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Enhancing Ship Roll Stabilization: Design of Active Fin Stabilizers Using Auto-Tuned PID Controllers

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Abstract

The rolling motion of any type of mechanical system can be realized by the linear differential equation with some constant coefficient. In the domain of marine industries, it is observed that the stabilization of the ship's roll motion is required due to the occurrence of the most unwanted water wave disturbances at the sea. It may cause serious types of damage to the equipment related to the ship. Active fin stabilizer is the most widely used stabilizer among all types of stabilizers like anti-roll tanks, gyroscopes, etc. This research article proposed a special type of auto-tuned PID controller that improves the stability of the fins of the stabilizer as well as roll frequency. Here three different conditions of ship roll motion are taken for the experimental purpose and PID controllers are designed according to them. Due to the nonlinearity, the fin angle is generally been considered by the previous researcher but in this work, some special types of nonlinearities are taken into consideration in the form of fin angle during the design of the controllers.

Keywords: Non-linear control, ship's roll, stabilizer, PID controller, system modeling

INTRODUCTION

The ships in the seas suffer from six different types of rolling issues and they use various types of stabilizers. The crews who take a vital role in the movement of a ship at sea, suffer from rolling motion and get interruptions in their tasks. It may even stop the total activities of the crews in adverse situations. Sometimes, it may cause the seasickness of the passengers from the unwanted roll motion that takes place far away from the centerline of the ship. Overall, it reduces the comfort of the passengers and causes cargo damage to fruits like soft items. If the roll angle increases beyond a limit, the capabilities of handling the equipment in the ship's board decline in the naval vessels to perform typical operations related to the weapon, launching some recovering system, sonar-related operations, etc. The stabilizer like fins or rotors below the waterline reduces some unwanted roll motions of the ship coming from the sea waves. A critical hull design and proper load distribution within the ship also take care of the stability. The active fins are generally been controlled by the gyroscope control system (GCS) which can sense the roll of the ship and according to the roll, it can change the fin's angle to overcome the roll. According to (Robert et al. 1997) [1], multidisciplinary design optimization of mechatronic systems is a complex task that involves integrating multiple engineering domains at the same time. (Alarçin 2007) [2] developed a neural network (NN) based on internal model control (IMC) to adjust the control parameters for the roll motions of a container ship. The controller architecture, which integrates a neural network with internal model control, was detailed, and its effectiveness was demonstrated on the container ship roll stabilizer. (Alarçin and Gulzer 2007) [3]

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present a neural network (NN) controller for a fishing vessel rudder roll system. This study aimed to build an NN controller that uses a rudder to regulate both the yaw and roll motion. The potential improvements in a warship's ability to conduct anti-submarine warfare missions in the North Atlantic are evaluated when different control strategies for fin roll stabilization are used. Additionally, an assessment of the potential benefits to the operational performance of an Integrated Fin Rudder Roll Stabilization system is included (Bhattacharyya 1978; Crossland 2003; Dubey et al. 2017) [4,5,6]. The sliding mode controller technique, equipped with a roll reduction function on the ship's rudder, simulates the vessel's motion in random seas. The rudder operation is used to examine the track-keeping ability of the sliding mode controller on the ship, utilizing the line-of-sight (LOS) guidance technique (Dallinga 1993; Fossen 1994; Fang and Luo 2006) [7-9]. (Fang and Luo 2007) [10] developed an autopilot system that modifies the rudder deflection to guide the ship over erratic waves using a sliding mode controller and a line-of-sight guiding method. There are two kinds of sliding mode controllers used: an integrated system that concurrently controls sway, roll, and yaw control, and a separate system for sway, yaw, and roll control. (Fang et al. 2010) [11] provide a mathematical model that incorporates maneuvering and seakeeping features to examine roll reduction for a ship using a stabilizer fin in erratic waves. By adjusting the ideal stabilizer fin angles, a self-tuning PID controller based on neural network theory lessens the roll motion of the ship in waves. (Jin et al. 2008) [12] examined the stresses on fin stabilizers caused by irregular flow velocity circumstances while analyzing unstable flows. They also created a brand-new model for lift generation. By contrasting experimental findings of fin stabilizer motion under non-standard velocity conditions obtained using fluid calculation software with results from the lift-generation model emulator, the correctness of this model was verified. The most popular sort of stabilizer, compared to others like anti-roll tanks and gyroscopes, is an active fin stabilizer (Kawazoe et al. 1994) [13]. (Kula 2014) [14] describe a roll stabilization control system with an extra feedback loop. The system must minimize any differences between the measured and controller-determined lift forces by modifying each fin's turn angle separately. The primary regulator is going to be a PDD2 controller. (Law et al. 2005) [15] show the outcomes of a fin-rudder controller synthesis that compares several controller types intending to lower roll. To stabilize ship motion, three primary kinds of controllers PID, advanced phase, dual loop transfer recovery (LTR), and sliding mode (SMC) were investigated. (Lee et al. 2011) [16] focused on roll motion caused by waves at sea. Consequently, fin stabilizers are installed to mitigate this roll motion. Fin stabilizers are effective in reducing roll motion at moderate speeds but less effective at lower speeds. More recently, pod propellers have been combined with fin stabilizers to enhance roll stabilization. (Liang et al. 2022) [17] design a method for a fin stabilizer based on the Lyapunov stability theory was investigated. The roll motion model of the ship was formulated, and roll reduction was achieved through a state feedback controller. The moment when the ship rolls, fixed fins, and bilge keels do not move from their original position as they die down the amount of roll by exerting some hydrodynamical forces (Arjm 1997) [18]. (Moaleji and Gerig 2006) [19] examined the complete six degrees of freedom motion of a cargo ship without roll stabilizers under rough sea conditions (sea state 5), testing multiple heading angles from 0° (follower seas) to 180° (head seas). Findings revealed that the ship experiences significant roll motion, particularly in quartering (45° off the stern), beam, and head seas. (Moaleji and Gerig 2007) [20] provide an overview of the evolution of ship anti-roll tanks from the 1880s to the present day, discussing their modeling, control strategies, and other ship roll stabilization systems. They also explore the adaptation of this technology to stabilize other structures. According to the righting arm's positive values, the ship receives the restoring moment to return to its former position and become stable. The right arm's negative values show that the system is unstable. The right arm's value changes from positive to negative at a specific angle known as the angle of vanishing stability (Ogata 1990, Perez, 2005) [21-22]. The hydrodynamic coefficients for the vessel are calculated, taking into account the lift capacity of the fins, as part of designing a controller for stabilizing roll motion using fin-based technology on a coastal research vessel (CRV). Fins are positioned mid-ship based on the actuator geometry (Patil et al. 2019, Perez et al. 2011) [23-24]. (Perez and Goodwin 2008) [25] explore the latter approach and suggest employing model predictive control (MPC) to mitigate the onset of these nonlinear effects. This method considers constraints on both the mechanical angle of the fins and the effective angle of attack. (Phairoh and Huang 2007) [26] investigated the active control of ship roll motion using various control techniques including proportional and derivative controllers, linear quadratic regulator (LQR), generalized predictive control (GPC), and deadbeat predictive control. A U-tube water tank was utilized for experimental validation. System identification was employed for predictive control, enabling the adaptation of parameters in the linear ship roll model within the U-tube tank to account for changes in ship dynamics. (Roberts 2008) [27] establish the context by reviewing the initial advancements in automatic control systems for ship navigation, culminating in the development of Sperry's automatic pilot. The ships which are made for long journeys in the sea include stabilizers. Despite the stabilizer, sometimes the damping of the hull is not sufficient to reduce the roll motion up to the mark or up to the satisfactory level (Lee et al. 2011) [28]. (Neves et al. 2003) [29] discuss an inquiry into the significance of parametric resonance for a standard fishing vessel encountering head seas. Findings from experimental, numerical, and analytical studies are presented for various Froude numbers. (Sharif et al. 1996) [30] provide findings from extensive roll stabilization trials conducted aboard a frigate-sized royal naval warship. These trials involved assessing the effectiveness of fins operating independently versus their combined operation with rudders, aimed at reducing roll motions. The roll-reducing equipment is loaded within the ship which is also useful to reduce the roll effect of the ship (Sathit et al. 2021) [31]. (Stettler and Hover 2004) [32] Share findings and analyses from an experimental investigation into how stationary and moving azimuth conditions affect the propulsion performance of a puller-podded unit in open water. (Tzeng and Wu 2000) [33] describe an Internal Model Control (IMC)-based controller for stabilizing ship fins is detailed. The method directly adjusts the output sensitivity function, linking wave disturbances to ship roll motion, to effectively reject disturbances. Some prototypes were designed by the previous researcher as a patent but still, in this research work, it is implemented the response of the stabilizer after incorporating the concept of autotuned PID controller (Umeda and Hashimoto 2000) [34]. An effective control scheme known as Robust Adaptive Fuzzy Control (RAFC) can be applied to manage uncertain nonlinear systems where the robust relative degree matches the system's degree, particularly addressing the challenge of stabilizing ship roll. Through a global diffeomorphism, the uncertain system can be transformed into a controllability canonical form (Yang et al. 2002, Whicker and Fehlner 1958) [35,36]. (Zhou et al. 2008) [37] discuss the growing significance of ocean utilization, highlighting the increasing need for anti-rolling stability in anchored ships. The lift generation theory of conventional fin stabilizers relies on incoming flow velocity, which fails to adequately explain the lift generated when a ship is at anchor. (Zhang et al. 2019) [38] examine the control mechanism of a fin stabilizer at zero speed using a combined approach of theoretical analysis and experimental research. Utilizing the established reaction force model, compare and analyze the forces generated on the fin moving in sinusoidal and trapezoidal patterns. This research gap has been found after studying various articles related to the Active fin stabilizer. But till today the non-linearity has not been included in the design. In this study, a novel kind of active fin stabilizer has been suggested that can recognize changes in weight and height. For the goal of this experiment, three different conditions for ship roll motion are chosen, and PID controllers are created following them. The fin angle is typically taken into account by previous researchers due to nonlinearity. However, in this work, some unique forms of nonlinearities are taken into consideration in the form of the fin angle during the construction of the controllers. The result section includes the relevant simulation results of the proposed design. The simulation's output describes how the ship's righting arm changes depending on the roll angle. The consistency of the ship's roll reveals the restoring force working on the ship to return to its initial location. The ship receives the restoring moment to return to its former position and become stable, according to the righting arm's positive values. The right arm's negative values show that the system is unstable. The right arm's value changes from positive to negative at a specific angle known as the angle of vanishing stability.

METHODOLOGY

There exist various types of stabilization techniques that use different principles to reduce the ship's roll. Some special types of stabilizers are selected and then the stabilization technique or principle used for the stabilizer is listed in Table 1 given below.

Bilge Keels

This is a fantastic device invented in the year 1950 that attained huge popularity in the ship for reducing the roll motion to a large extent. These are nothing but a plate coming out from the turn of the bilge. Figure 1 shows the bilge keel for the ship stabilizer.

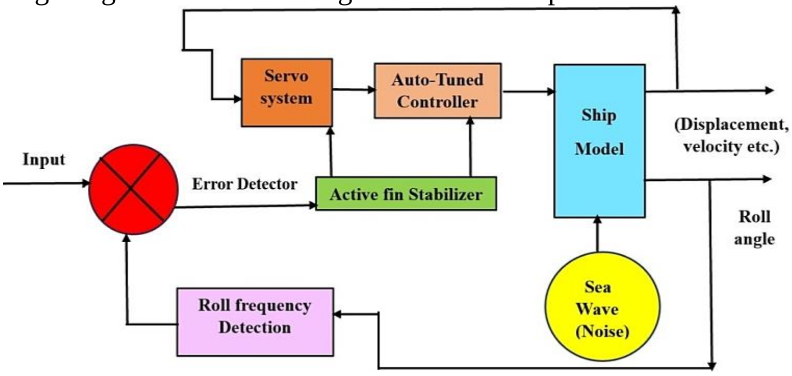

Figure 1. Bilge keel for ship stabilizer.

Table 1. Stabilization technique and principle used for various Stabilizer.

S.N.	Stabilization technique	Principle used
1	Bilge keels	Acceleration of external fluid mass
2	Fins	Acceleration of external fluid mass
3	Rudder	Acceleration of external fluid mass
4	Motion of weights	Displacement of internal solid mass
5	Anti-roll tanks	Displacement of internal fluid mass

The length of the plate is half or two-thirds of the length of the ship. It is operating on the principle that it increases the hull damping after generating some special types of balancing force which are almost perpendicular to the keels and are used to reduce the unpredictable roll motion of the ship. The conversion from one energy to another energy takes place in this principle. Here kinetic energy of the roll of the ship is converted into viscous energy.

Anti-rolling Tanks

There are various types of anti-rolling tanks used to minimize the roll of the ship. All types are used to minimize the roll angle. But among all types of rolling tanks, the ‘U Tube Tank’ is widely used as its efficiency is too high. This consists of mainly three components. Two reservoirs and a special type of connector. Figure 2 shows the top view of the anti-roll tank**.** These two reservoirs are placed in a proper place. One is placed on the port and the other is placed on the starboard. Between them, a connector is placed appropriately. The basic principle is that the fluid existing inside the tank moves at the same speed at the ship. Hence the device can control the speed of the roll motion. The efficiency can be maximized up to 80% if the design of the stabilizer is made in a sophisticated way.

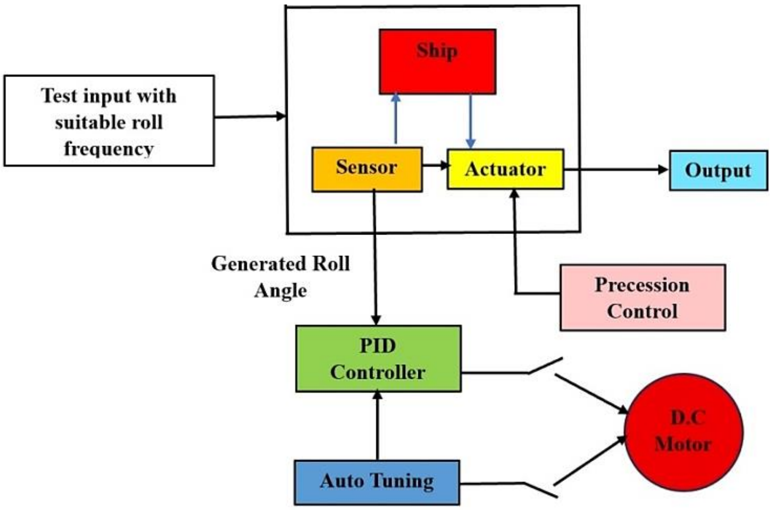

Figure 2. A top view of the anti-roll tank.

Active Fin Stabilizers

It is framed on moving stocks and consists of a pair of hydrofoils. The structure is shown in Figure 3 given below. In the rough seas, the performance of the speed improves due to the reduction of rolling. Using the passive device, the amplitude of the roll can be reduced. This type of technique requires the forward motion of the ship to lift the system. The construction is non-erectable.

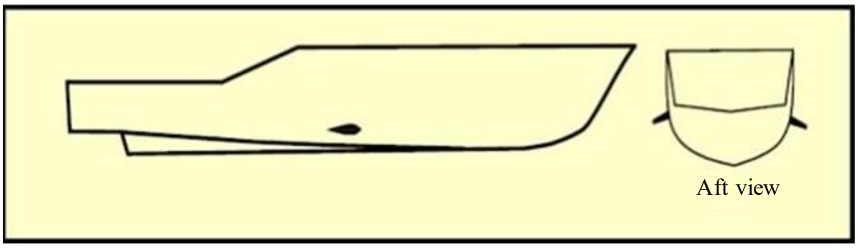

Figure 3. Active fin stabilizer.

Rubber Roll Stabilizers

In this stabilizer, a rubber is placed the underneath center of gravity of the vessel. As a result, it provides an extra feature like self-driven capability. The drawbacks of the anti-roll tank can be overcome by the help of a rubber roll stabilizer. Figure 4 shows the different types of the stabilizer at a glance. After going through the detailed discussion of four types of stabilizers it can be concluded that the active fin type stabilizer is the best one.

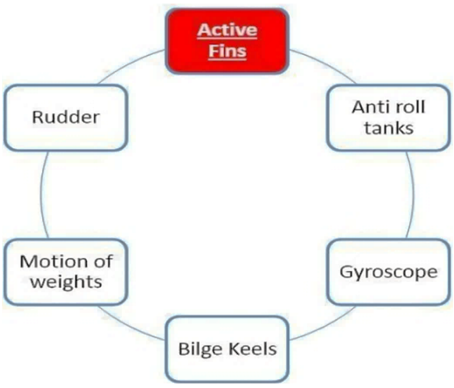

Figure 4. Various types of stabilizers

Working Principle of Active fin Stabilizer

The working principle of the active fin stabilizer is very simple. It works with the principle of generation of the hydro-dynamical forces within the water due to the relative movement of the fins of the stabilizers. The Figure 5 given below describes the different forces acting on the stabilizer. The fins can be turned clockwise or can be turned in an anticlockwise direction. The turning angle of the fin is decided by the speed of the ship's roll.

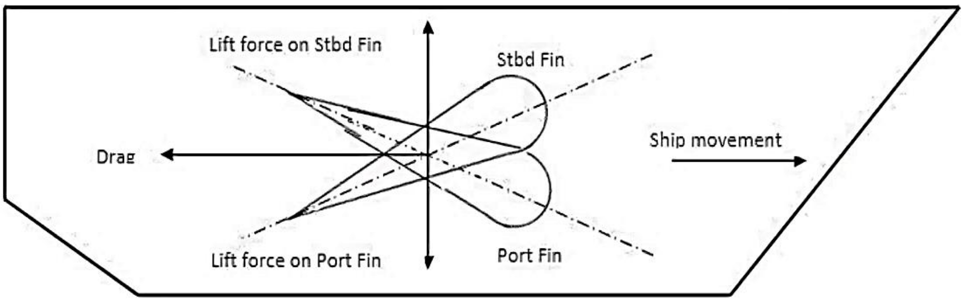

Figure 5. Hydro dynamical forces acting on active fin stabilizer.

A Ship consists of two fins where the movement of the fins is moving in opposite directions to each other. The direction of the fins only changes when the ship is moving in another direction. In the above figure, the stabilizer is not only used to reduce the rolling of the ship, rather it also begins the rolling.

Proposed Model for the Ship's Roll Active Fin Stabilizer

Under the water level, to understand the activities of the rolling of the ship we are assuming that the system is linear in nature or linear time-invariant. Hence, it is allowed to apply the superposition theorem. Let us suppose the roll angle is described by $'\theta'$, roll velocity is decided by $'\dot{\theta}'$ and roll acceleration is delineated by $'\ddot{\theta}'$. Here some assumption is made. For example, the clockwise movement of the fin is taken as positive while the anticlockwise movement of the fin is taken as negative. Five types of moments come into play in the understanding of the ship's rolling forces. Some of them are delineated in the following Figure 6. For example, rolling force, Buoyancy, center of gravity, etc.

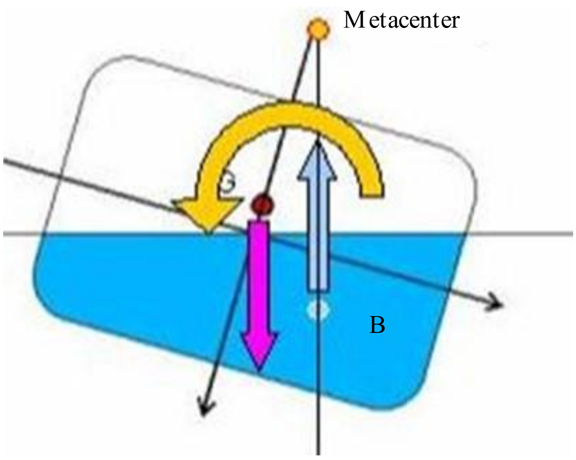

Figure 6. Restoring force, buoyancy, and center of gravity of the design

Anyway, the moment required to get back the ship to its original position is given by the following expression.

$$M(\theta) = (-x.h.\theta) \qquad (1)$$

In the above equation, $'h'$presents the meta-centric height and $'x'$ represents the displacement of the ship. The damping coefficient expresses the moment required to restrict the motion of the ship $'\delta'$. The following expression gives the equation related to the damping coefficient.

$$M(\dot{\theta}) = (-\delta \, . \, \dot{\theta}) \tag{2}$$

The additional inertial moment of the ship is expressed in terms of $I_{yy}$by the following equation.

$$M(\ddot{\theta}) = [(-I_{yy} + \Delta yy)\ddot{\theta}] \tag{3}$$

In the above equation, Δyy is representing the 15% deviation from its true value. The generation of the moment due to random wave disturbance is discussed later. There are other moments generated due to the movement of the fins of the stabilizer denoted by the $'\beta_f'$. This type of moment also depends on the wave angle. The equation (4) given below expresses the required mathematical equation for this moment.

$$M(\theta) = (-x.h.\beta_f) \tag{4}$$

Considering the above equations [1-4], the dynamical model of the proposed design toward the ship's stabilizer is explained in detail in which all the moments add up and make zero. This is nothing but the condition of equilibrium. The necessary equation for this equilibrium is given by

$$\begin{cases} (-I_{yy} + \Delta yy)\ddot{\theta} + 2.\delta \, . \, \dot{\theta} + x.h.\theta - x.h.\beta = 0 \\ or \\ (-I_{yy} + \Delta yy)\ddot{\theta} + 2.\delta \, . \, \dot{\theta} + x.h.\theta = x.h.\beta \end{cases} \tag{5}$$

The most important assumption regarding the designing of the active fin roll stabilizer is that we are going to analyze only the system having three degrees of freedom. Considering three degrees of freedom, the equation of dynamics towards the system is given by the following equation.

$$(-I_{yy} + \Delta yy)\ddot{\theta} + 2.\delta \, . \, \dot{\theta} + 2.\Upsilon.\dot{\theta} + x.h.\theta = x.h.\beta_f + K.s \tag{6}$$

In the above equation, some new parameters have been introduced called $'K'$ due to the moment caused by the sea waves that are completely unpredictable and $'\Upsilon'$ which represents the damping coefficient of the sway velocity. Now our main intention is to find the transfer functions of the proposed design. Hence Laplace transformation is to be taken for both sides of equation 5. Before taking the Laplace transformation, it is assumed that, all the initial conditions for $\ddot{\theta}, \dot{\theta}, \theta$ are considered to be zero. Now taking the transformation on both sides of equation 6, are getting the transfer function of the proposed design and expressed by the following equation [7–11].

$$\frac{\theta(s)}{\beta(s)} = \frac{-x.h}{(-I_{yy} + \Delta yy)s^2 + 2.\delta.s + x.h} \tag{7}$$

$$\frac{\theta(s)}{\beta(s)} = G(s) = \frac{-1}{\frac{(-I_{yy} + \Delta yy)}{x.h}s^2 + \frac{2.\delta}{x.h}.s + 1} \tag{8}$$

Comparing the above equation with the standard second-order equation

$$G(s) = \frac{1}{T_s.s^2 + 2.T.\delta^*.s + 1},$$

$$\begin{cases} T_s = \sqrt{\frac{-I_{yy} + \Delta yy}{x.h}} \\ \delta^* = \frac{\delta}{\sqrt{x.h(-I_{yy} + \Delta yy)}} \end{cases} \tag{9}$$

Putting the standard values of $(-I_{yy} + \Delta yy) = 1.76 \times 10^6 \text{ kg.m}^2, T_s = 1.28, \delta = .2, h = 1.1\text{m}$ we are going to find the transfer function of the proposed design. Finally, the transfer function of the proposed design is given by the following equation.

$$G(s) = \frac{1}{.49s + 1 + 1.62s^2}$$

Shaping Filter for the Proposed Design

The roll motion of the ship is disturbed by the sea waves as it consists of an infinite number of sine waves. The waves have different magnitudes and frequencies. As a result, it is very difficult to design the model under external disturbances. Hence to approximate the model a low pass filter is required whose transfer function is given below.

$$H(s) = \frac{K.\omega_n^2}{\omega_n^2 + 2.\delta\omega_n.s + s^2}$$

It is the low pass system in nature having open loop DC gain of the system. The parameter δ is varying from 0.1 to 0.9 as we consider an under-damped system. Actually, in practice, an over-damped system is slow and unstable while a critically damped system can never be implemented. Here for the designing purpose, we consider that, $\omega_n = 4\, rad/sec\ and\ K = 10,\ \ \delta = 0.75$.putting all these values we are obtaining the shaping filter for the proposed design. Thus, the transfer function of the shaping filter is given by the following equation.

$$G_{Shaping} = \frac{10.s}{s^2 + 0.06\, s + 0.16}$$

PID Controller and Auto Tuner

In the industrial application, the most used controller is the PID Controller. To design a 'Roll Controller', it has taken the strategies of PID auto tuner. In the PID controller, the actuating signal of the controller is given by the following equation.

$$a(t) = k_p\varphi_e(t) + k_i\int_0^t \varphi_e(t)dt + k_d\frac{d\varphi_e}{dt} \qquad (10)$$

In the above equation, the$\varphi_e(t)$ is the error signal produced after the comparator. $k_p, k_i, k_d$are the proportional gain, integral gain, and derivative gain respectively. The transfer function of the controller is given by the following equation 11.

$$G_C(s) = k_p(1 + \frac{1}{s.T_i} + s.T_d) \qquad (11)$$

Transfer Function of Three Types of Ship Model

For the experimental purpose, three different transfer functions have been chosen in the form of $\frac{a}{d+c.s+b.s^2}$, where $a, b, c, d$are some coefficients of the transfer function. Choosing some typical values of a, b, c, d three transfer functions are obtained and given in Table 2.

Table 2. Transfer function of three different models

Name of the Ship along with Designed Controller.	Transfer Function	Remarks
A	$\frac{1}{1 + (0.47).s + (1.61)s^2}$	Normal Condition
B	$\frac{1.45}{1 + (0.6).s + (1.2)s^2}$	Highly Stable
C	$\frac{1}{1 + (0.47).s + (2.1)s^2}$	Less Stable

RESULTS AND DISCUSSION

The controller used for the ship's roll is called as roll controller. The dynamics of the ship's roll have already been discussed in detail. Figure 7 is describing the control system-based model of the Ship's roll controller like the PID Controller or NN Controller.

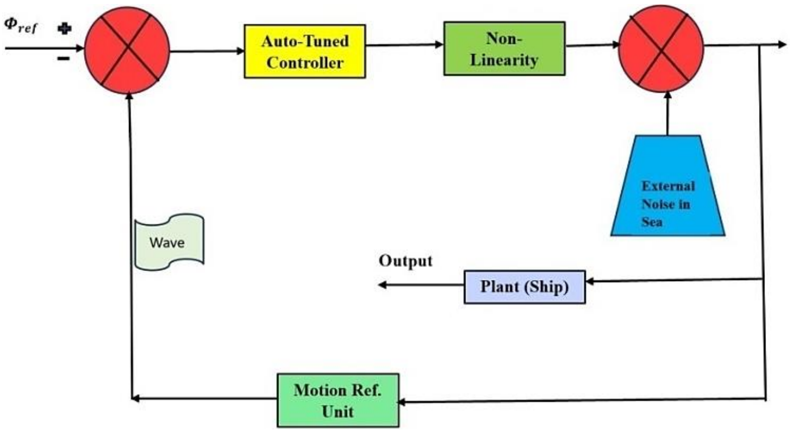

Figure 7. Linear control system-based model of ship roll stabilizer

The wave disturbances are additive in nature and white in type. When it passes through the shaping filter, it will eliminate all the high frequencies. In practice, all the disturbances are added to the output of the ship and that is measured by the angle of rotation $'\varphi'$. φ_{ref} is representing the reference roll angle and φ_{ref} is the error of roll angle produced by the comparator. Generally, for simplicity, the reference angle is set to zero. When the roll is desired to be introduced within the system for testing purposes, then a wave disturbance is to be created. Now the roll controller is used to manage all the errors produced in the system and the output of the ship will be produced according to the controller action. How the novelty of this research work, objectives or methodologies or expected outcomes, and the applications are connected in this research article can be easily understood by the following Figure 8. Rolling motion with differential equations along with pilot studies with different cases is known to us. Now we are applying the novelty related to our research work in the cognitive domain to get the desired output. It is nothing but the designing of a controller considering some typical types of nonlinearities. The entire design finally creates the objective of the work. Not only that the design structure is directly related to the application-based domain.

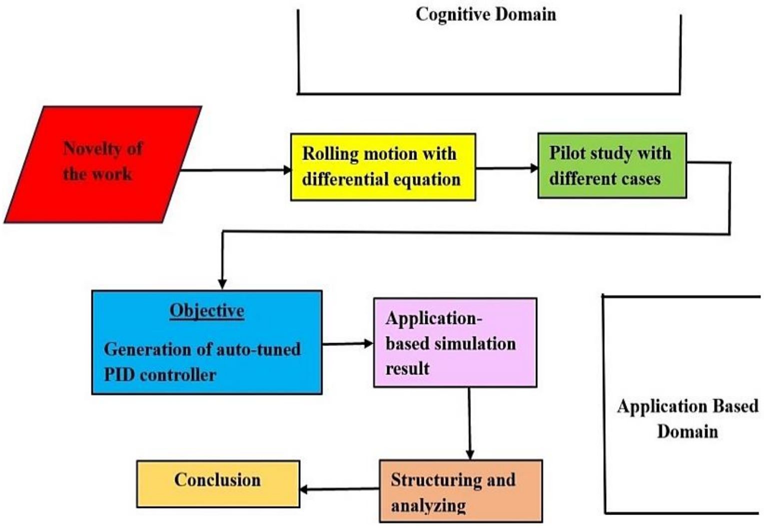

Figure 8. Vector diagram of Novelty, Objective, and expected outcome.

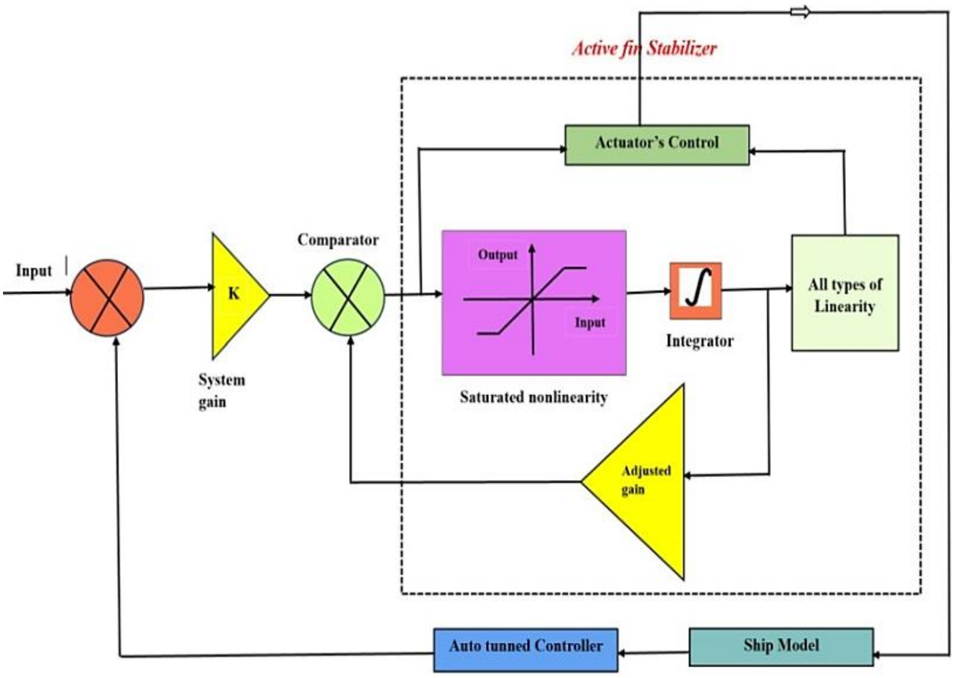

Figure 9. Overall vector diagram of our proposed work.

The colorful infographic vector diagram of the present method of the proposed method is depicted in above Figure 9. How auto-tuned PID controller considering nonlinearity works is mentioned here using the basic elements like integrator and gain comparator along with proper directional arrow sign. For the proper functioning of the controller, tuning is necessary. Here that is done by the adjustable gain block. The most interesting case in this vector diagram is that all sorts of linearity and non-linearity are separated using two different blocks so that in the future we will be able to improve the entire design in terms of describing functions. The block represented in the name of the actuator is used to transform the input energy into the nonlinear motion of the active fin stabilizer. Considering only saturated types of nonlinearities is a limitation of this research work.

All the necessary simulation results are given in this section and it is observed that the proposed controllers are giving satisfactory results. Here all the necessary simulation results are given in a very systematic way so that a reader can easily understand the novelty of the research work. In Figure 10, the ship roll motion considering the wave disturbances is plotted. It is observed that there is an unpredictable nature of the roll angle concerning the time.

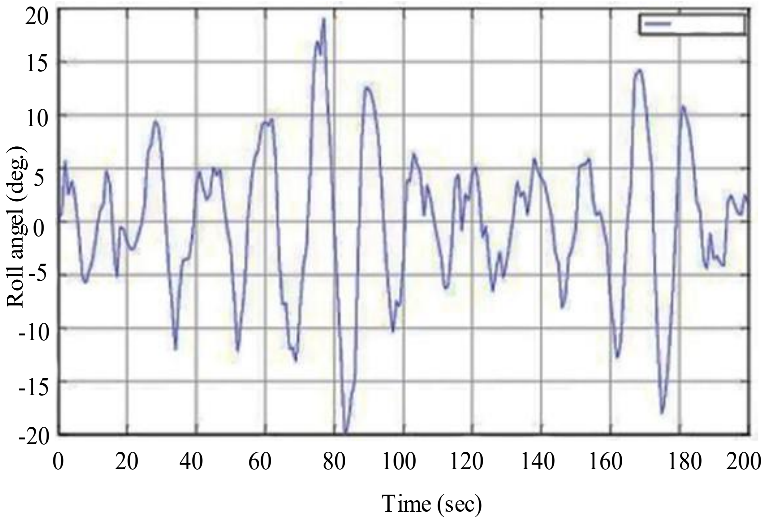

Figure 10. Ship's roll motion considering wave disturbances.

Now after connecting the proper PID controller, the response has improved a lot which is shown by the pink color in Figure 11.

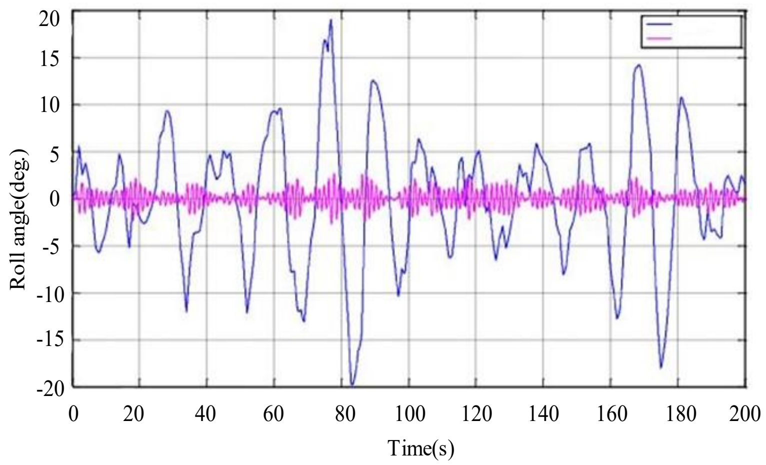

Figure 11. Ship's response with PID controller.

The variation of the roll angle of the selected transfer function with the designed PID controller has been simulated and shown in the Figures 12,13 and 14 respectively.

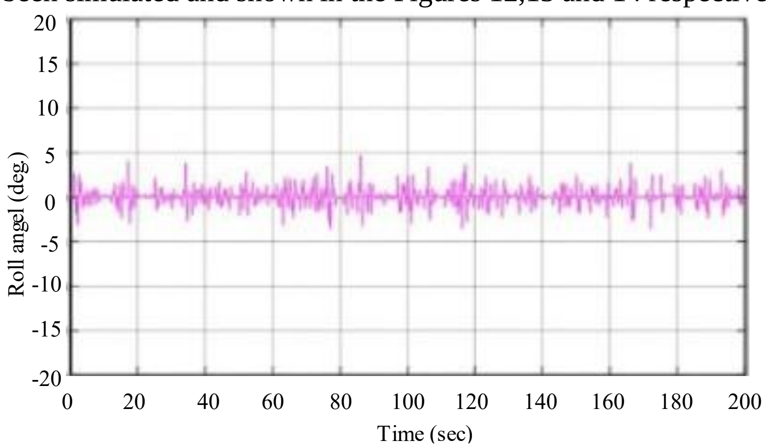

Figure 12. Variation of the roll angle of ship A with controller.

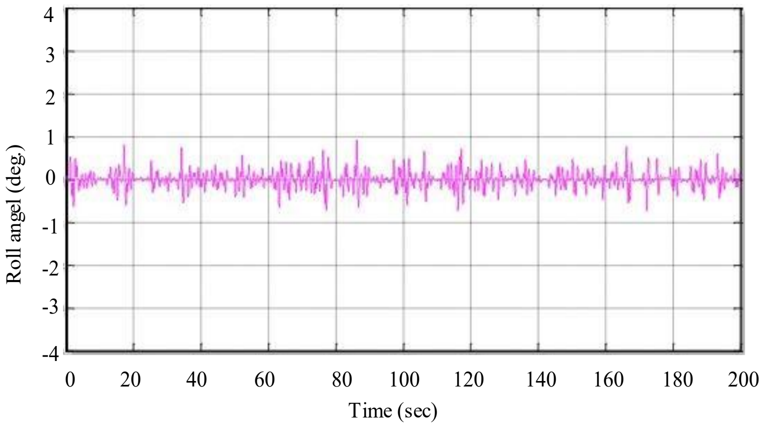

Figure 13. Variation of roll angle of ship B with controller.

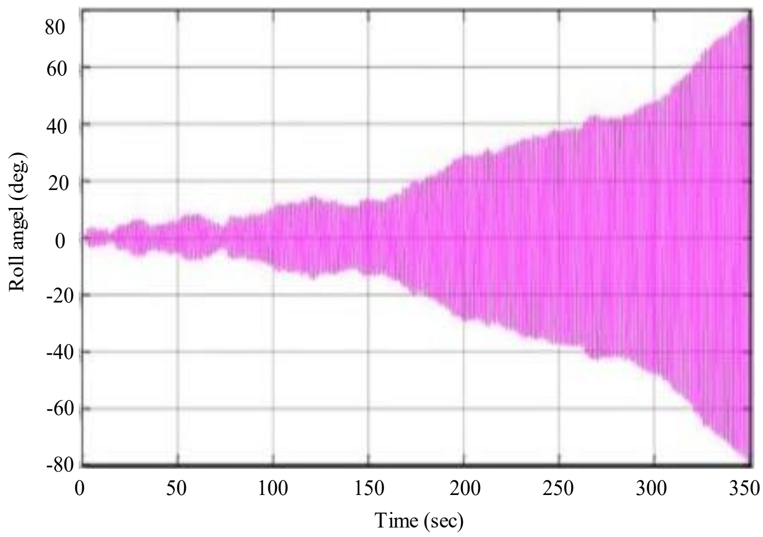

Figure 14. Variation of roll angle of ship C with controller.

After observing Figures 12–14, it can be concluded that the design concerning Figure 10 is good as the variation of the roll angle is nominal. But if we look at Figure 13, it is observed that the variation of the roll angle for the design is much less at any instant of time. Hence the design with PID Controller is highly stable. But if we look at Figure 14, it is found that the design is most unstable as the roll angle increases up to a certain time but after that, it increases rapidly which implies the most unstable system.

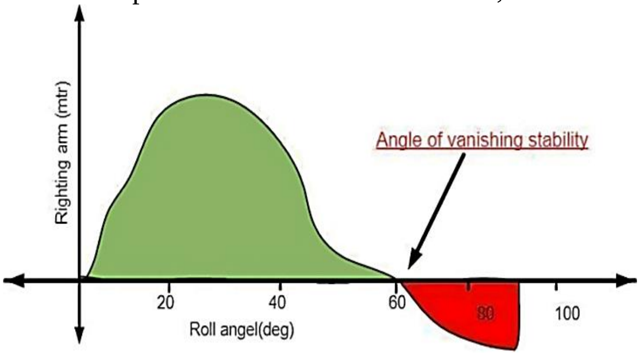

Figure 15. Variation of righting arm vs. roll angle**.**

Figure 15 describes the variation of the righting arm of the ship at sea versus roll angle. The stability of the ship's roll talks about the restoring moment acting on the ship to get back into its original position. The positive values of the righting arm indicate that the ship gets the restoring moment to get back into its original position and hence stable. The negative values of the righting arm indicate the instability of the system. A particular angle is called the angle of vanishing stability where the values of the righting arm are changing its value from positive to negative.

CONCLUSION

The Ship's roll faces serious types of problems when it is flowing in the sea. Due to the very unpredictable nature of the water waves, it is very difficult to anticipate the future of the ship when it is in the middle of the sea. This research work proposed a special type of 'active fin stabilizer' that can detect the change in height and change in weight (concerning roll frequency). Active fin roll stabilizer is designed to solve the issues related to the Ship's roll. Generally, the PID Controller is designed with some fixed type of transfer function but may cause the ship's sink. Roll motion may deteriorate with the change of parameters related to the ship. The stabilizer of the fin has some saturation limit in the perspective of the fin angle. This kind of nonlinearity dies down the effect of the fins of the stabilizer but at the same time, it also increases the roll angle. In this paper, we proposed a special type of auto-tuned-based PID controller that improves the stability of the stabilizer's fins and roll frequency. The proposed design is simulated with the help of MATLAB 17.0 and it is observed that the simulation results are very satisfactory concerning the design.

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Author Contributions

Bikash Banerjee: Conceptualization, methodology, Writing-original drafting, software simulation, drawing. Jinia Datta: Visualization, Writing-review & Editing, data curation.

Data availability

Data can be accessed upon request by contacting [author/institution] at [email/website].

Declarations

Conflict of Interest This study has not received dedicated funding from any government, commercial, or non-profit entity. The research has been conducted without any conflicts of interest.

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