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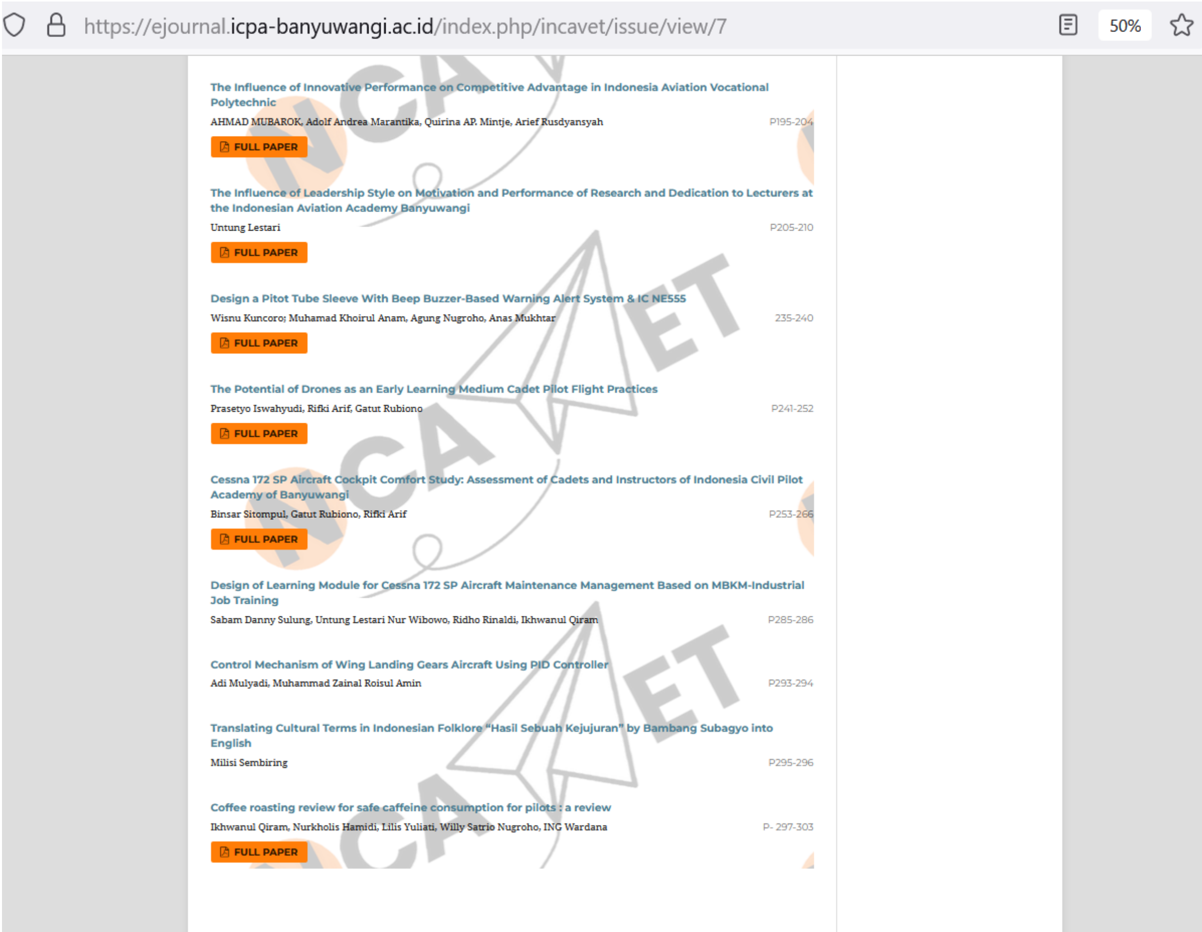

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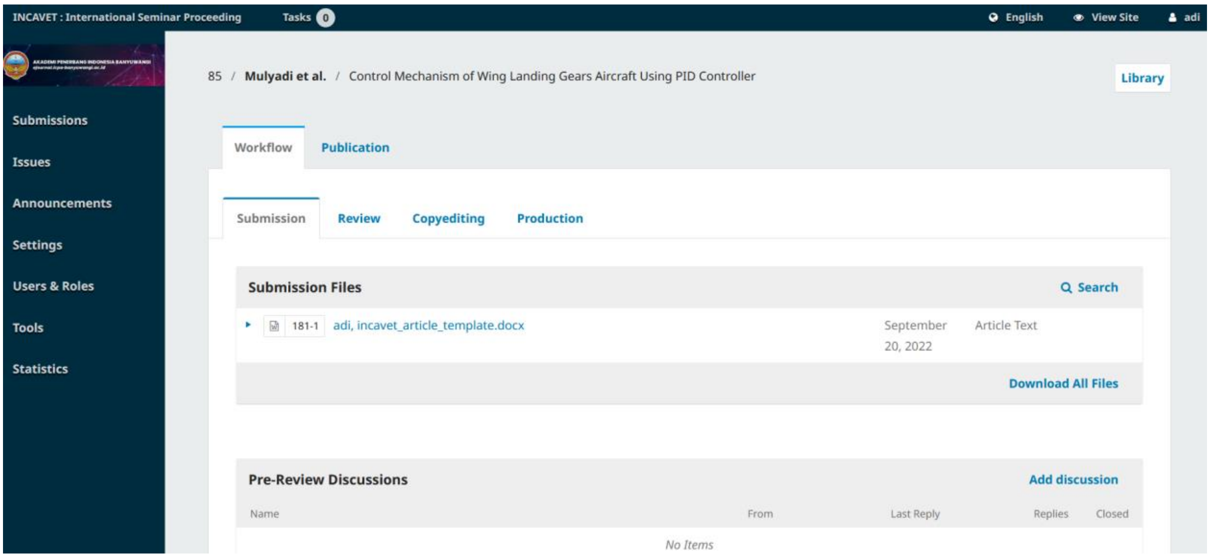

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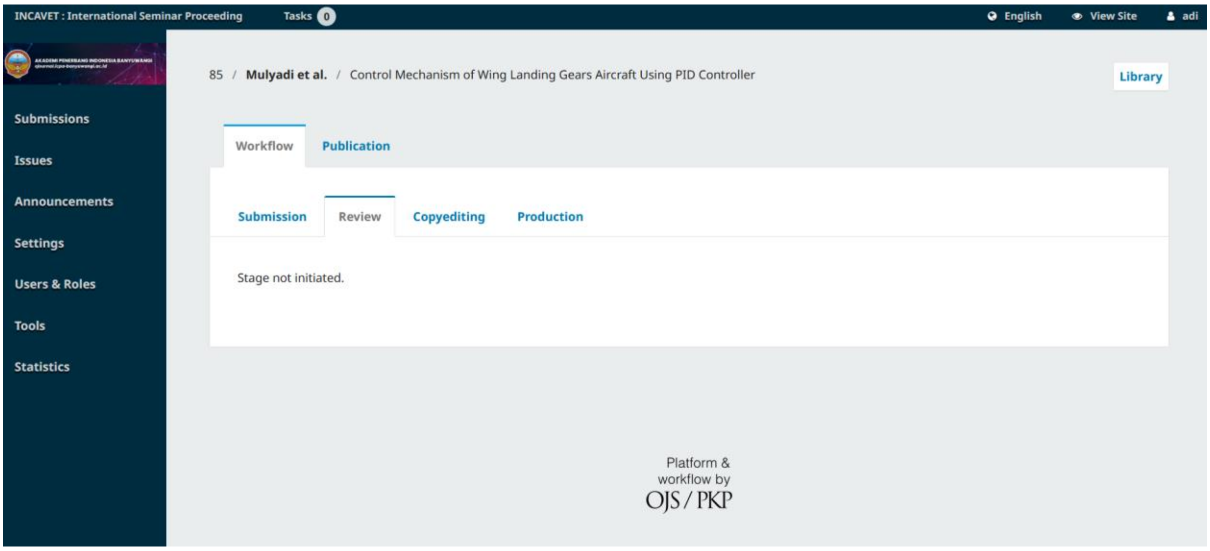

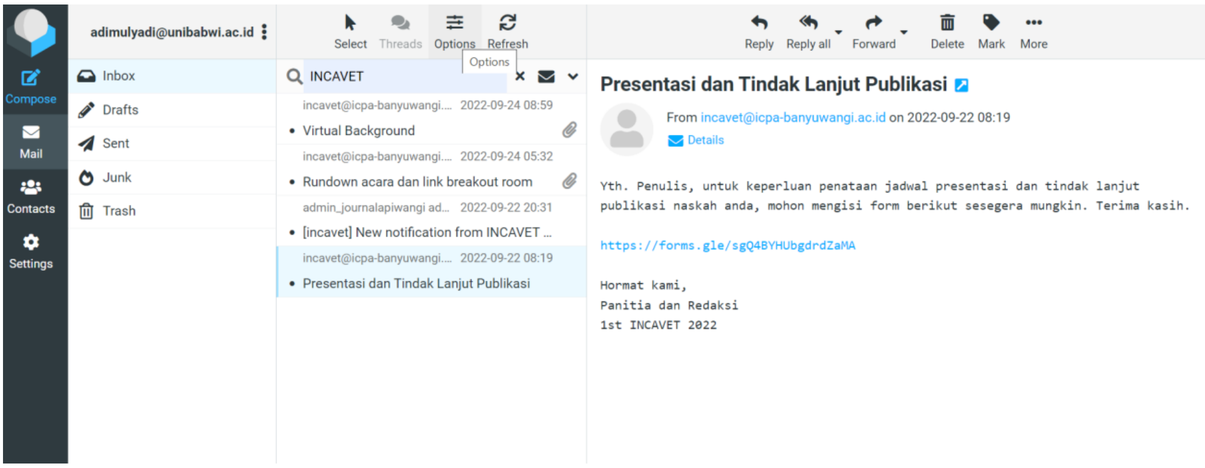

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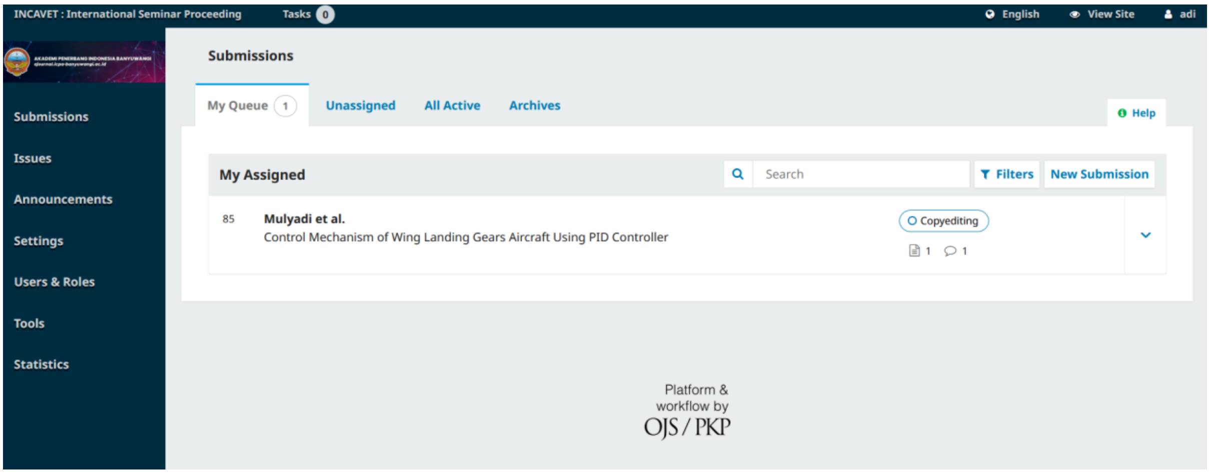

5) **Artikel**

Control Mechanism of Wing Landing Gears Aircraft Using PID Controller

Adi Mulyadi*, Muhammad Zainal Roisul Amin
Electrical Engineering, Universitas PGRI Banyuwangi
*** Email : adimulyadi@unibabwi.ac.id**

ABSTRACT

Introduction. *This paper deals with the control mechanism of wing landing gears aircraft. The mechanism consists of wheel assembly deployed/retract and lock position based on an input signal. The mechanism is controlled by using a PID controller.* ***Methods.*** *The PID controller is used to deploy/retract the main column, and to lock or unlock the main column into position.* ***Result & Discussion.*** *The result shows that the parameter values in the deploy/retract control P=17.73, I=2.251 and D=82.33 resulted in a decrease in the main column angle from* $90°$ *to* $10°$ *and* $0°$ *with a time of 1 second with an overshoot of* $-0{,}7 \times 10^5$ *seconds. While the PID parameter values for locking control P=20.23, I=5.001 and D=34.56 resulted in locking landing gear torque occurring at 2.1 seconds and overshoot at 2.6 seconds with delay conditions from 3 to 6 seconds.* ***Conclusion.*** *The deploy/retract control mechanism is slower than the locking torque to achieve the main column into position.*

Keywords : *aircraft, wing landing gears, PID controller.*

INTRODUCTION

The landing gear is the most important in the aircraft stage, which take-off and landing had impacted passenger safety [1]. The landing gear system is complex and used for primary flight control [2] that consists of structural members, hydraulic, energy absorption components, brakes, wheels, tires [3], retraction, and extension [4]. Three types of landing gear are used such as tail-wheel, tandem, and tricycle [5]. A Tricycle consists of two main wheels in the middle which support the load and one wheel on the front or nose of the aircraft which functions to control the maneuvers of the aircraft [6]. Tail-wheel type is used to increase the ground clearance of the propeller, and the tandem type is the same structure as the tricycle, but it is integrated into the wings [7]. According to aircraft accidents in Indonesia from 1959-2017, 63% occurred during takeoff, 49% occurred during landing, and 7% occurred during the initial climb phase [8]. Based on data from Boeing Aircraft in 1996-1999 report that the failure of the landing gear was 15.2%, 17%, 16.7%, and 16.8% [9] Saudi Airlines got an accident in 2018-2021 which was caused by the failure of the nose landing gear. The travel of Saudi Airlines A330-200 was from Madinah to Makkah and Bangladesh [10]. The world survey of flight accidents was 74.2% of the military, and 80,5% of civil flights were caused by human factors [11]. ICAO clarify that human error was caused by preventive safety systems [12], and 15-20% included maintenance error [13]. An analysis was conducted to obtain the optimum design of the best-fit landing gear, stroke, dimension, pressure, and gear wheel. The important load is the linked gear component during the touchdown. The result shows that the fork of the nose is maximum von mises stress of landing gear 159 Mpa and inner oleo strut 139 Mpa [14]. A landing gear system had been designed to analyze the aircraft industry. Design and analysis used to CATIA and ANSYS software. The result implied that optimization of each failure system like reduced cost, enhanced life, minimum value, high performance, minimum weight, and providing improved landing gear [15]. The landing gear is one of the critical impacts on health status and health that have to make a decision. Fuzzy C-mean Algorithm (FCM) control was proposed to monitor the gear landing health state. The result shows that FCM gives a great effect [16]. The aviation industry has used radio frequency identifiers (RFID) to track and identify equipment for passenger health. A Health-Monitoring (HM) is utilized to reduce maintenance costs and service life. RFID system combines active and passive sensors. Ultra-High-Frequency (UHF) is measured by landing gear and aircraft-mounted fixed. The result shows that the landing gear component was identified by EPC and reader antenna which tolerate degradation caused by harsh environments and update information [17]. The testing landing gear was developed by a dynamometer and a wheel system. The dynamometer was utilized to test forces and moments of landing gears using a wireless data transferring system. The resulting test is measured by five elements that are capable simultaneous of forces F_x, F_z, and M_x, M_y, M_z. But it modifies to complete system such as a sensor, rim, data transfer, acquisition system, and control software [18].

The control software has been proposed by using modern intelligent flight safety. Modern intelligence based on detector deep convolutional neural networks (CNN) fails to discovery accurately land gear in real-time. CNN detector failed to discover small objects significantly. Therefore, the optimization of a high computational image resolution proposed a Dynamic Up-Sampling Network (DUN) and lightweight one-stage detector (LWOD). The result shows the comparison of DUN and LWOD to convince the effective method. DUN accomplished accuracy and speed small landing gears in 24 ms at 97.2 AP [19]. The model system of normal structure landing gears is designed to accurately simulate energy absorption. The complexity model was carried by aircraft weight which requires landing, take-off, taxing, and towing. The results implied that the model was applied by helicopter crash type system landing gear and simulation was conducted by Finite Elemen Machine (FEM), then it compared using difference necessary data which crash structure test can accomplish a composite [20]. A mechanism of landing gears investigated quasi-static landing in three-dimensional aircraft. A mechanism used 19 static equilibrium equations and 20 equations to describe the geometric constraints. The problem formulation shows that extremely flexible and allows actuator force, length, and efficiency to achieve computation with minimal data post-processing. Furthermore, this study suggests that the analysis of the mechanism is more complex than one side stay [21]. The aircraft landing gear controller based on state feedback magneto rheological damper (MRP) proposed to achieve performance safety. A dynamic modeling fluid was established. The landing gear has been impacted by force which changes in real-time. So that the optimization cushioning system is simulated. The simulation implied that the control could effectively absorb impact load energy [22]. The modeling control based on Event-B proposed to show a great solving problem of the landing gear. The control not only gave simple modeling and approachable but also makes to find requirements and understanding of the system [23]. PID controller using linear interpolation fuzzy is designed to adjust slow landing and taxiing. The mathematical model used to reduce aircraft landing gear of semi-active damping system. The result indicates that the shock absorber of the linear interpolation fuzzy PID is better than conventional fuzzy PID [24]. The using software of domain-specific (D-S) was applied to simulate dynamic flight, aerodynamics, dynamic landing gear, and mechanical load [25]. The simulation landing gear occurs for deployed and retracted when landing and take-off. The result shows that the landing gear system represents the change of force and moment in the take-off and landing conditions. On the other hand, the flight simulation was increased [26]. The suspension of the landing gear was controlled by a semi-active Magnetorheological damper (SAMD) to overcome the dumper of excessive vibration. The controller was switched from a single-degree-of-freedom (1-DOF) to a three-degree-of-freedom 3-DOF to simulate the touch-wheel and nose-wheel of the ground. A semi-active was developed by linear-quadratic-regulator and $H\infty$. The simulation result indicates that reducing overshoot and improving performance disturbance during landing [27].

According to the model structure [20], the problem was founded that the complexity model requires landing, take-off, taxing, and towing. As the mechanism of the aircraft landing gear was proposed, [21] the formulation indicates flexible and efficient to achieve computation with minimal data post-processing. A controller based on state feedback MRP was proposed [22] to achieve performance safety. The control could effectively absorb impact load energy. The modeling control based on Event-B was proposed [23] to solve the landing gear problem. The best control accomplished simple modeling, approachable, and understanding of the system. PID fuzzy controller using linear interpolation is designed [24] to adjust slow landing and taxiing. The (D-S) software was applied [25] to experiment with dynamic flight, aerodynamics, dynamic landing gear, and mechanical load. The deployed and retracted landing gear were simulated [26] during landing and take-off. The change of force and moment occurs the landing gear system represents. The suspension of the landing gear was controlled by SAMD [27] to overcome the dumper of excessive vibration, and 1-DOF to 3-DOF are switched to touch-wheel and nose-wheel of the ground. The performance of disturbance landing gear could reduce overshoot. But many researchers concern that the controller focuses on take-off, landing gear problems, performance safety, load energy, taxiing, deployed, retracted, touch-wheel, and nose-wheel. The landing gear such as tricycle landing gear is a complex system in which the structure, motions mechanism, locking mechanism, control sub-system, and the interface between the landing gear and hydraulic system. The tricycle landing gear has to avoid risk and be stable on the ground [28], [29]. Furthermore, this paper proposed a control mechanism for wing landing gear aircraft. The mechanism consists of wheel assembly and lock deployed position based on an input signal. The mechanism is controlled by using a two-level PID controller. The PID controller regulates to deploy or retract the main column and locks or unlocks the main column into position in figure 1. The simulation integrated multi-physics sim-mechanic Matlab. For retractable landing gear mechanisms, the performance retraction and deployment (R and D) have a robust controller for flight safety [30]. The requirement of the R and D system has to be capable of retraction and deployment smoothly so that the time would not be extended [31], [32]. The result shows that the PID controller turns on the deploy and retracts landing gear when the main column is close enough to the deployed position. On the other hand, it disables the deploy or retract controller and uses to lock the mechanism into position when the reverse happens during retraction.

METHOD

The controller of the mechanism of wing landing gear is shown in figure 1. The controller divides into the master control, locking control, deploy and retract control, and coordinate control. According to Yin Yin et al [33] the locking mechanism is used to achieve smooth locking of the landing gear in the up and down position after being pulled into the aircraft. The locking mechanism consists of a linkage and bracket (an unlocking actuator). In the locking process, the landing gear is pulled slowly by the retraction actuator, and when the lock is almost closed, the locking roller on the gear strikes the locking by the action of the retraction actuator. The pressure in the retraction actuator chamber is removed. After the landing gear loses support from the retraction driving force that originally hit during locking then turns into the defensive. The lower edge is due to the action of gravity on the landing gear. This will complete the process of locking the lock on the landing gear. The lock is opened by a force that is opposite to the direction of the locking force. Because the whole landing gear depends on linkages 1 and 2. So that the locking mechanism remains stable and the rollers will separate to complete the unlocking. This is due to the action of gravity on the landing gear.

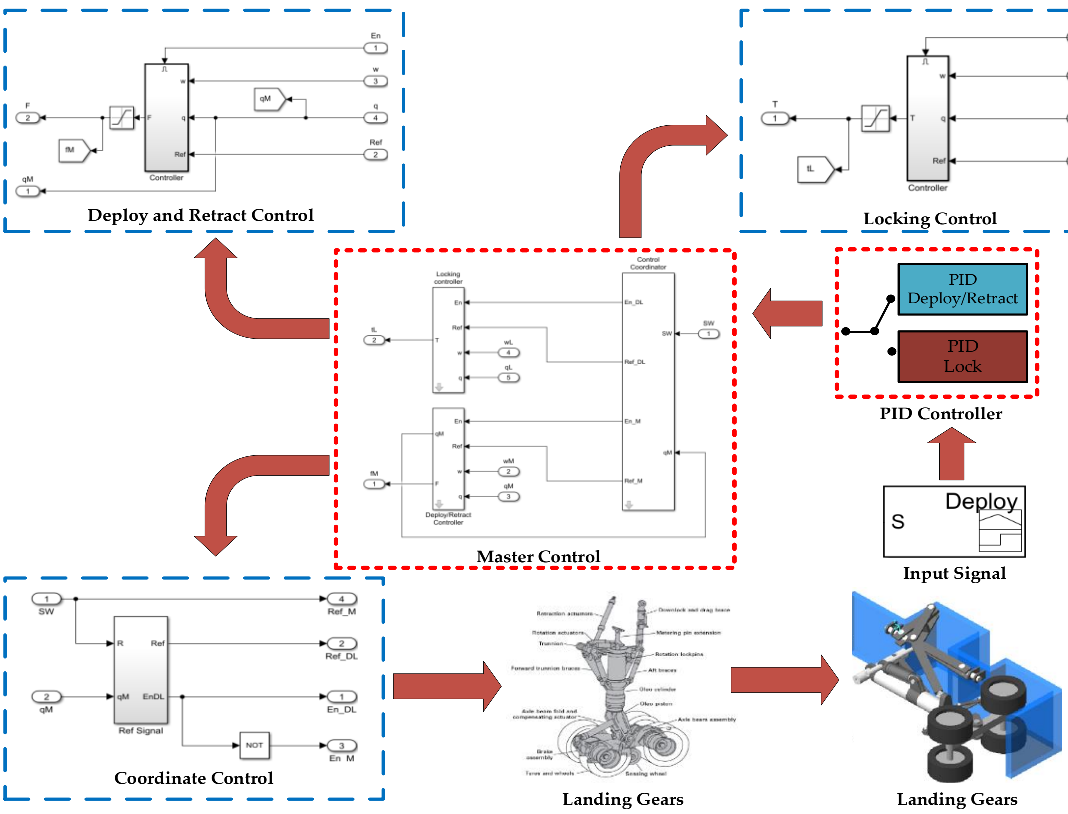

Figure 1. The Mechanism of PID Controller [4]

1. Proportional Action

According to expression 1.1, proportional control is used to overcome the amplification error of the current. A simple gain K_p that is applied to increase the control variable when a large error occurs. Major mistakes should be avoided and excessive control efforts should be made. The disadvantage of pure proportional control is that it produces a steady-state error [34].

$$u(t) = K_p e(t) = K_p(r(t) - y(t)) \tag{1.1}$$

2. Integral Action

The control integral is matching to control error. K_i is the gain that relates to the past value of error. Based on the expression below 1.2. The integral control is capable to adjust the value automatically. Furthermore, the output oscillatory response achieving the error steady state is zero [35].

$$u(t) = K_i \int_0^t e(\tau)d\tau \tag{1.2}$$

3. Derivative Action

The control derivative is predicted to be the value of the control error. The K_d expression is defined 1.3. where the control can improve performance and anticipate the error. The modification of derivative value impacted the integral and proportional responses [36].

$$u(t) = K_d \frac{de(t)}{d\tau} \tag{1.3}$$

4. PID Controller

The input PID control represents the deploy signal to respective links lock, deploy and retract, and coordinate. The parameter PID regulates to perform deploy signal is based on error response to distinctive inputs. The distinctive input controls deploy, retract, and coordinate on landing gear with feedback in major error. The large error value is corrected by the value of K_i K_d automatically and the response is excessive.

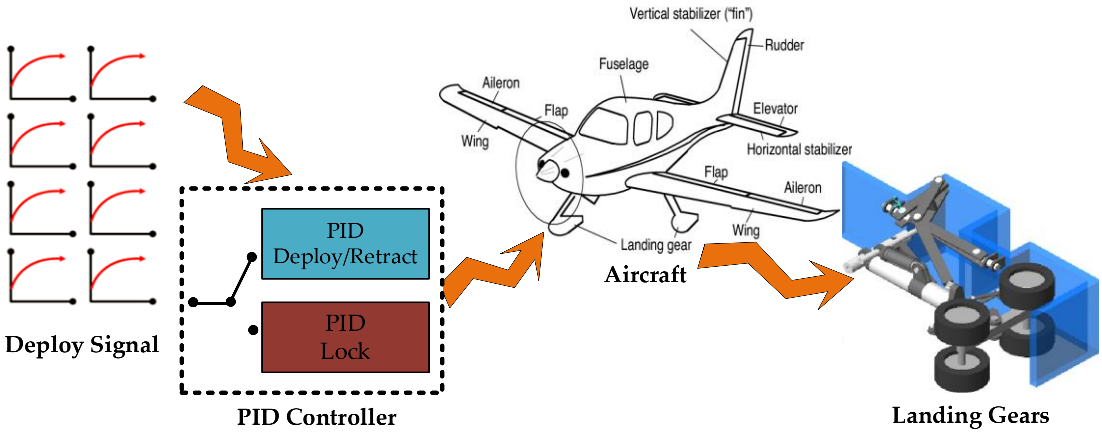

Figure 2. The Landing Gears Controller [37]

RESULTS AND DISCUSSION

1. Research Results

The input to the control system is a deploy signal with a low setting mechanism. The mechanism is controlled by two low-level controllers which deploy and retract to lock and unlock and return to position. Two mechanisms are carried out by the master controller. The controller used is a PID controller to get a smooth landing gear spreading and pulling mechanism. The main controller turns on the deployment controller to deploy the landing gear and when the position is close enough to the deployment position, it then deactivates the deployment controller and uses the locking controller to lock the mechanism into position. While the second controller turns on the pullout controller on the landing gear and when the position is close enough to the tow position, then the controller deactivates the retract and uses the locking controller to lock the mechanism into position. Rommy [38] clarified that the landing gear is charged to the front wheels by determining the center of gravity of the aircraft. And Pakan [39] the center of gravity and the load determine the center of gravity.

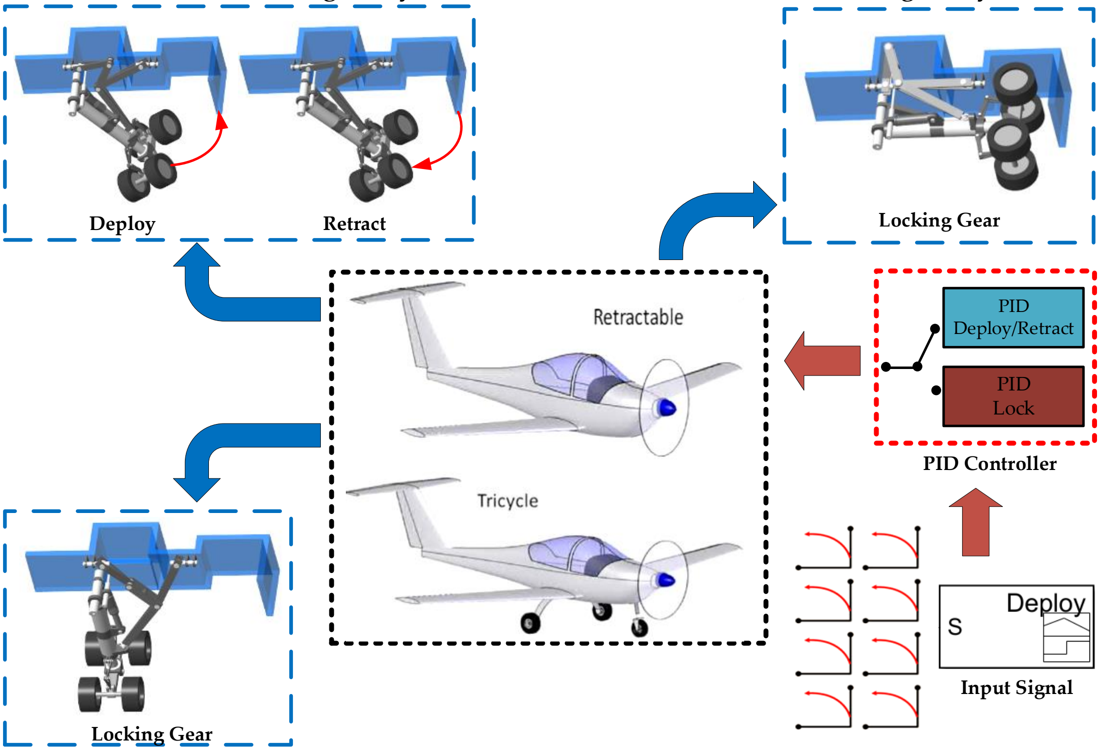

Figure 3. The Landing Gears Controller [40]

2. *Discussion*

Figure 5.a describes the application of PID control to the wing landing gear aircraft to control deploy/retract and locking. The values of the deploy and retract control parameters are P=17.73, I=2.251 and D=82.33. while the values of the locking control parameters are P=20.23, I=5,001 and D=34.56. The determination of the PID parameter values affects the angle of deploy and retract to achieve seamless control. The main column angle is 90° that occurs at a time of 1 second. Then the main column angle decreases from 90° become 10° and 0°. The decrease is caused by the dispersal mechanism at the moment when the condition reaches an angle close to the point of spread. During wing landing gear deploy angles are in the corners at a time of 2.7 seconds to 7 seconds. Furthermore, the wing landing gear will pull the force to close and return to the starting position with an angle 90° increases to a steady state. Figure 5.b describes the conditions of deploy and retract of landing gears. Deploy occurs at a time of 1 second with 1×10^5 and 1.2 seconds overshoot $-0{,}7 \times 10^5$ time second. Overshoot is caused by gravitational force to adjust the angular conditions close to the point of spread. Figure 5.c describes the locking torque in the landing gear spread occurs at a time of 2.1 seconds and the overshoot occurs at a time of 2.6 seconds with a delay condition of from 3 to 6 seconds. However, the locking torque on the recall to reach the initial state experienced a breakdown caused by the locking angle not closing completely.

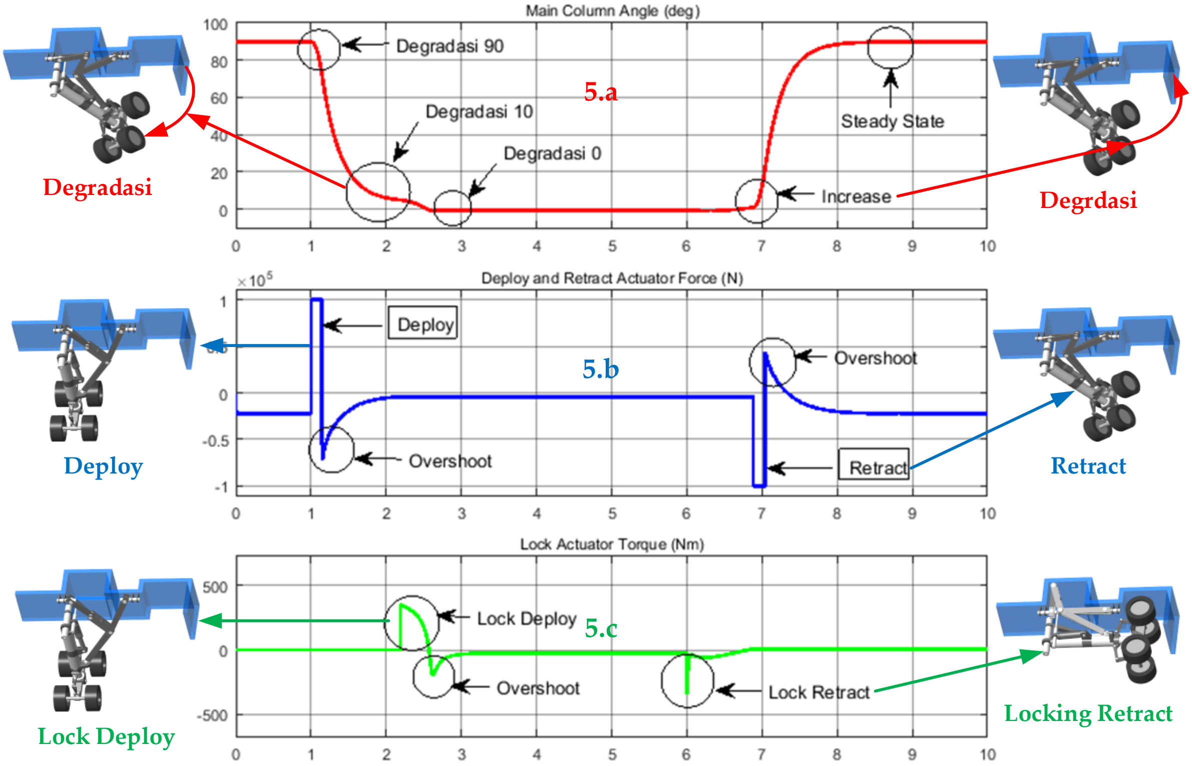

Figure 5. The Mechanism of Wing Landing Gears.

CONCLUSION

The control mechanism of wing landing gear uses PID control. The PID control is set based on the deploy signal input to determine the control mechanism in the two conditions of deploy/retract and locking. The determination of PID parameter values affects deploy/retract and locking angles to achieve smooth control. The simulation results show that the parameter values in the deploy/retract control P=17.73, I=2.251 and D=82.33 resulted in a decrease in the main column angle from 90° to 10° and 0° with a time of 1 second with an overshoot of $-0{,}7 \times 10^5$ seconds. While the PID parameter values for locking control P=20.23, I=5.001 and D=34.56 resulted in locking landing gear torque occurring at 2.1 seconds and overshoot at 2.6 seconds with delay conditions from 3 to 6 seconds. So that the deploy/retract control mechanism is slower than the locking torque to achieve the main column into position.

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