of process of states changing for considered system as it is shown in table 2.

Taking into consideration that all elements of A are identical then some states are identical too, from the reliability point of view. So

$S_2 = S_3 = S_4$, $S_5 = S_6$, $S_7 = S_8 = S_9 = S_{12}$,

$S_{10} = S_{11} = S_{13} = S_{14} = S_{15} = S_{16}$,

$S_{19} = S_{20} = S_{22} = S_{23}$, $S_{24} = S_{25} = S_{26}$,

$S_{28} = S_{30}$, $S_{29} = S_{31} = S_{32}$.

In the light of above the number of interesting states was reduced to 13. States S_j; $j = 1, 2, 3, 4$ are of full capability of system, states S_k; $k = 5-16, 19, 20, 22, 23$ are of partial capability of system where one brake is in work state only, second one is in repair. The remainning subset of states consists of repair states of system.

Let us show the set of reliability factors for considered system.

Table 2

Exploitation repertoire of process of states changing for system from fig. 1

System	Element						System	Element				
state	A	A	A	B	B	H	state	A	A	A	B	B	H
S_1	W	W	$\overline{R}$	W	W	1	S_{17}	(W)	(W)	$\overline{R}$	R	R	0
S_2	R	W	W	W	W	1	S_{18}	R	R	R	(W)	(W)	0
S_3	W	R	W	W	W	1	S_{19}	R	R	W	R	W	
S_4	W	W	R	W	W	1	S_{20}	R	R	W	W	R	
S_5	(W)	W	$\overline{R}$	R	W		S_{21}	(W)	R	R	R	(W)	0
S_6	W	(W)	$\overline{R}$	W	R		S_{22}	W	R	R	W	R	
S_7	R	R	W	W	(W)		S_{23}	R	W	R	R	W	
S_8	R	R	W	(W)	W		S_{24}	(W)	(W)	R	R	R	0
S_9	R	W	R	(W)	W		S_{25}	R	(W)	$\overline{R}$	R	R	0
S10	R	W	$\overline{R}$	R	W		S_{26}	(W)	R	$\overline{R}$	R	R	0
S_{11}	R	(W)	W	W	R		S_{27}	R	(W)	R	(W)	R	0
S_{12}	W	R	R	W	(W)		S_{28}	R	R	R	R	(W)	0
S_{13}	(W)	R	W	R	W		S_{29}	R	R	(W)	R	R	0
S_{14}	W	R	$\overline{R}$	W	R		S_{30}	R	R	R	(W)	R	0
S_{15}	(W)	W	R	R	W		S_{31}	(W)	R	R	R	R	0
S_{16}	W	(W)	R	W	R		S_{32}	R	(W)	R	R	R	0

Explanation: W - work, R - repair, (W) - standstill, $\overline{R}$ - reserve, H - whole brake system, 1 - full work of system H, 0 - full repair of system H.

Note. States (W) and $\overline{R}$ are identyties from the reliability point of view.

1. Probability that both brakes are working

$$P(W)_I = P_1 + P_2 + P_3 + P_4.$$

2. Probability that one brake is working only

$$P(W)_I = \sum_{i=5}^{16} P_i + P_{19} + P_{20} + P_{22} + {}_{23}.$$

3. Probability of repair of both brakes

$$P(R)_I = 1 - P(W)_I - P(W)_I.$$

4. Mean work time for both brakes of full capability MWT_I.
5. Mean repair time for repair of both brakes MRT_I.

Constructing a matrix of transitions between the states shown in the table 2 and using well-known principles [5] one can get:

$$P(W)_I = 0.9977956,$$

$$P(W)_I = 0.0021990,$$

$$P(R)_I = 0.0000054,$$

$$MWT_I = 755.89 \text{ h},$$

$$MRT_I = 1.67 \text{ h},$$

Let us consider the solution II. Here we have two threeelemented systems. Elements B can be in two states: work or repair, elements A in three states: work, repair, reserve. Number of theoretically possible states equals

$$L = 2^2 \times 3^4 = 324.$$

Nevertheless our problem is very simple due to the fact that brakes are identical and independent. In such a ligth number of practically interesting states equals four, namely:

- both brakes work, full capability of system,
- one brake is down, partial capability of system,
- both brakes are down, ful repair of system.

Calculations are trivial and results are as follows:

1. Probability that both brakes are working

$$P(W)_{II} = 0.9978076.$$

2. Probability that one brake is working only

$$P(W)_{II} = 0.0021912.$$

3. Probability of repair of both brakes

$$P(R)_{II} = 0.0000012.$$

4. Mean work time of full capability MWT_{II} = 755.91 h.
5. Mean time of repair for both brakes MRT_{II} = 1.66 h.

3. CONCLUSIONS

Comparing both sets of reliability factors for both constructional solutions one can get that reliability decrement due to usage of one common cold reserve pump unit for two brakes is negligible.

When technical difficulties is solved, the solution I will be more profitable than solution II used in Poland now. Mentioning about technical troubles one means problems concerning the moment of reserve connection with the brake. In this very moment it is necessary coordinate precisely technical parameters of both connected units. But such problems are out of the consideration scope of the reliability theory.

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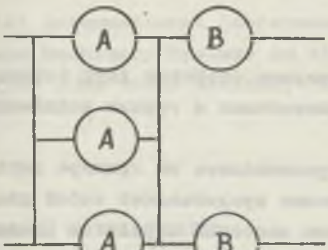

Fig. 1. System of two hydraulic disc brakes with one common reserve

Rys. 1. Układ dwu hydraulicznych hamulców tarczowych z jednym wspólnym agregatem rezerwowym

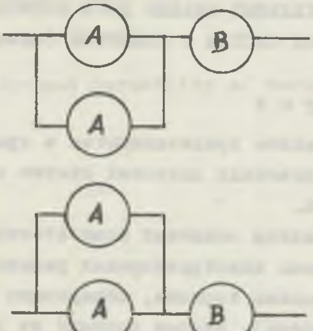

Fig. 2. System of two hydraulic disc brakes; each one has its own reserve

Rys. 2. Układ dwu hydraulicznych hamulców tarczowych z osobnymi agregatami rezerwowymi dla każdego systemu

ANALIZA PORÓWNAWCZA DWU SYSTEMÓW Z REZERWĄ HYDRAULICZNYCH HAMULCÓW TARCZOWYCH MASZYN WYCIĄGOWYCH

S t r e s z c z e n i e

W pracy rozważono pewne właściwości dwu systemów hamulcowych hydraulicznych tarczowych z rezerwą stosowanych w górniczych maszynach wyciągowych. Wartości podstawowych wskaźników niezawodności zostały porównane dla dwu różnych rozwiązań konstrukcyjnych. Pierwsze rozwiązanie składa się z dwu niezależnych hamulców posiadających wspólny rezerwowy agregat pompowy (rezerwa zimna). Drugie rozwiązanie składa się z dwu niezależnych hamulców, z których każdy posiada swą rezerwę. Jako wartości wskaźników niezawodności użyto oceny uzyskane z eksploatacyjnych badań niezawodności hamulców hydraulicznych tarczowych produkcji szwedzkiej ASEA pracujących w Polsce. Wykazano, że spadek niezawodności w przypadku zastosowania jednego tylko agregatu rezerwowego w porównaniu z rozwiązaniem z dwoma agregatami rezerwowymi jest pomijalnie mały z praktycznego punktu widzenia.

СРАВНИТЕЛЬНЫХ АНАЛИЗ ДВУХ ТОРМОЗНЫХ ГИДРАВЛИЧЕСКИХ ДИСКОВЫХ СИСТЕМ С РЕЗЕРВОМ (-ами) ПОДЪЕМНЫХ МАШИН

Р е з ю м е

В работе представляются в сравнении определенные свойства двух тормозных гидравлических дисковых систем с резервом, применяемых в горных подъемных машинах.

Величины основных показателей надежности сравнивались на примере двух различных конструкторских решений. Первое решение представляет собой два независимых тормоза, обладающих общим резервным насосным агрегатом (холодный резерв). Второе состоит из двух независимых тормозов, каждый из которых обладает своим резервом.

В качестве величин показателей надежности использовались оценки, полученные при эксплуатационных испытаниях надежности гидравлических дисковых тормозов шведского производства ASEA, работающих в ПНР (Польше).

Доказано (обнаружено), что с практической точки зрения падение надёжности в случае использования только одного резервного агрегата по сравнению с решением, использующих два резервных агрегата, очень мало (невелико).