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Improved ship position stability on offshore-based dynamic position maintenance with the PID method

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Abstract ANCHOR Handling Tug and Supply (AHTS) vessel is a type of vessel designed to support oil and gas drilling facility activities and work, in addition to serving offshore oil and gas exploration work. The special feature of this ship is that the hull is not too large, equipped with a large auxiliary engine with propeller driving (double) at the rear and equipped with maneuvering aids to maintain position, namely Bow Thruster, Stern Thruster and Dynamic Position System for AHTS ships so that they can work maneuvering at sea to be fast and accurate in determining the ship's position. One solution to overcome this problem in this research is to create a control simulation so that the ship remains stable in a state of floating above the offshore waters. The control method used is a PID-based dynamic method. The sensors used are accelerometers and gyroscopes that can read the movement and angle changes in the blood vessels. From the results of testing and analysis of parameters Kp: 60, Ki: 2, and Kd: 30 for ship control gave good results, namely the ship will return to its original position when it floats.

Keywords: AHTS, Oil and gas drilling, PID, Ship control

1. INTRODUCTION

Many types of microcontroller equipment can be used for training in electronic practice and electronic prototypes, such as intelligent electronics and special input devices. In the research that has been carried out is a PID with the Arduino method that can make the work system of electronic components efficient, effective, and work quickly. This method can be designed in less time and the prototyping of low-cost products. Dynamic position (DP) is a ship control system with a computer as the main motherboard system. This complexly integrated system can make the ship in position and automatically move according to a predetermined reference point or in the arrangement[1]. This control system is not only applied to oil and gas supporting ships. There are several types of ships or marine buildings that also use the same Dynamic Position system. Such as ships for laying sea cables, ships with accommodation facilities, even passenger ships. The advantage of using a DP drive system is that it facilitates the work of the crew and minimizes the reduction of operational costs and for the fuel efficiency of the fleet, since diesel propulsion motors are replaced by electric motors. The classification of the use of DP on ships is based on the degree of risk of work and the possible danger that occurs during the operation of the vessel that can result from the ship losing its coordinate position. Dp vessels have a continuous active sensitivity system that is useful for reducing and minimizing the possibility of failure to lose position when the DP system is operated[2]. These support thrusters are mounted on the lower hulls in front and rear operated by an electric motor with clockwise or counterclockwise rotation. In other words, it can get a push that can spread towards the horizontal surface. Sensors for the coordinates of position points are connected wind direction indicator sensors, motion marker sensors and gyrocompass pointing sensors, which are interrelated to provide computer systems in the form of information related to the coordinates of the position of the ship and its magnitude and direction of the weather force at that time[3]. The dp computer system program contains files about data from all text files connected with the sensor.

The use of direct current (DC) motors as a control system as one of the main drivers is both in terms of use and more profitable. Direct current electric motors are used for main power drive control systems, the system is implemented by ships at a high level of operational capabilities, special ships supporting oil and gas, ships with a large and spacious capacity[4]. The electric propulsion ship propulsion system is a ship propulsion system where there are main components, namely electric motors, electric motors can work from electric power from ship generators. The electric generator gets power from the movement by the ship's diesel engine. The electric generator serves to meet the needs of the ship's propulsion electric motor as well as all electrical equipment related to the smooth operation of the ship such as a winch for pulling heavy loads, an anchor machine for raising and lowering the anchor, and there are still many machine tools that depend on ship generators. The advantages of ships where the electric propulsion system is compared to the mechanical diesel propulsion system of the ship is that it can further dampen vibrations because it is smoother, reduces air pollution, lighter construction and saves space, saves ship fuel, and long-term investment. The dynamic positioning system calculates the balance of coordinate points and predetermined directions with changes occurring due to the external forces of the environment, which then calculates the force that must be provided by the driving support machine to reduce errors from the position and direction to zero[5]. The main systems in dynamic positioning systems are Power sytem, Thuster system and DP control system. advantages of using dynamic positioning include, the accuracy rate of the ship is better at low speed than the main propulsion system[6].

The Power of Control

The division of power in the driving engine is very important because it requires a balance between the two opposing parties to be a stable or balanced state. Motors installed at the front and rear usefully control the speed of the vessel without human intervention in an environmentally friendly and economical way. The drive motor as a forward wave feed speed control that can predict the change in speed according to the wave load and compensate for it to reduce fluctuations in speed, power and fuel consumption. The system was developed by adding variable resistances and analyzing motion propulsion. The wave graph readings were validated using a power control optimization simulation program through a comparison between the front drive motor and the rear drive motor. The purpose of the power division is to increase the motor movement deficit so that the optimization of the performance of the front and rear motors can be achieved and the control of the ship can be implemented properly.

Bow truster and Stern thuster

Bow Thruster and *stern trusther* are auxiliary engines on ships that are useful as auxiliary engines on ships to assist the movement of ships. *Arc propulsion* and stern soters *are* very useful for ships when carrying out motion processing when the ship is about to dock and exit the port. In *the manufacture of arc thrusters* and *stern soters* should be considered from the selection of materials to the selection of an electro motor for *propeller* drive on *the arc thrusters*[7].

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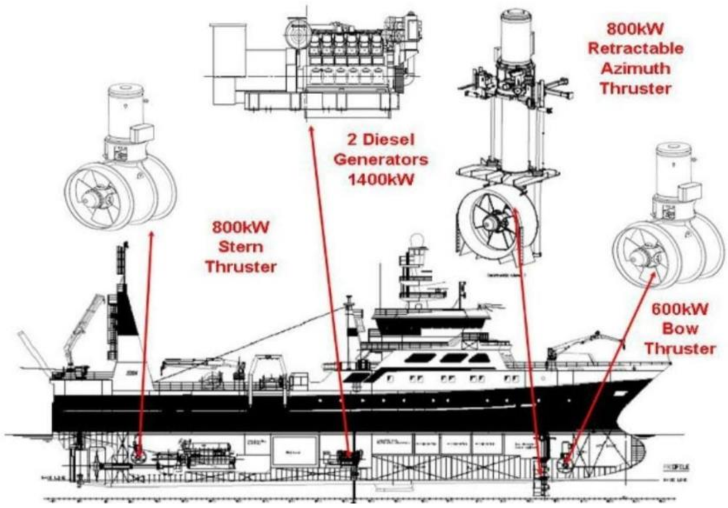

Figure 1. Placement of the bow soter and stren stuster

Arc propulsion thrusters and *stern soters* are propulsion devices attached to several types of vessels to increase maneuverability. The installation *of the bow and stern thrusters thus* enlarges the maneuverability of ships having a round bow and *aft*. By utilizing the rotational energy of the *propeller* on *the ship's thrusters*, the ship's direction can be deflected faster than a ship without *a bow thruster*[8].

Dynamic Positioning System

A ship equipped with a DP system can perform several jobs including: diving and ROV support operations, *offshore supply support*, cable mounting and repair operations, *seabed tractor* and dredging operations, *survey operations* and ROV support, pipe laying operations, *stone removal* operations, *dredging* operations and and maintenance *offshore platforms* . With the help of the DP system, the efficiency of operation increases very drastically, since there is no need for manual operation with the system[9].

Figure 2. DP placement system on board

AHTS Ships

Anchor Handling Tug Supply (AHTS) vessels can be defined as vessels specially assigned to support offshore operations that are generally required to install systems that make them different from other vessels. In terms of governance, various activities of the source of initial discovery of oil and gas can be carried out onshore and can be found on mid-sea platforms (*offshore*) according to the point where the source is found, but including activities there are possible dangers posed during this petroleum exploration activity are increasingly carried out in oil mines at sea (*offshore offshore*)) in addition, it is also found in deep-sea offshore mines[10].

Offshore Platform

The rough state of the marine environment is that it will inevitably result in corrosion damage and weaken the strength of the platform. The effect is more severe for an aging platform or an extended service platform[11]. Derived from the dual effects of earthquakes and corrosion, the probability of platform collapse is greatly increased, and the seismic capacity of the platform is also reduced[12]. The jacket offshore platform is exposed to marine corrosion environments for a long period of time. The steel material in the platform may deteriorate due to chemical or electrochemical reactions. Based on the differences in corrosion mechanisms and corrosion environments, exposure to the jacket platform can be classified into five zones, namely *the atmospheric* zone, spark zone, tidal zone, submerged zone or the ground below.

Ship Drive Electric Motor

The issue of offshore wind energy is discussed. A proposal for an electrical propulsion system that could be used on units to transport crews served by offshore wind farms was presented. The possibility of using a purely electric drive system or a hybrid drive system operating in a diesel-electric configuration is analyzed[13]. By observing the movements of CTV units, based on data from the *MarineTraffic* service, a mathematical simulation model was developed, in which a number of simulations were carried out in *the Modelica environment*[14].

Proportional Integral Derivatives (PID)

The PID controller (*proportional integral derivative*) is one of many automatic controllers implemented in the industry at a time due to its very fast system response but having a very large *overshoot*. The value of conventional PID parameters will remain during operation, as a result of which the controller becomes inefficient to control the system if there are unknown faults or because the environment around the system changes[15]. As a result, the PID control system is not adaptive enough and also the determination of PID parameters is also very difficult. There are many ways to determine the pid parameter, one of the ways is the *Ziegler-Nichols*[16]. PID control is an automatic controller that uses a feedback mechanism often used in industrial control systems. In the PID control, it will continuously calculate the error value as a *comparison (feedback*) with the set of points predetermined by the operator[17]. The controller tries to minimize the error value each time by adjusting *the control variables*, such as the position of the control tap, damper, or power on the heating element, to a new value determined by the sum:

$$m\mathcal{v}(t) = K_p e(t) + K_i \int_0^t e(\mathcal{T})d\mathcal{T} + K_d \frac{de(t)}{dt} \quad \ldots\ldots\ldots (1)$$

Information:

mv(t) : output of the controller PID or Manipulation variable
Kp : Proportional Constant
Kand : Constant Integral
Kd : Constant Detivative
E(t) : *Error* (difference between set point and actual level)

Proportional Controller (Kp) acts as a Gain (booster) only without providing a dynamic effect on controller performance[18]. Kp will give the effect of reducing the time of ascending, but does not eliminate the error of a fixed state. *The controller integral* (Ki) can correct *the steady-state response*[19]. Ki will have the effect of removing the error of the state of disability, but resulting in a temporary deterioration of the response. The controller derivative (Kd) will provide the effect of increasing system stability, reducing overshoot, and improving transfer response[20]. The effects of each controller (Kp, Ki, Kd) in a closed system are shown in Table 1 below:

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Table 1. *Characteristics of the PID controller*

No	Closed Loop Response	Risen Time (tr)	Overshoot (OV)	Turnaround Time(ts)	Error stable status (ess)
1	Kp	Decreased	Add	Small Changes	Decreased
2	Which	Decreased	Add	Add	Disappear
3	Kd	Small Changes	Decreased	Decreased	Small Changes

Pid components are of three types, namely Proportional, Integral and Derivative. All three can be used together or individually as needed. PID control is applied in position control research to control position and speed control to control the rotational speed of the motor contained in the elevator system[21]. Speed and position control use the PID method to minimize errors arising from the elevator system. The set-point used is the height and rotational speed of the motor of the lift system. The data obtained is then processed using ESP32 with the PID method to produce output in the form of PWM values. The PWM value is then used to rotate the DC motor, so that the lift will reach the desired speed and height. It was found that the tool can control the speed and position of the elevator, only that there is still an error in the position control system made[22].

2. METHOD

This research uses research and development methods (reasearch and development /r&d) to improved ship position stability on offshore-based dynamic position maintenance with the PID method.

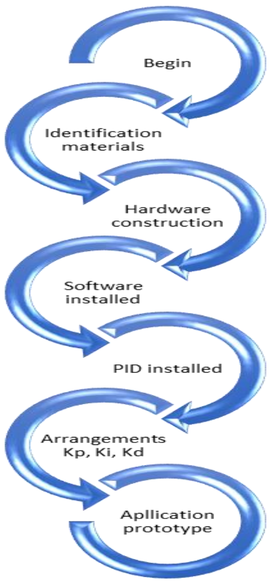

Figure 4. chat flow research step

Hardware Design

The design *of the hardware* and its specifications and the creation of schematic diagrams are used as follows:

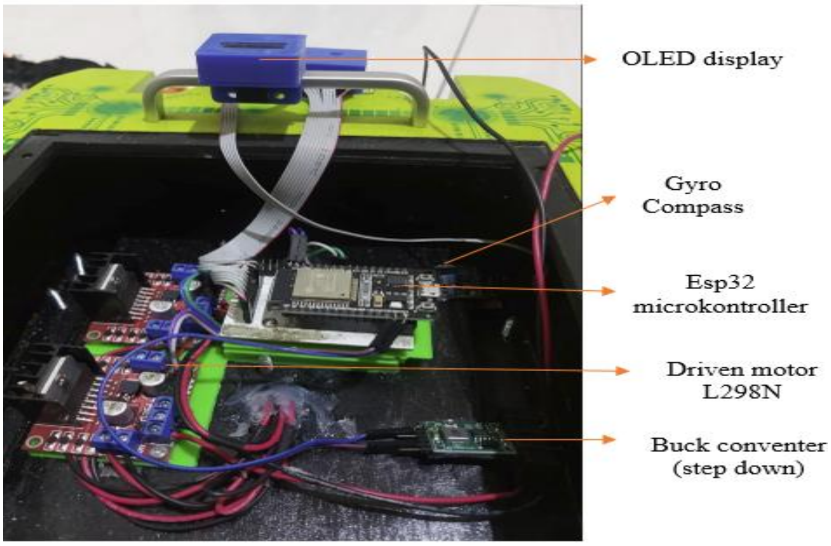

Figure 5. Schematic Design of Ship prototype

Software design

PID control is applied in position control to control position and speed control to control the rotational speed of the motor. Speed and position control use the PID method to minimize errors caused. The data obtained is then processed using ESP32 with the PID method to produce output in the form of PWM values. The PWM value is then used to rotate the DC motor. The output of the PID controller is the sum result of the sum of the three components. The characteristics of this PID controller are influenced by the three components P, I, and D, the adjustment of the values of each of the constants Kp, Ki, and Kd will result in a protrusion of the properties of each component. Limiting the value of the resulting manipulated variable requires minimum and maximum limit values to maximize the work of the controller[23]. One or two of the three constants can be set to stand out more than the others. These are prominent constants that will contribute to the influence on the overall response of the system. To get a good control action, a trial &error step with a combination of P, I and D is needed until the Kp, Ki and Kd values are found as desired. Determining pid control parameters for plants whose mathematical model unknown can apply *arduino tuning*[24]. For current control (*level control*), for example, *the plant* consists of *a feed screw* and a *conveyor belt* that transfers raw materials to the reservoir, the Arduino open loop method is used appropriately[25].

There are many ways to determine the pid parameters, one of the ways is the Ziegler-Nichols method. Method as a way to set up online[26].

Table 2. Zieger-Nichols parameters

Controller	K_p	T_i	T_d
P	$0.5 * K_c$		
PD	$0.65 * K_c$		$0.12 * P_c$
PI	$0.45 * K_c$	$0.85 * P_c$	
PID	$0.65 * K_c$	$0.5 * P_c$	$0.12 * P_c$

PID control is applied in position control research to control position and speed control to control the rotational speed of the motor contained in the elevator system. Speed and position control use the PID method to minimize errors arising from the elevator system. The set-point used is the height and rotational speed of the motor of the lift system[27]. The input used is the height of the lift obtained using ultrasonic sensors and the rotational speed of the motor obtained using the optocoupler sensor. The data obtained is then processed using ESP32 with the PID method to produce output in the form of PWM values[28]. The PWM value is then used to rotate the DC motor, so that the lift will reach the desired speed and height. It was found that the tool can control the speed and position of the elevator, except that there is still an error in the position control system created[29].

Ziegler Nichols' method proposes rules forUK k determining the values of Kp, Ti, and Td based on the characteristics of a given response[30]. Ziegler Nichols' first method is to determine the values of a, h, Kp, and Tc as in Figure 6.

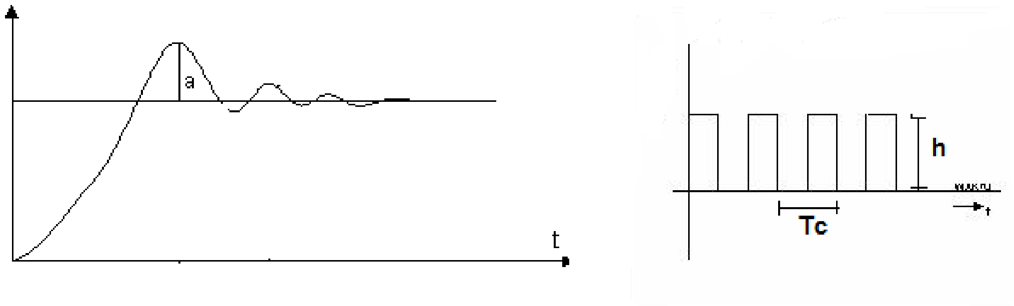

Figure 6. Zieger Nichols method curve

To obtain the values of h, a, and Tc, experiments should be carried out on the vessel by the on-off control method with a PWM value of at least 0 (motor condition OFF) and a maximum PWM value of 255 (motor condition ON) With a set point from the initial position of the vessel.

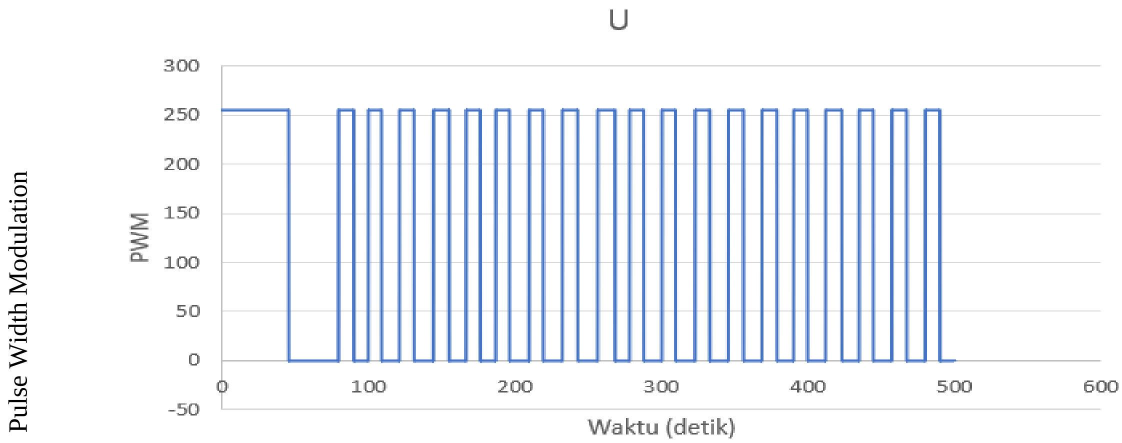

Figure 7. On-off control PWM Response **1Graph**

h = 255
a = 10.56
Kc = $\frac{4h}{\pi a}$
Kc = $\frac{4*255}{3.14*.10.56}$
Kc = 30.76
Kp = 0.65 * Kc

Kp = 20
Tc = 80.1
Tuesday = 40.05
Td= 9,612
Ki =Kp/Ti =0.49
Kd =Kp*Td =1.15

3. RESULTS AND DISCUSSION

Prototype testing

A very important aspect of PID control is the determination of the parameters of the PID controller so that the system meets the desired performance criteria. So that manual-tuning is needed by changing the parameters Kp, Ki, Kd. Tuning on the PID aims to find out the parameters or values of the controls P, I, and D. Manual-tuning process of the PID is carried out by *trial and error* until it gets the desired response result. This tuning process can optimize the process system and minimize *errors* between process *variables* and *set points*.

```
void draw_arrow(int x2, int y2, int x1, int y1, int alength, int awidth, int
colour) {
  float distance;
  int dx, dy, x2o,y2o,x3,y3,x4,y4,k;
  distance = sqrt(pow((x1 - x2),2) + pow((y1 - y2), 2));
  dx = x2 + (x1 - x2) * alength / distance;
  dy = y2 + (y1 - y2) * alength / distance;
  k = awidth / alength;
  x2o = x2 - dx;
  y2o = dy - y2;
  x3 = y2o * k + dx;
  y3 = x2o * k + dy;
  x4 = dx - y2o * k;
  y4 = dy - x2o * k;
  display.drawLine(x1, y1, x2, y2, colour);
  display.drawLine(x1, y1, dx, dy, colour);
  display.drawLine(x3, y3, x4, y4, colour);
  display.drawLine(x3, y3, x2, y2, colour);
  display.drawLine(x2, y2, x4, y4, colour);
}

void Draw_Compass() {
  int dxo, dyo, dxi, dyi;
  display.drawCircle(centreX,centreY,radius,WHITE);  // Draw compass circle
  for (float i = 0; i <360; i = i + 22.5) {
    dxo = radius * cos(i*3.14/180);
    dyo = radius * sin(i*3.14/180);
    dxi = dxo * 0.95;
    dyi = dyo * 0.95;
    display.drawLine(dxi+centreX,dyi+centreY,dxo+centreX,dyo+centreY,WHITE);
  }
}

float hitungPID(int sudt){
  Error=setPoin-sudt;
  integralErr+=Error;
  //float rest=(Kp*Error)+Ki*(Error+LastError)+Kd*(Error-LastError);
  float rest=(Kp*Error)+(Ki*integralErr)+Kd*(Error-LastError);

  LastError=Error;
  return rest;
```

Set Ki and Kd to zero. Then slowly increase the Kp value until it reaches the oscillation then set it back to about half. Ki is improved until it achieves better results. An oversized Ki value will cause an excessive response and *overshoot*. Tuning parameters are required to optimize the performance of the PID controller. The PID controller will not work properly or will only work on a small area around a specific *state* system.

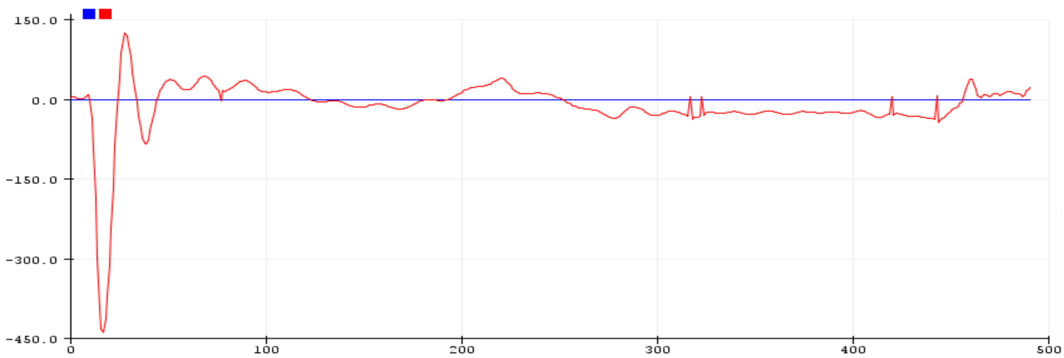

Figure 2. Response Graph with KP=20, KD=4, and KI=0.5

Figure 2 is the Rpm Response Graph to *the set point*, with KP=20, KD=4, and KI=0.5. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

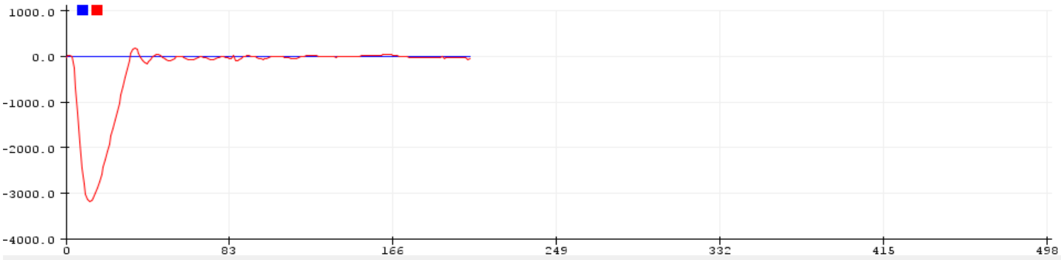

Figure 3 Response Graph with KP=41, KD=21, and KI=3

Figure 3 is the Rpm Response Graph to *the set point*, with KP=41, KD=21, and KI=3. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

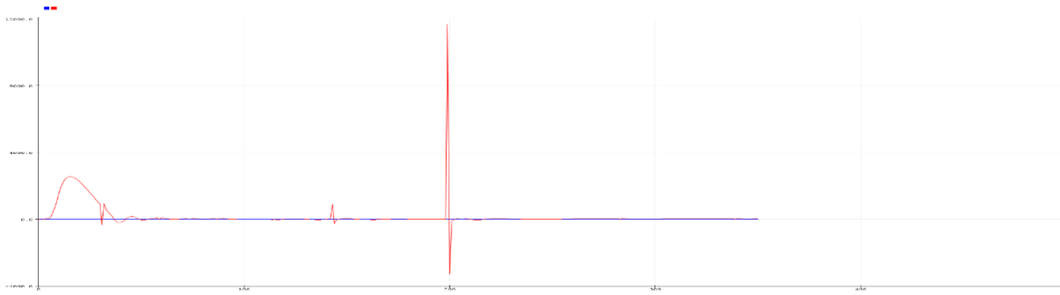

Figure 4 Response Graph with KP=41, KD=21, and KI=3

Figure 4 is the Rpm Response Graph to *the set point*, with KP=41, KD=21, and KI=3. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

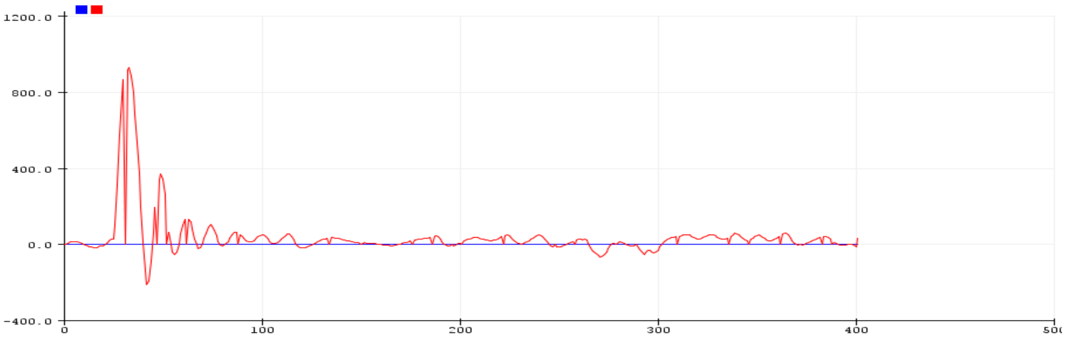

Figure 5 Response Graph with KP=50, KD=1, and KI=1

Figure 5 is the Rpm Response Graph to *the set point*, with KP=50, KD=1, and KI=1. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the response generated by the set point of the scabpai has not been as desired.

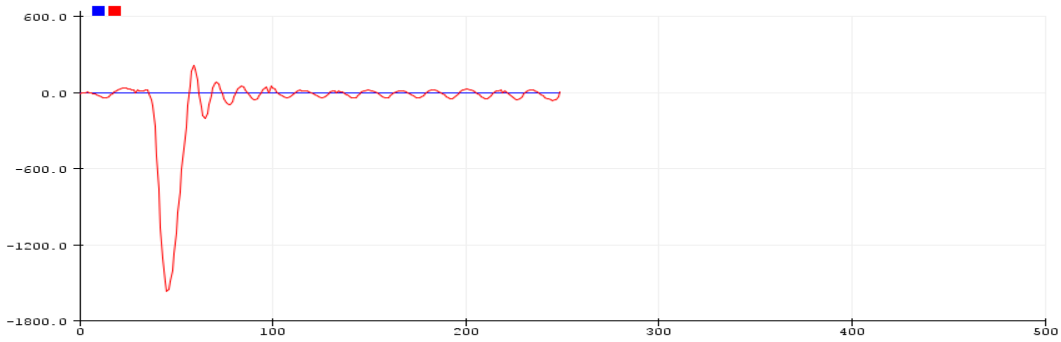

Figure 6 Response Graph with KP=50, KD=11, and KI=1

Figure 6 is the Rpm Response Graph to *the set point*, with KP=50, KD=11, and KI=1. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

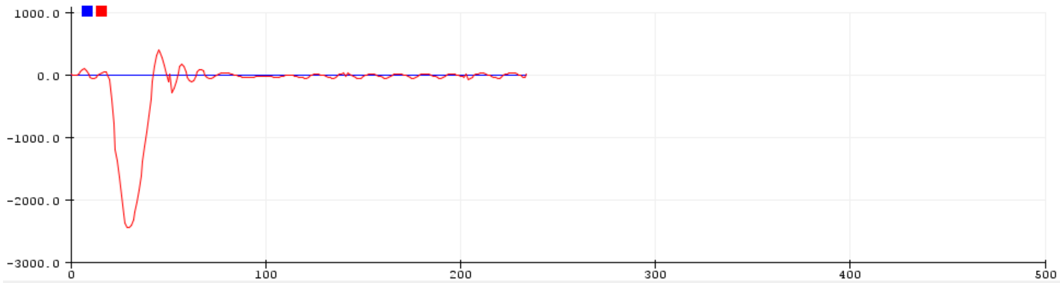

Figure 7 Response Graph with KP=60, KD=10, and KI=2

Figure 7 is the Rpm Response Graph to *the set point*, with KP=60, KD=10, and KI=2. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

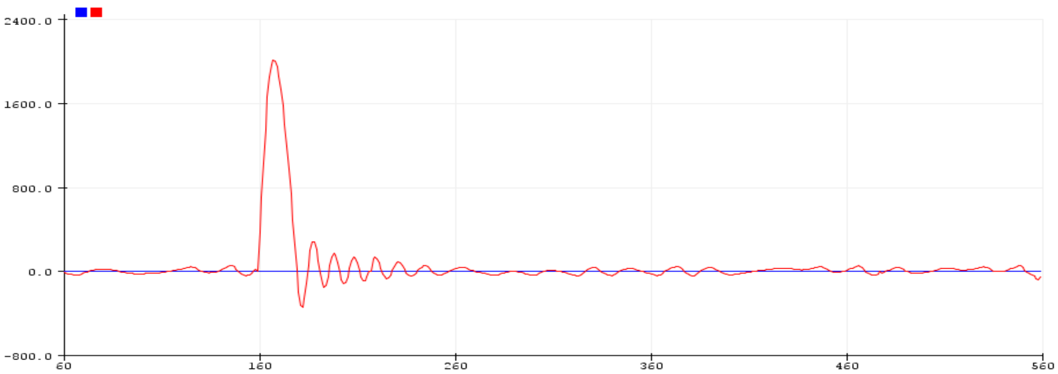

Figure 8 Response Graph with KP=60, KD=10, and KI=2

Figure 8 is the rpm Response Graph for *assigning points*, with KP=20, KD=4, and KI=0.5 version 2. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

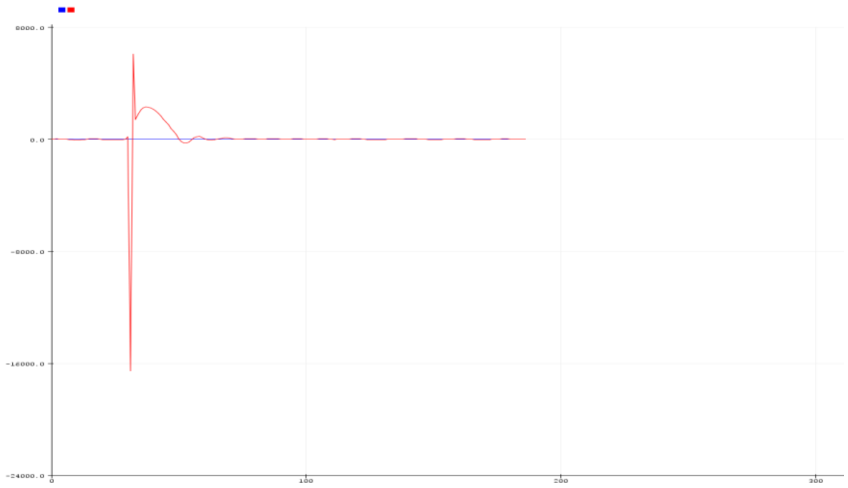

Figure 9 Response Graph with KP=60, KD=30, and KI=2

Figure 9 is the rpm Response Graph for *the set point*, with KP=60, KD=30, and KI=2. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings Kp, Ki, Kd, the resulting response reaches *the point of set* as desired.

Figure 10 Response Graph with KP=60, KD=45, and KI=2

Figure 10 is the Rpm Response Graph to *the set point*, with KP=60, KD=45, and KI=2. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired.

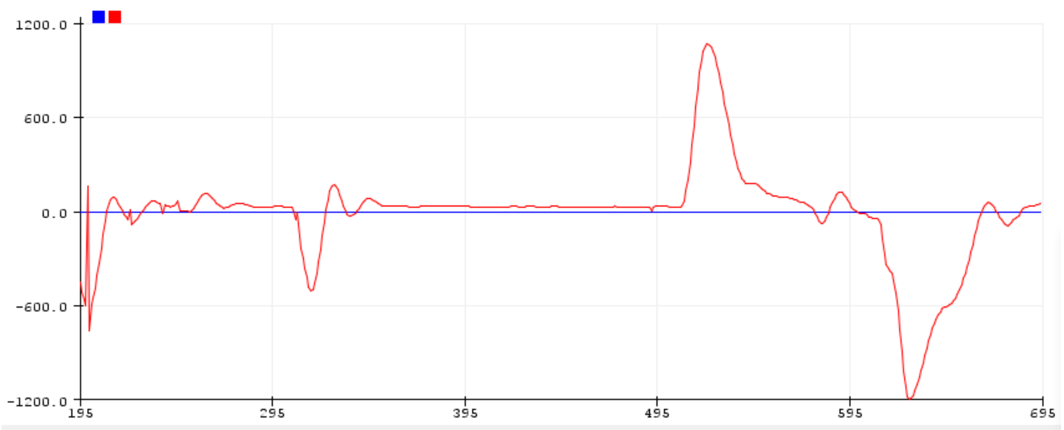

Figure 11 Response Graph with KP=13, KD=2, and KI=3

Figure 11 is the Rpm Response Graph to *the set point*, with KP=13, KD=2, and KI=3. The rpm value is obtained from the linear regression formula of stretching to frequency. The results of the graph state that with the settings of Kp, Ki, Kd, the resulting response reaches *the set point* not yet as desired. On the position chart at the time of the 0 initial condition the ship is resting, there is a spike in the chart going up or down as the ship moves to see the PID response. The rise of the chart is called *over shoot*. If it is already at point 0 then it will be stationary with the position of the ship. From the above experiments we can conclude that the rpm response to the set point is the values KP=60, KD=30, and KI=2.

4. CONCLUSION (10 PT)

The PID-based dynamic position control system in ship prototyping can reach a stable point by setting a predetermined point using a gyrocompass. Control of the ship prototype can be carried out stably when the position of the setting point has been determined by a combination of setting constants P, I, D which minimizes the error value (interference) when testing the appliance. From the test results of the ship prototype, the best response rpm to the set point is the values of KP = 60, KD = 30, and KI = 2.

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