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MAINTENANCE PLANS FOR KNOWN FAULTS EVENTS, ADJUSTED WITH FUZZY LOGIC SUPPORT

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ABSTRACT

For an organization that has physical assets oriented to manufacturing and production, all maintenance plans and actions to be considered as a consequence of the occurrence of certain failure events will be linked to the safety standards and protocols established for each sector in the organization to attend such events. These rules can sometimes be inflexible, somewhat rigid in the identification and classification of fault events and the mitigation procedures of the possible consequences caused by the failures. In response to this concern, a modification of a risk identification system is proposed in the safety of industrial equipment, using fuzzy logic as a method to achieve transitions between the limits of the classifications of the events that occur in a system and to refine the risk classification, this is done in order to establish priorities in the application of palliative or preventive measures, understanding the limitations of resources, but without neglecting the attention to risk through the respective maintenance actions. In the present article a way of combining the strength of focus of the diffuse logic with the decisions on the action plans carried out in maintenance is achieved, starting from having made a classification, which is based on a matrix methodology of qualification, it is shown the results taking as an example a group of 54 crude pumps whose operation has been registered in hours of operation between failures, and decisions must be taken on their maintenance.

Keywords: Maintenance, plans, risk, fuzzy logic, decisions, matrix.

INTRODUCTION

Over the years, industrial processes and systems have become more complicated and complex with great challenges to meet the modern demand for very diverse and complex products. If you increase the number of parts and components of the system that makes the production, there will be a greater probability of failure. In these cases, the maintenance plans must be specified to achieve as much as possible an uninterrupted operation, trying to have the least amount of interruptions and ensure that they last the shortest period of time.

One step in deciding what action to take is to record each and every one of the failed events and their successful solution to be a practical guide of support in future events, but when the system becomes too complex and increasingly important, for continue to do its function, there are more disadvantages than advantages with traditional planning, not only because of the large number of possible events and solutions, but because of the time to discover the specific failure and identify the best solution.

An alternative to the previous statement is using fuzzy logic decision making criticality theory, to predict failure scenarios by monitoring the working state, days since the last maintenance, revision frequency, and how critical is the object analyzed to the process in order to suggest not only the more suitable action but also to decide those events that are more relevant

In this paper is described the methodology in which the decisions are made and the results of not only the action plan to be taken but how important is the immediate implementation of such plans.

ORIGINAL METHODOLOGY (A REVIEW)

To explain more about the methodology proposed in this paper, first it is worth to review the Ciliberti's methodology for determining the criticality of a system. It consists on setting two parameters: Hazard Criticality Rating (HCR) and Process Criticality Rating (PCR).

The first parameter refers to the operation variables involved in a specific process such as temperature, pressure, rotational speed or any other measurable variable. Those variables are classified in ranges according to their respective values.

The second parameter has to be with how important is the equipment, or sub process, to the entire process. This variable cannot be measurable but defined in accordance with an expert knowledge in the area; it is also classified into five groups.

All those variables defined before, are combined into a table in order to get an indicator called Process and Hazard Criticality Rating (PHCR). This table gives a classification for the equipment or sub process inside a larger process. Table 1 shows the PHCR table originally proposed.

Table 1 - PHCR from the original methodology

Process and Hazard Criticality (PHCR)					
PCR	**HCR**				
	4	3	2	1	0
4	A44	A34	A24	A14	A04
3	A43	B33	B23	B13	B03
2	A42	B32	C22	C12	C02
1	A41	B31	C21	D11	D01
0	A40	B30	C20	D10	D00

Where the character designates the category, the first number value designates the Hazard Criticality Rating and the second number designates the Process Criticality.

After the PHCR is determined, the methodology proposes that a new value should be determined in order to establish the called Criticality and Reliability Index (CRI), in order to do a classification of the sub process or equipment and establish comparisons between them. In Table 2 is showing the proposed classification of the CRI for rotating equipment.

Table 2 - Criticality and Reliability Index from the original methodology

CRI Values for rotating equipment				
PHCR	**Mean Time Between Failure**			
	0 - 6	6 - 12	12 - 24	> 24
A	a4	a3	a2	a1
B	a3	b3	b2	b1
C	a2	b2	c2	c1
D	a1	b1	c1	d1

Where the Mean Time between Failures could be any time measurement, including days, weeks, months, etc.

With the equipment classification done, the methodology proposes an inspection interval with an action list, to prevent possible failures. Table 3 shows the proposed inspection interval for rotating equipments.

Table 3 - Inspection Interval from the original methodology

Inspection Intervals					
CRI	**Frequency (days)**				
	7	30	90	180	360
a3,a4	V	L			
a1,a2		V	L		
b1,b3			V	L	
c2,d1					V
V = vibration monitoring L = lubrication monitoring					

All of the values determined in this methodology are fixed quantities, which is correct to begin to understand the relevance of equipment in the whole process and to start to determine actions to be taken in case of an event occurrence. All of this with the main goal of saving time and resources by maximizing the operating time and the safety of the entire process but, the main problem is that when there are big numbers of similar equipments, working on similar conditions and with similar associated risks, this method tends to classify all of them in the same category.

METHODOLOGY - PROPOSED IN PREVIOUS WORK

In previous work a modification was proposed, based on fuzzy logic, to calculate a more accurate value to perform the classification of a set of oil pumps working under similar conditions, but with different Mean Time Between Failure values. This gave as a result, a better classification of the Criticality and Reliability Index in order to know which of the pumps represented the most critical factor in the entire process.

Below, in Table , are presented some values calculated, according to the previous work methodology, for the CRI calculated for 12 pumps working at similar conditions.

Table 4 - CRI values calculated in the previous work

Pump id.	CRI	Pump id.	CRI	Pump id.	CRI
1	7,272554	5	6,116590	9	3,544662
2	7,272554	6	4,411878	10	3,268606
3	6,286704	7	4,411878	11	1,546760
4	6,231221	8	4,411878	12	1,546760

METHODOLOGY PROPOSED

The objective of this paper is to give a specific action, based on a fuzzy logic decision making system, to a particular set of working conditions to similar equipments or parts of an entire process, avoiding to get the exactly same action to different situations or, in the worst scenario in which the action is the same, to assign a priority to an equipment or process. To achieve this, two input values are proposed, the first is the CRI value previously calculated, and the second one is the time period between the current time and the last time an action was performed. Those inputs have to be converted into fuzzy values to be processed.

The first input is defined in the range from 0 to 10, and the same membership functions from the previous methodology are assigned, so no information is lost during the calculations.

The second input consists on the time period between the performance of any actions for each equipment or process. For simulation purposes, this input variable is defined in a range of days 0 days and 360 days, assigning five membership functions to cover all this range.

An output variable is also defined as a fuzzy value but, in difference with the original methodology which only has two possible actions, we are defining a list of 8 different actions. This is done to take advantage out of the fuzzy system by covering an output range value from 0 to 9. Then, in Table 5 is presented a list of actions proposed for this paper.

Table 5 - Proposed action list

Action	Definition	Action	Definition
N	Do nothing	V ½L	Normal vibration inspection and rough lubrication inspection
½V	Rough vibration inspection	V! L	Urgent vibration inspection and normal lubrication inspection
½V ½ L	Rough vibration inspection and rough lubrication inspection	L!	Urgent lubrication inspection
V	Normal vibration inspection	F	Imminent failure

The last definition needed in order to the fuzzy logic system could be completed are the rule system. For the proposed methodology a set of 50 rules are defined to combine all the inputs membership functions to cover all the possibilities. In Table 6 is presented the combination of the inputs and outputs.

Table 6 - Combination of the inputs and the output to obtain the rule system

		Time between inspections				
		7	**30**	**90**	**180**	**360**
CRI value from the previous calculations	**a4**	V	V! L	L!	F	F
	a3	V	V! L	L!	F	F
	a2	½ V	V ½L	V! L	L!	F
	a1	½ V	V ½L	V! L	L!	F
	b3	N	½V	V ½L	V! L	L!
	b2	N	½V	V ½L	V! L	L!
	b1	N	½V	V ½L	V! L	L!
	c2	N	N	N	½V ½ L	V
	c1	N	N	N	½V ½ L	V
	d1	N	N	N	½V ½ L	V

RESULTS AND CONCLUSIONS

The proposed decision making system is defined using trapezoidal membership functions; these allows more degrees of freedom when they are been defined to obtain a large number of configurations, to choose the best that fits the particular system needs. Below, in Figure 1, is presented the first input for the proposed methodology.

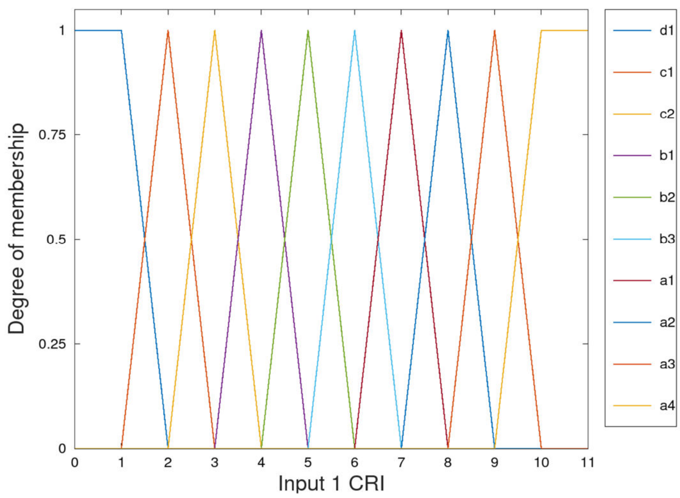

Fig. 1 - First input membership functions.

The second input for the decision making methodology, is presented below in Figure 2. These membership functions are chosen trapezoidal in order to get as many configurations as needed.

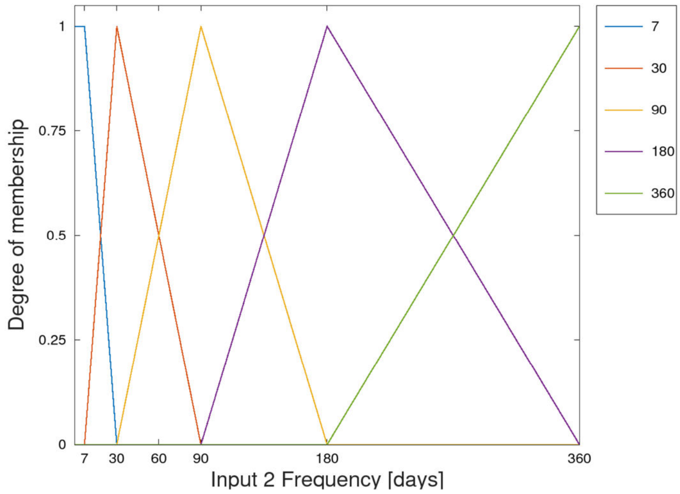

Fig. 2 - Second input membership functions.

The output membership functions are shown in the Figure 3, also presenting trapezoidal membership functions.

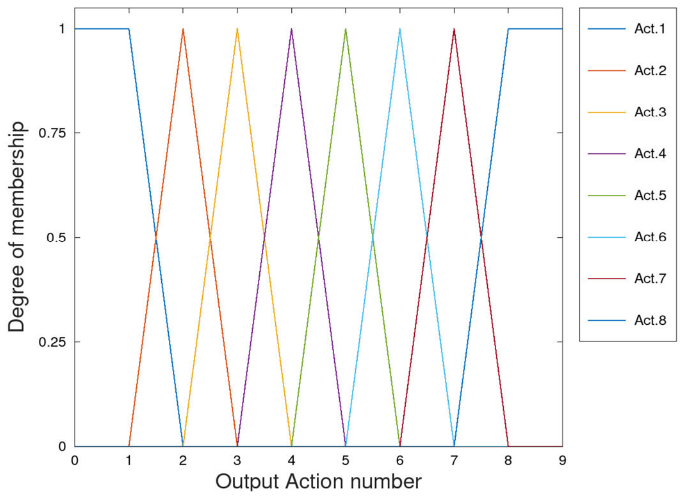

Fig. 3 - Output membership functions

To demonstrate the final output of the decision making system, a series of three examples are tested. They consists in three pumps with different CRI values, see Table 7, which are going to be the first input of the system; and the second input is going to be the whole frequency range (days from 0 to 360). This will allow knowing the degree of importance for all the possible scenarios for each pump at each frequency.

Table 7 - CRI values for the pumps tested

Pump identification number	CRI
1	7.272554
2	4.411878
3	1.546760

The result of analyse those pumps using the proposed system, is presented in Figure 4, where can be seen the change of importance of a maintenance plan according to the frequency of the last action taken for each pump.

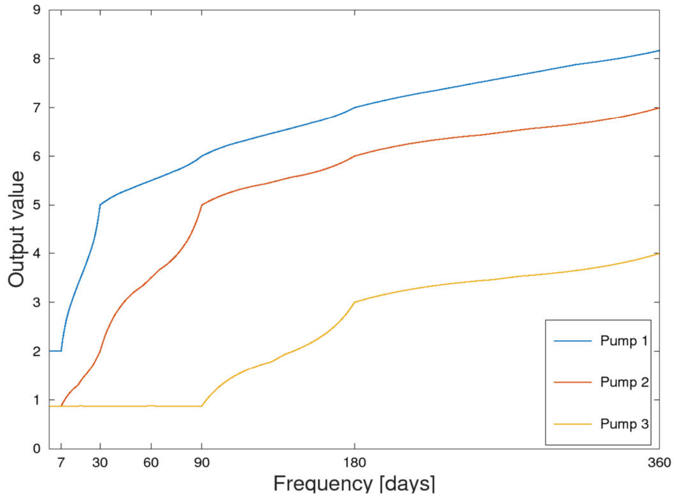

Fig. 4 - Results of the three pumps analysed

The result of the simulation for a particular frequency of maintenance of 180 days can be seen in Table 8 for the three pumps analyzed with the maintenance action to be performed according to the system designed.

Table 8 - Action list and priority for the three pumps at the same frequency

Pump identification number	CRI	Output value	Action
1	7.272554	6.9995	Urgent lubrication
2	4.411878	5.9992	Urgent vibration check and lubrication
3	1.546760	3.0003	Less important vibration and less important lubrication check

Achieving criticality and using fuzzy to the process allows better attention in generating maintenance plans.

Achieving a hierarchy of actions through criticality criteria will favor the replacement of the affected function, doing so in times that will allow greater operational availability and a reduction in risks as a result of unexpected stops.

The priority established trough the maintenance plans, will allow focus on the items with less reliability, this kind of action help to reduce risk.

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