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An Evaluation for Stabilizing Device of Naval Ships Using Fuzzy VIKOR

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Abstract

For naval ships, some operations have critical importance. For example, landing a helicopter is one of the major parts of military action and undesirable roll motion make difficult this operation. Also, the crew can show inadequate performance because of roll motion effect. So, determining of the most effective stabilizing device for naval ships is crucial related to reducing of roll motion fastly.

This study evaluates the relationship between criteria and alternatives in order to select most effective roll stabilizer system for naval ships based on expert opinions. Fuzzy VIKOR was used to list the alternatives. As a result of the obtained values, the most effective roll stabilizer device has been chosen for the naval ships.

Keywords: *Navigation Safety, MCDM, VIKOR*

1. Introduction

Rolling is one of the most damaging motions for a ship. It is very important reduction of roll motion to improve ship operability. Especially naval ships have to be highly manoeuvrable in various operation conditions. So, different stabilizing devices for naval ships are examined and evaluated their performance by many researchers.

Baitis (1983) examined feasibility of rudder roll stabilization for coast guard cutters and frigates. He discussed costs and benefits of anti-roll fin system, as well as two different performance level Rudder Roll Stabilization systems. Baitis (1989) proposed rudder roll stabilization in the U.S. Navy as an alternative to the more common approach of roll-fin stabilization to reduce ship roll motion in the high sea states. Ferreiro et al. (1994) used rudder pitch stabilization system for a destroyer. They recommended a program to further develop pitch stabilization using high lift canted rudders. Surendran et al. (2007) suggested fin stabilizer system to reduce the roll motions of a frigate-type warship in the various sea states. Stafford and Osborne (2008) proposed a new programme evaluating stabilizer performance for an operational type 23 Frigate. Swartz et al. (2012) examined the structural behaviour of high-speed littoral combat vessel ship during their operation at sea. Perez and Blanke (2012) investigated development of various ship roll motion control systems together with the challenges associated with their design. They discussed the performance and the applicability of these systems. Sutton et al. (2014) used fin stabilizers to reduce roll motion of a modern warship. They improved operational efficiency with this way. Kim et al. (2014) examined the roll damping characteristics of bilge keels as stabilizing device. They expressed results of their study for three types of the bilge keel. Zihnioglu et al. (2016) studied parametrically model hydraulic system of a ship motion reduction active fin stabilizer system with fins. They verified simulation results with full scale sea trials using a ship named Volcano71.

2. The fuzzy VIKOR method

The fuzzy VIKOR method can be used to identify conciliatory solutions to problems with multiple criteria. The proposed fuzzy VIKOR decides to make the decision-makers choose the most appropriate solution for a particular decision problem in real environments. The concept of fuzzy logic and the VIKOR method was created to provide a rational and systematic process to discover the most appropriate and conciliatory solution that can be used to solve a fuzzy multi-criteria decision. The development of VIKOR method started with the following form of Lp-metric (Opricovic, 2011; Vahabzadeh, et al. 2015; Rostamzadeh et al. 2015; Balin, et al. 2015; Balin et al. 2016); Zhao, et al. 2017; Ren, et al. 2017:

$$L_{pi} = \left\{ \sum_{j=1}^{n} W_j \left[\left(\frac{f_j^* - f_{ij}}{f_j^* - f_j^-} \right) \right] \right\}^{1/p} \qquad 1 \le p \le +\infty; 1 = 1, 2, \ldots I$$

The VIKOR method uses formulated $\left(L_{1,i}\ as\ S_i\right)$ and $\left(L_{\infty,i}\ as\ R_i\right)$ to rank. The solution obtained by min S_i represents the maximum group utility, while the solution obtained by min R_i represents individual regret. The following figure 1 generate the algorithm of the fuzzy VIKOR method. Figure 1 shows diagram of Fuzzy VIKOR technique presented by Anvari, at al., (2014).

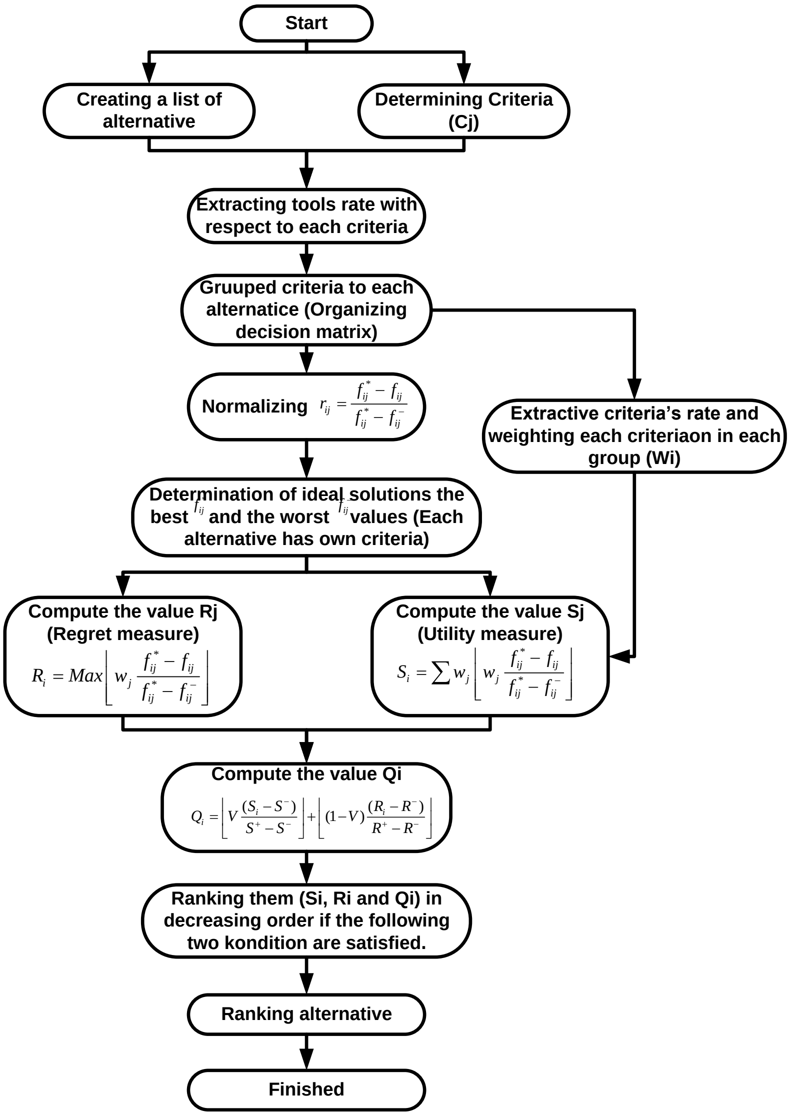

Figure 1. Diagram of modified VIKOR technique adopted from Anvari, at al., (2014)

3. A Real Case Study For Selection Of Roll Stabilizer For Naval Ships

Roll stabilization systems have been the subject of scientific research for years. Ships are not required to move unexpectedly during operation. Recently, the importance of which type of stabilizing system is more suitable for which type of ship. This article reviews all stabilization devices and proposes the methodology of choosing the most suitable roll motion stabilization system for military boats.

Depending on the type and conditions of operation, selecting the appropriate stabilization system requires evaluation of various criteria. The performance of naval ships operating in ports, inland waters or offshore is directly affected by these criteria. This choice should be made by experts with high experience, as well as technical knowledge of balancing systems and operations. Twelve criteria and four alternatives (A1 Gyroscopic roll stabilizer, A2 Anti-Rolling Tanks, A3 Activated Fins, A4 Rudder Roll Stabilization) obtained through literature review and matured through interviews with the sector are presented in Table 1 with brief explanations. Figure 2 illustrates the relationship between the criteria and alternatives categorized according to the VIKOR method.

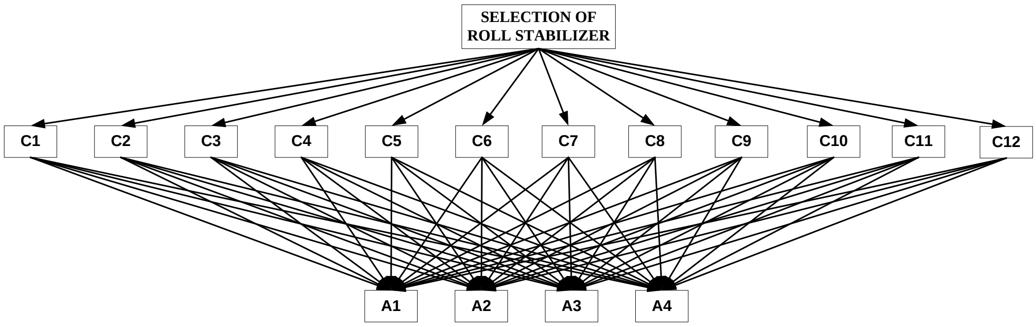

Figure 2. Hierarchical structure for selection of roll stabilizer

Table 1. Definitions of defined criteria for roll stabilizer selection problem (Sellars and Martin, (1992)

No	Criteria	Definition
C1	Total İnitial Cost	Investment cost of stabilization system
C2	Cargo Carrying Capability	Effect on ship's carrying Capacity
C3	Crew Performance	Ease of movement on ship
C4	Influence On Speed, Power And Resistance	Effect of stabilization system on ship performance
C5	Maintenance Requirements	Ease of service and additional cost effect
C6	Roll Reduction	Improvement rate of roll motion
C7	Underwater Noice	Noise effect caused by stabilization systems during full operation
C8	Expensive Pieces Of Equipment	High cost availability for active stabilization systems
C9	Working on Low Speed Range	Effect on low speed of stabilization system
C10	Working on High Speed Range	Effect on high speed of stabilization system
C11	Motion Limitations	Effect of limiting the movement of the ship
C12	Wave Conditions	Working condition in rough seas of stabilization system

The weights matrix of the alternatives-criteria was calculated by fuzzy VIKOR. Normalized decision matrix has been prepared, as shown in Table 2.

Table 2. The normalized decision matrix calculated.

	A1	A2	A3	A4
C1	(0.24,0.13,0)	(1,1,1)	(0,0,0)	(0.24,0.13,0)
C2	(0.667,0.5,0.167)	(0.333,0.833,0.833)	(0,0,0)	(0.833,0.833,0.333)
C3	(0,0,0)	(1.625,1.071,0.75)	(2.167,2.5,2.5)	(2.167,2.5,2.5)
C4	(0.588,0.556,0.333)	(2.5,2.5,2.5)	(0,0,0)	(0.882,0.833,0.5)
C5	(0.533,0.628,0.5)	(0.833,1.167,1.167)	(0,0,0)	(0.133,0.09,0)
C6	(1.273,0.921,0.269)	(3.5,3.5,3.5)	(0,0,0)	(0.955,0.553,0)
C7	(1.587,1.407,0.964)	(2.833,3.167,3.167)	(0,0,0)	(0.68,0.469,0.138)
C8	(0.19,0.143,0.059)	(1,1,1)	(0,0,0)	(0.286,0.238,0.118)
C9	(0.647,0.619,0.6)	(0,0,0)	(1,1,1)	(0.118,0.095,0)
C10	(0,0,0)	(3.5,3.5,3.5)	(0,0,0)	(1.167,1.167,1.167)
C11	(2.5,2.5,2.5)	(2.5,2.5,2.5)	(0,0,0)	(0.5,0.441,0.227)
C12	(3.5,3.167,3.167)	(3.5,3.167,3.167)	(0,0,0)	(0,0,0)

S, R, Q value were calculated for each alternative, results and ranking of the alternatives are shown in Table 3 and Table 4, respectively. Table 3 demonstrates that Activated Fins and Rudder Roll Stabilization have been chosen as the most appropriate alternatives with the 0.000 and 0.091 Q value as the common opinion of all subject-matter-experts, where Anti-Rolling Tanks has been determined as the last option with the 1.000 Q value. Gyroscopic roll stabilizer has been ranked as the third with 0.537 Q value.

Table 3. The evaluation value of each roll stabilizer system type

	A1	A2	A3	A4
S	10.428	23.305	3.444	7.057
R	3.222	3.500	2.444	2.444
Q	0.537	1.000	0.000	0.091

Table 4. Ranking of the roll stabilizer system types by VIKOR

	A1	A2	A3	A4
S	3	4	1	2
R	3	4	1-2	1-2
Q	3	4	1	2

According to Q(a(2)) − Q(a(1)) > 1/(m − 1) (where Q(a(2)) is the suboptimal scheme in Q rank tables and Q's VIKOR evaluation value), we can get Q(A4) − Q(A3) = 0.091– 0.000= 0.091< 1/3 for A3 and A4. therefore, there is no significant difference between a3 and a4 and therefore both alternatives are the most preferable alternatives. According to Q(a(3)) − Q(a(1)) > 1/(m − 1) (where Q(a(3)) is the third suboptimal scheme in Q rank tables and we can get Q(A1) − Q(A3) = 0.537– 0.000= 0.537>1/3 for A3 and A1.

The A3 and A4 alternatives are the optimal solution for S and R sorting tables and Q rankings simultaneously. Therefore, the final ranking according to the fuzzy VIKOR method is A3 = A4> A1> A2 respectively, and the best alternative is A3 and A4.

4. Conclusion

The objective of the present work is to determine the most effective stabilizing device for naval ships. The use of different roll stabilizers is discussed considering many parameters. In the proposed methodology, the fuzzy VIKOR method was used and it was analysed by using the expert opinion on the alternative-criterion. Therefore, the use of fuzzy weights in VIKOR makes the application more realistic and reliable. The methodology developed seems to be functional to solve such questions.

In order to achieve this result, twelve criteria for four stabilizing systems have been examined, considering the opinions of the experts. In the decision-making model, it was modelled and evaluated by the engineers, technical experts, engineers of design firms and academicians who worked on general naval ships.

When the effect of the criteria on the alternative types of system is examined, it is found that Activated Fins and Rudder Roll Stabilization are the most functional alternative as a result of the common opinion of all subject experts. It should be noted that the results of these assessments may vary due to expert change.

The choice of ships to be invested in the countries operating in various national or international waters may be determined by similar methods in future studies by increasing or decreasing the number of criteria.

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