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FUZZY LOGIC-BASED MAINTENANCE DECISION

The real world has some uncertainty and people do not always use precise definitions. The very great experience of engineers and technicians is similar to the real world's feature mentioned above. The fuzzy logic based methods can be used to make maintenance management-decision. This paper shows an example to determine time between state-estimation and permissible parameter values.

INTRODUCTION

As humans, we often rely on imprecise expressions like “usually”, “expensive” or “far”. Therefore, the real world has some uncertainty and people do not use always-precise definitions. In the engineering these ones can be error in measurement, inaccuracy results from digitalization or the integrated system's parameter-uncertainties.
The fuzzy logic is a relatively new mathematical tool, which can be used to model the inaccuracies and uncertainties of the real world mentioned above. LOFTI ZADEH, at the BERKELEY UNIVERSITY, issued first publications in the middle of 60's about the fuzzy logic. He was the first researcher who successfully applied non-binary logic in his work and called this part of the mathematics as “fuzzy”. Within conventional logic, terms can be only “true” or “false”. Fuzzy logic allows a generalization of conventional logic. It provides for terms between “true” and “false” like “almost true” or “partially false” [1].
In the aircraft engineering and in the technical management, the fuzzy logic is – can be or should be – used as a fuzzy control, decision making and diagnostic expert systems.
The very great experience of engineers and technicians is similar to the real world's characteristics mentioned above. This experience can be analyzed and utilized statistically applying the fuzzy logic. The fuzzy logic based methods can be used during trouble-shooting and to make management-decision. Using the fuzzy logic, the experts can model and solve the complicated and antinomic tasks.
The author met similar problem his earlier scientific work, when he developed a mathematical model-based maintenance management method [7]. The regulations and technical specifications do not have date about the permissible parameter values of pneumatic break system of helicopter Mi-8. Therefore the experts (pilots and

mechanical engineers) were reported. The Table 1. shows statistical results of survey. The valuable answerers were 35% of the expert population.

Statistical Results of Expert Reports Table 1.

Permissible values		Engineers	Pilots
Break-effort [%]	Minimum	0,0	0,0
	Maximum	50,0	50,0
	Medium	20,5	17,8
	Median	20,0	17,5
Break asymmetry [%]	Minimum	0,0	0,0
	Maximum	35,0	25,0
	Medium	10,1	7,4
	Median	5,0	5,0
Correlation between parameters		0,475	0,164
Times between state-estimations			
Flying hours [hour]	Minimum	5,0	
	Maximum	200,0	
	Medium	79,8	
	Median	100,0	
Calendar time [day]	Minimum	3,0	
	Maximum	365	
	Medium	120,7	
	Median	60	

DETERMINATION OF PERMISSIBLE PARAMETERS

To determine the permissible parameters on depend of expert reports the logical expression of decision should be taken down:

IF break-effort
OR break asymmetry meets the critical value (1)
THEN the system should be maintained.

The membership functions of necessity of break-effort and break asymmetry determined by Table 1. are shown by Fig 1.

It is interesting to mention that pilots suggested lesser permissible parameters than engineers did. Because of they experience consequence of failure directly. But engineers have stronger correlation between break-effort and asymmetry. These can be expounded that engineers have more consequent technical knowledge. The main task and aim of fuzzy logic is to model and solve mathematically these different opinions.

Analog fuzzy one of logical operation **OR** is the **MAXIMUM,** so the logical expression (1) meets the given value if one of assumptions meets it. Therefore the determination of permissible values is to determine parameter values, in case of which their truth-values meet the given value.

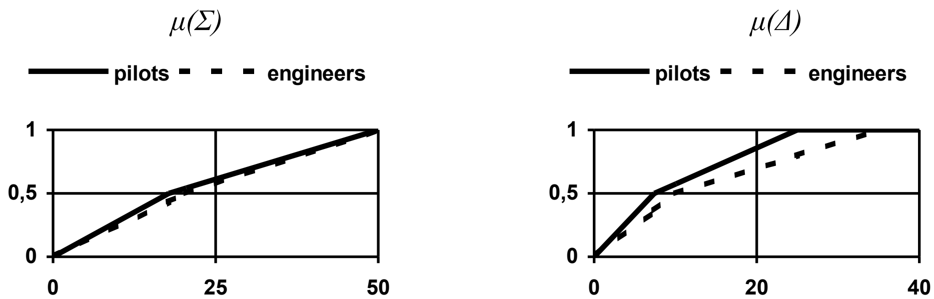

Fig. 1. Membership Functions of Permissible Values

It is expedient that the permissible truth-value of logical expression (1) is 0,7 ~ 0,8. It means that the truth-value of inadmissibility of maintenance of break-system is 0,3 ~ 0,2.

Permissible Values Determined by Fuzzy logic Table 2.

	$\delta F_{\Sigma h}$ [%]		$\delta F_{\Delta h}$ [%]	
	$\mu(\Sigma) = 0{,}7$	$\mu(\Sigma) = 0{,}8$	$\mu(\Delta) = 0{,}7$	$\mu(\Delta) = 0{,}8$
Pilots	30,68	37,10	14,44	17,96
Engineers	32,30	38,20	20,06	25,04

The Table 2. shows permissible values of parameters incident to the truth-values mentioned above.

DETERMINATION OF TIME BETWEEN STATE-ESTIMATIONS

Because of the developed diagnostic method should be adapted to an existing maintenance system, the state-estimation can be applied in earlier-determined period.

To determine time between state-estimations firstly the logical expression of decision should be taken down:

IF	checking is need taking into calendar time	
OR	taking into flying hours	(2)
THEN	state-estimation is need.	

The membership functions of necessity depend on calendar and flying time determined by Table 1. can be seen in Fig. 2. These functions have been determined by results of the expert reports mentioned above.

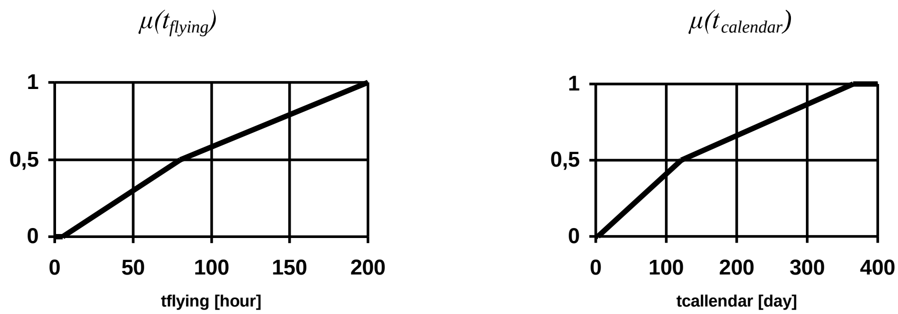

Fig. 2. Membership Function of Times

The task is to determine truth-values of expression (2) in case of practicable (used) calendar and flying time periods (see Table 3.).

Truth-values of Practicable Time Periods Table 3.

by Flying Time	t_{flying} [hour]	$\mu(t_{flying})$	by Calendar Time	$t_{calendar}$ [nap]	$\mu(t_{calendar})$
50^{+10}_{-5} hour	60	0,367	After 60^{+5} days	65	0,263
	45	0,267		60	0,242
100^{+20}_{-10} hour	120	0,667	During provisions	240	0,745
	90	0,542		120	0,496
200^{+40}_{-20} hour	240	1			
	180	0,917			

The recommended truth-value of logical expression (2), that is necessity of system controlling is 0,7 ~ 0,8. This means that needless of state-estimation is 02 ~ 0,3.

Therefore, the suggested times between state-estimation of pneumatic break system of helicopter Mi-8 *Hip* are:

$$100^{+20}_{-10} \text{ flying hours}$$

and

during summer and winter provisions.

It is important to mention that these results are less weighty than ones determined by other (statistical) methods. The time intervals are longer and permissible parameter values were augmented too. The author thinks that the results of fuzzy investigation mentioned above are fitter than other ones. But he cannot explain his opinion exactly, "only" on the basis of his experiences got during longtime practical and mathematical modeling work.

CLOSING REMARKS

This paper showed the possibilities of use of fuzzy logic during maintenance decision making. This methods was shown by simplified determination of permissible parameter values and inter-state-estimation times of pneumatic break system of helicopter Mi-8 Hip.

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