EJSIT
European Journal of Science, Innovation and Technology
ISSN: 2786-4936
www.ejsit-journal.com
Volume 5 | Number 1 | 2025

Control Process Stability Analysis of a Solid-Liquid Separation System

Tamunobere, A. A.[1*], Jaja Z. [2], Sodiki, J. I. [3]
[1, 3]Department of Mechanical Engineering, Rivers State University, Nigeria
[2]Department of Chemical/Petrochemical Engineering, Rivers State University, Nigeria

ABSTRACT

A key performance indicator in any control process is the sustainability of steady state operation for attainment of stability of the applicable control mechanism. In this work, analysis is carried out on the response of a pressure controller with set pressure of 3bar, 7bar and 12bar and the time stability is attained. Pressure is considered as the operating parameter of the control process using a Differential Pressure Cell (DPC) as the controller mechanism. Using a Proportional Integral Derivative (PID) process controller, the performance of a desander was monitored. At 12 bar set point, the result showed that, with PID values of 0.09518, 0.1438/s, 0s, the operation attained stability in 5.53s in the automatic mode, whereas in the manual mode operation, stability was achieved after 7.96s with PID values of 13, 8/s and 7s manually selected. At 7bar set point, stability was attained in 4.7s with PID values of 1.076, 0.87798/s, 0.19657s in automatic mode whereas in manual mode the system stabilized in 4.79s with PID values of 7, 9/s, 5s. At 3bar set point, the controller gain stability in 5.19s, with PID values of 1.3608, 1.0562, 0.41093s in automatic mode whereas in manual mode, stability was attained in 12.5s with PID values of 12, 8/s, 5s respectively.

Keywords: PID Pressure Controller, Multi-phase desander, Simulation, Pressure control, Process stability analysis

INTRODUCTION

Rawlins (2002) presented an article on application of multiphase desander technology to oil and gas production. It looked in-depth at the background of multiphase desanding and its application. The paper summarized the work achieved in recent times on modelling pressure drop and separation efficiency using Computational Fluid Dynamics (CFD). Rawlins (2013) conducted further research on sand management methodologies for sustained facilities operations. Zhang *et al*. (2021) carried out a study on the effectiveness of separation of solid-liquid fluid flow under the operating condition of tangential and axial flow inside the hydrocyclone. Models were developed to study the process. The models were simulated numerically considering the effects of seven particle sizes, two particle concentrations and two feed rates on solid-liquid flow-ability. The study did not consider performance monitoring with a control process and stability response analysis. Hongyan *et al*. (2021) examined the influence of the vortex finder diameter and length on the performance of a 50 mm diameter hydrocyclone for particle separation. The study showed that large particles (>25µm) are removed entirely when the vortex finder diameter was lower than 20 mm. However, for large vortex finders above diameter 25mm, particles escaped from the vortex finder. Also, negligible impact was recorded when the vortex finder diameter and its length on the cut-size diameter was less than 20 mm. Empirical correlations were established to quantitatively predict the optimum vortex finder length, separation efficiency, and Euler number. Azimian and Bart (2016) in a publication on numerical analysis of hydroabrasion looked at CFD model in developing the velocity profiles and separation efficiency curves of a hydrocyclone and how it can be

* Corresponding Author

predicted. The study employed the application of Euler-Euler model using computational fluid dynamics tool ANSYS-CFX 14.5. The main reason for using the Euler-Euler approach is due to its ability in understanding and resolving particle interactions and well suited for heavily laden solid-liquid mixtures. The results that were predicted got good validation with experimented results when comparison was made. Hisham *et al.* (2019) stated that sand control in the oil and gas industry is a phenomenon focusing on the management of sand at production phase. Solids in the fluid stream of producing oil reservoirs have huge impact on the surface processing equipment depending on the operating framework deployed to manage the oil field. The need to deploy surface processing equipment to manage this phenomenon cannot be over emphasized. To experience production of sand alongside oil and gas will result in erosion and wear of surface production facilities and equipment. The key factors that influence the tendency of a well to produce sand include degree of consolidation of the formation, production rate of the reservoir fluid, drawdown following bean sequence management (differential between reservoir pressure and the well bore pressure), reduction of pore pressure, reservoir fluid viscosity and increasing water production (Hisham *et al*., 2019). Sand production from a well is always detrimental to surface processing equipment regardless of the productivity condition. As a key objective in the processing of reservoir fluid, the effective separation of solids from the fluid stream in the processing facility must be given priority attention in order to save the downstream equipment. During operation, it is very important to keep availability of the processing plant at designed level over a desired duration before intervention when required. The hydrocyclone, whose principle of operation is used in operating multiphase desander, requires the flow parameters and mechanical properties of the fluid to be monitored to efficiently remove solid particles from the crude oil stream. Tamunobere and Sodiki (2024) state, in a paper on Multiphase Desander Performance Monitoring with Pressure Control Mechanism, the stabilization time of a PID controller applied in solid liquid separation. In their work, pressure at 12bar was considered as the operating parameter and the control process using Differential Pressure Cell (DPC) as the controller mechanism. Using a Proportional Integral Derivative (PID) process controller, the performance of the desander was monitored. The results achieved showed that, with PID values of 0.66038, 0.78599/s and 0s, the operation attained stability in 5.53s in the automatic mode, whereas in the manual mode operation, stability was achieved after 7.96s with PID values of 13, 8/s and 7s manually selected. This work provided opportunity to study the stability of the system using different pressure set points. This work is focused on analyzing further the response of a PID controller using 3bar and 7bar pressure set points as compared to 12bar operating pressure being maximum operating pressure for most processing facilities in the Niger Delta in Nigeria. This involves incorporation of a control process with pressure as operating parameter using Proportional Integral Derivative controller to maintain stability for effective functionality of the desander. Preventing frequent physical intervention of the field equipment, by way of controlling the operation remotely, will ensure improvement of the processing facility. With a pressure control mechanism, the separation efficiency of hydrocyclone would be greatly improved owing to the elimination of disturbances arising from pressure variations.

MATERIALS AND METHODS

Materials

Thermodynamic data were sourced to carry out the analysis using software. Operational data obtained from one of the multinational oil and gas companies operating in Nigeria were applied in the simulation of the fluid flow and process models.

Methods

Methods used for the study include fluid flow equations, hydrodynamics models, continuity equations, application of Newton's laws of forces, Laplace transform techniques, and material and energy balance principles.

Hydrocyclone and separation efficiency governing equations

The derivation of the hydrocyclone equations was carried out using the material, energy and momentum balance principles. The derivation follows Navier-Stokes equation, Bernoulli's equation and continuity equation (Marvin *et al.*, 2020). Tamunobere *et al.* (2023) presented a study on Performance Monitoring of a Multi-Phase Desander with a Flow Control System where the determination of hydrocyclone separation efficiency was detailed. This current work has considered the separation efficiency result presented in that study which also showed details of the governing equations used in the simulation.

Application of Control Process Model

From operational studies, the disturbances that affect solid-liquid separation of crude in a desander (multiphase hydrocyclone) are flow rates, pressure P, Temperature T, and level h. Applying the model in their work, this study looks at the control stability response sensitivity in a multiphase desander using a pressure controller with varying pressure input set points to monitor the performance. The development of the governing equations used for the simulation was based on previous work done by same author in a paper titled; Multiphase Desander Performance Monitoring with Pressure Control Mechanism (Tamunobere & Sodiki, 2024). Considering a pressure controller, a mathematical model of the hydrocyclone was applied based on pressure as disturbance variable and converted to transfer functions, a control environment of the process using Laplace Transform approach. Using a Proportional Integral Derivative controller the disturbance arising from pressure variation were measured, checked with standard values (set points) and compared. At every operation, the error signal was checked at the controller via a feedback control loop.

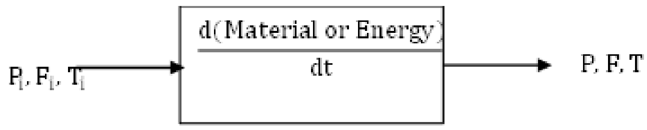

Figure 1: Schematic of Hydrocyclone Block Diagram Indicating Material and Energy Balance

The material and energy block diagram showing the inflow, accumulation and outflow of disturbance variables is shown in Figure 1.

The processing of streams of crude oil is designed such that it exits the desander and further processed via the respective separators installed to process wells with low pressure and those with high pressure. Based on the design of the processing facility as shown in Figure 2, all wells with high pressure are routed to the high-pressure separator and pre-set to operate at 12bar, which reduced the pressure to 3bar at the outflow. The wellhead desander, presented in Figure 3, is a particular tool designed to remove solid particles from multiphase fluids and is installed prior to the choke valve. The wellhead desander operates by utilizing some of the pressure taken through the valve bean, thereby, reducing the erosion problem and adapts the pressure in the separation process. These attendant problems have been reviewed by some operators and as part of effort to mitigate the risk, sand traps or desanders have been incorporated in the flow stream upstream of the processing facilities.

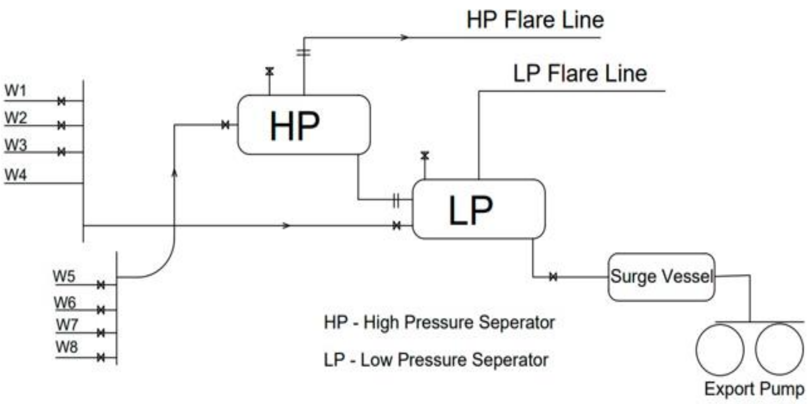

Figure 2: Process Flow Diagram

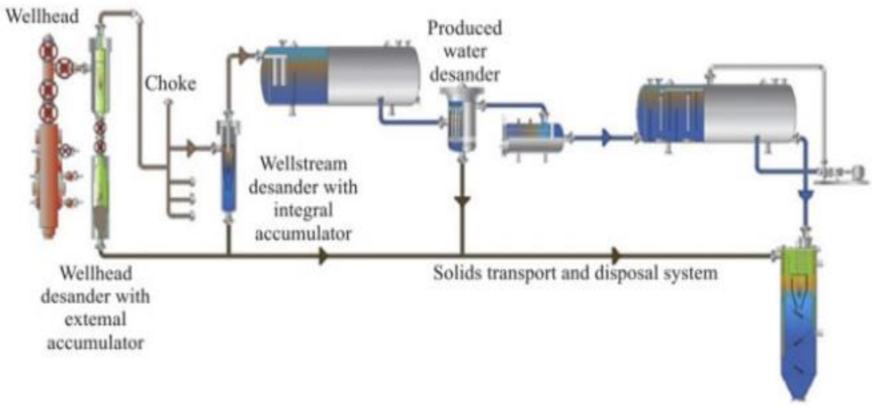

Figure 3: Cyclonic Location-Based Solids Separation Equipment at Surface Facilities
(Source: Hisham *et al*., 2019)

RESULTS AND DISCUSSION

The block diagram shown in Figure 4 is a closed loop feedback PID pressure controller showing the transfer function and the necessary step inputs for smooth process response.

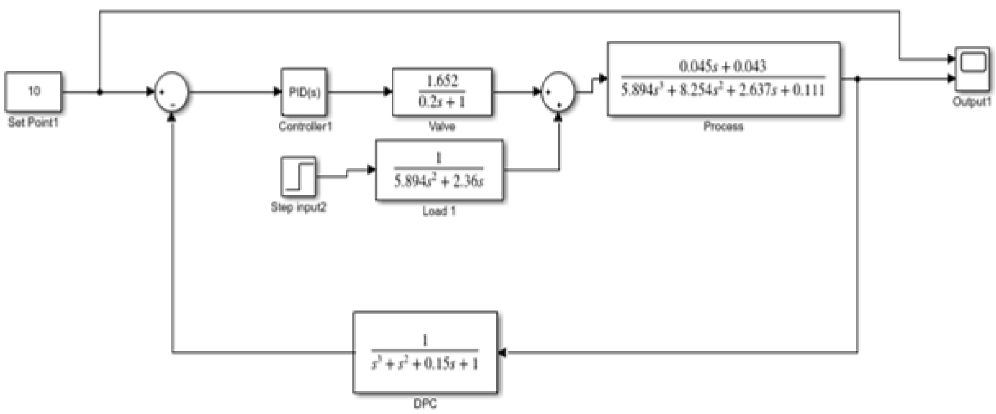

Figure 4: Block Diagram for a Closed Loop Feedback PID Pressure Control

Figure 4 further shows the configuration of the control process using a differential pressure cell DPC to measure the pressure output to compare with the set point. The simulation was carried out in SIMULINK embedded in MAT-LAB.

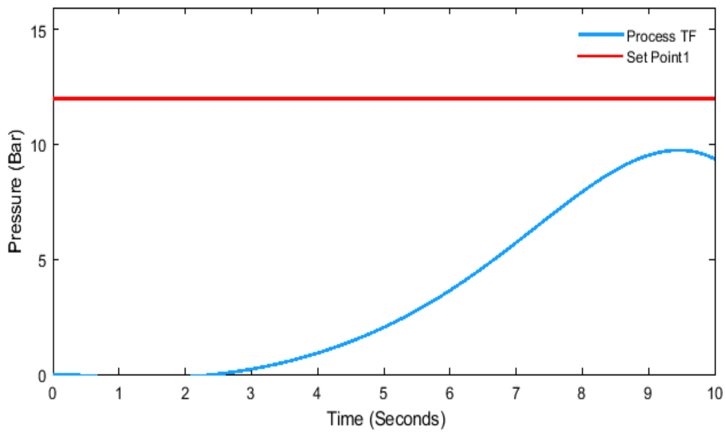

Figure 5: Pressure vs Time Graph of the controller with PID data 2.5, 1.25/s, 1.55s

Figure 5 shows the response profile of the controller indicating that there was no stability with the data chosen and therefore requires further tuning to get a stabilized response.

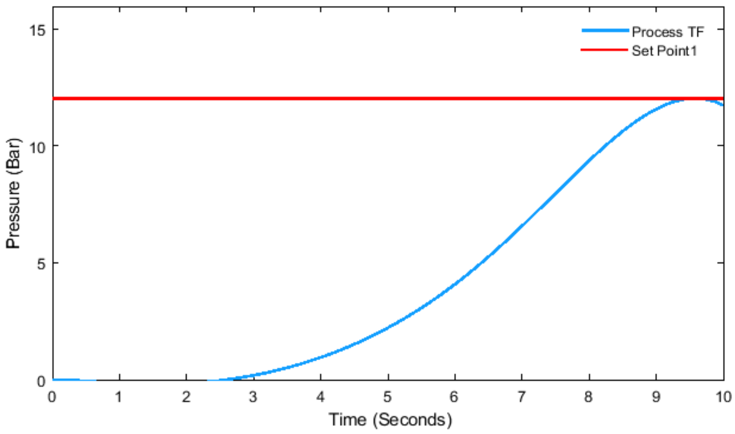

Figure 6: Pressure vs Time Graph of the Controller with PID Values of 3, 1.05/s, 2s

The profile of the controller response as shown in Figure 6 does indicate some level of stability after 9 seconds but immediately departed from the set point showing further instability. The process was subjected to further tuning to achive the desired response. The profile in Figure 7 also showed no stability on the controller. Figures 5 to 7 show the result of the controller with various manually manipulated PID values with the desire to attain process stability and enable the hydrocyclone perform to achieve the simulated efficiency. No stability was achieved with the manually selected PID values as shown in the figures. The operation of the system continued with different PID data which indicated that stability was attained as shown in Figure 8. It also shows the amplitude of response of the controller in both manual and automatic mode at 12bar set point. PID values were selected accurately by the controller to achieve the desired stability. The manipulated PID values (13, 8/s,7s) to operate the controller showed a huge overshoot of 1.4m and stabilized at the set point after 5.53 seconds. Furthermore, the manually tuned process response was faster to correct the overshoot when compared with the automatic mode performance. The rise time of the automatically manipulated process was higher but the overshoot was very small. The rise time was 1.35s for the automatic mode whereas as the manual mode resulted in 0.231s. Table 1 shows details of the process parameters for both automatic and manual control mode using 12 bar as set pressure and resulting in stability.

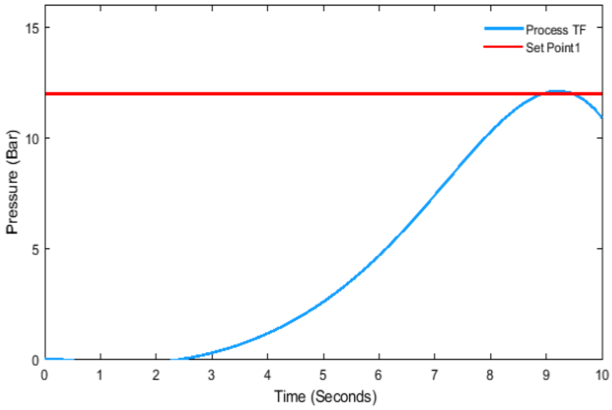

Figure 7: Pressure vs Time Graph of the controller with PID data 4, 1.25/s, 2.3s

Table 1: Controller Parameters for Automatic and Manual Pressure Control at 12 bar pressure

Controller Parameters	Tuned	Blocked
P	0.09518	13
I	0.1438	8
D	0	7
N	100	100
Performance and Robustness	**Tuned**	**Blocked**
Rise time	1.35 seconds	0.213 seconds
Settling time	5.53 seconds	7.96 seconds
Overshoot	12 %	63.6 %
Peak	1.12	1.64
Gain margin	8.63 dB @ 1.93 rad/s	12.5 dB @ 11 rad/s
Phase margin	60 deg @ 0.795 rad/s	10.8 deg @ 5.51 rad/s
Closed-loop stability	Stable	Stable

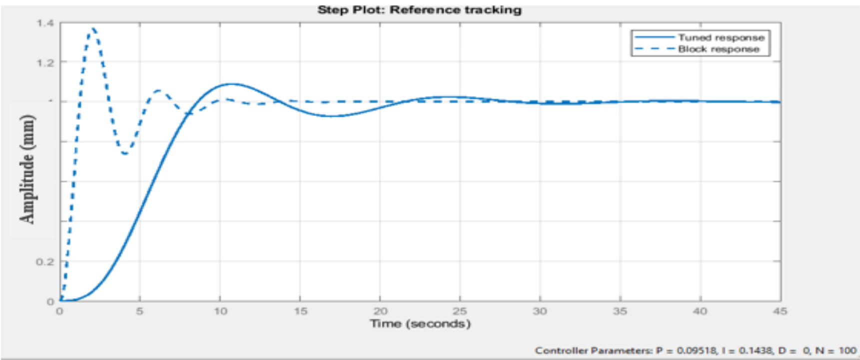

Figure 8: Transient Response Amplitude vs Time Graph of Pressure Controller with Tuned and Blocked PID Values at 12 bar

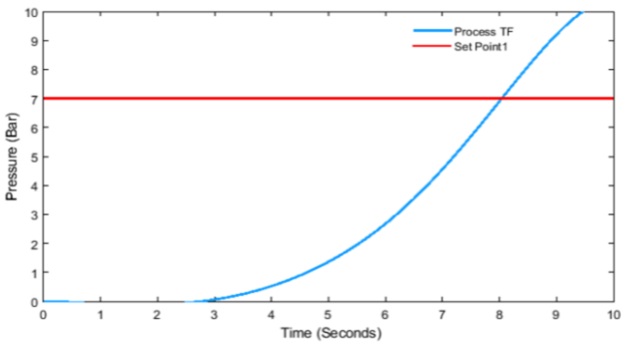

Figure 9: Pressure vs Time Graph of the Controller with PID Values of 3, 2.25/s, 1.52s

Figure 9 shows the simulation result of the PID controller using PID values of 3, 2.25/s, 1.52s with pressure set at 7bar. In this scenario a manual manipulation of the PID controller was carried out with a desire to achieve set value. The graph showed a gentle rise time with significant overshoot after 8s above the set point, indicating that the operation did not attain stability. The output achieved did not give the desired response as compared to the set value, hence it requires further tuning of the controller with a new set of PID values.

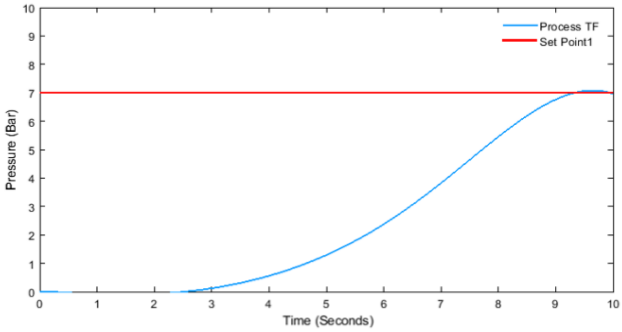

Figure 10: Pressure vs Time Graph of the Controller with PID Values of 3, 1.4/s, 2s

Figure 10 shows the simulation result of the PID controller using PID values of 3, 1.4/s, 2s with pressure set at 7bar. The graph showed a gentle rise time with no significant damping when compared to the set point, showing there was stability after 10s. The output gave the desired response hence it does not require further tuning of the controller with a new set of PID values.

Table 2: Controller Parameters for Automatic and Manual Pressure Control at 7bar Pressure

Controller Parameters	**Tuned**	**Blocked**
P	1.076	7
I	0.87798	9
D	0.19657	5
N	114.3229	150
Performance and Robustness	**Tuned**	**Blocked**
Rise time	1.22 seconds	0.271 seconds
Settling time	4.7 seconds	4.79 seconds
Overshoot	4.61 %	48.5 %
Peak	1.05	1.48
Gain margin	12.2 dB @ 2.96 rad/s	21.6 dB @ 15.6 rad/s
Phase margin	69 deg @ 1 rad/s	20.7 deg @ 4.55 rad/s
Closed-loop stability	Stable	Stable

Table 2 shows the corresponding input data for the controller robustness in processing the input to achieve the desired response. The table further shows the performance of the PID controller with two sets of data. The process of the controller was compared using data generated by the system and those manually selected. The tuned data were those generated by the system whereas block data were those selected manually to monitor the PID controller performance.

Figure 11 shows the simulation result of the PID controller using PID values of 2, 1.5/s, 3s with pressure set at 7bar. This was achieved by manually tuning the controller with a set of PID values to manipulate the error to get the desired response.

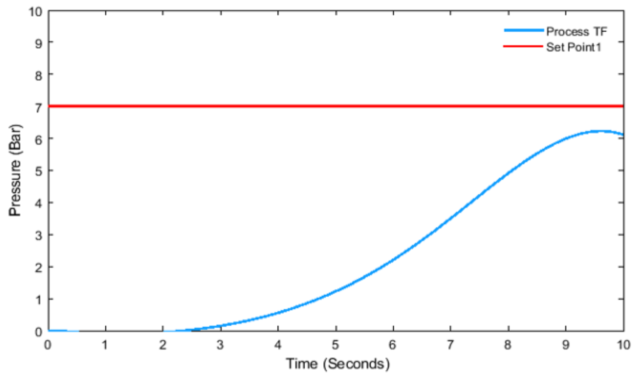

Figure 11: Pressure vs Time Graph of the Controller with PID Values of 2, 1.5/s, 3s

The graph showed a gentle rise time with significant damping when compared to the set point, indicating that there was no stability after 10s. The output achieved did not give the desired response as compared to the set value, hence it requires further tuning of the controller with a new set of PID values.

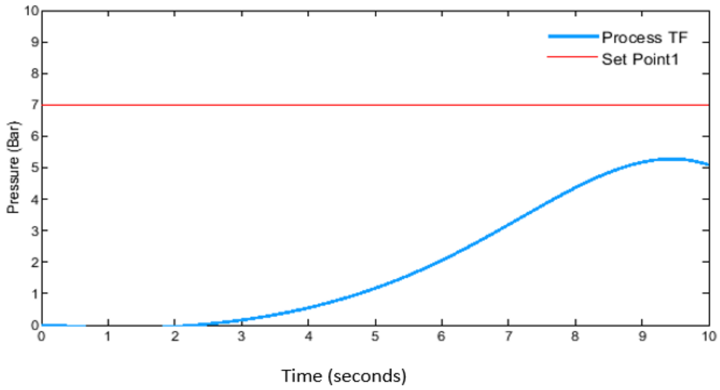

Figure 12: Pressure vs Time Graph of the Controller with PID Values of 2, 1.2/s, 3s

Figure 12 shows the simulation result of the PID controller using PID values of 2, 1.2/s, 3s with pressure set at 7bar. This performance was achieved by manually tuning the controller with the new set of PID values and manipulating the error to get the desired response. The graph showed a gentle rise time with significant damping when compared to the set point, indicating that there was no stability after 9s. The output achieved did not give the desired response hence it requires further tuning of the controller with a new set of PID values.

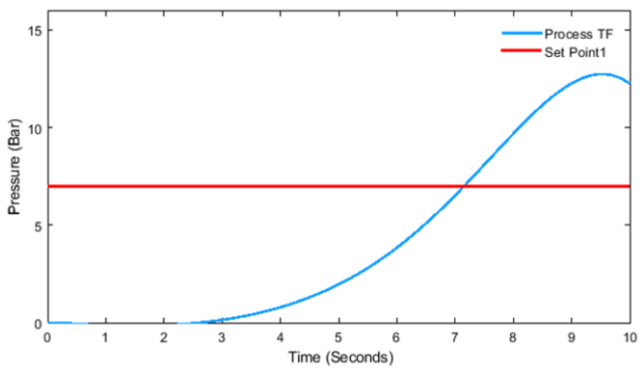

Figure 13: Pressure vs Time Graph of the Controller with PID Values of 4, 2.95/s, 3.15s

Figure 13 shows the simulation result of the PID controller using PID values of 4, 2.95/s, 3.15s with pressure set at 7bar. A manual manipulation of the PID controller was carried out with a desire to achieve set value. The graph showed a gentle rise time with significant overshoot after 8s above the set point, indicating that the operation did not attain stability. The output achieved did not give the desired response, hence it requires further tuning of the controller with a new set of PID values. Figure 14 shows the transient response amplitude of the controller of the process to achieve the desired performance. The controller on automatic mode operation showed a rise time within 1.22 seconds but remained unstable till after 8 seconds when it attained the set point. The PID values (1.076, 0.878/s, 0.1966s) were selected accurately by the controller to achieve stability. The response of the controller was smooth from beginning till it attained stability. On the contrary, the manually selected PID values of 7, 9/s, 5s initially showed a huge overshoot and remained very unstable but stabilized at the set point after 6 seconds. However, it eventually achieved the required stability after 10s, having attained the set point. Furthermore, the manual process response was faster to correct the overshoot bringing it to attain stability when compared to the automatic operation. Both mode of manipulation of the process achieved stability after 10s hence no real advantage judging from the response of the controller performance.

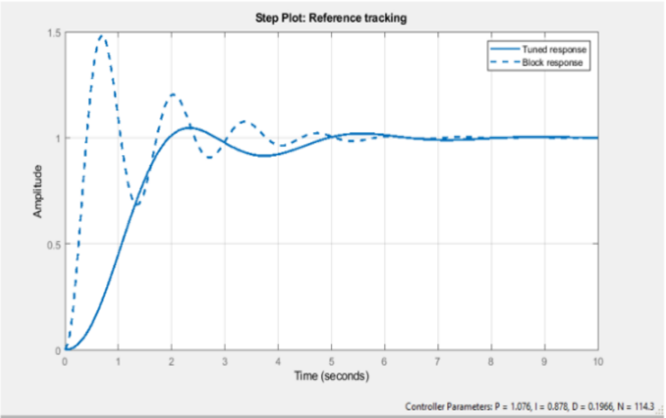

Figure 14: Transient Response Amplitude vs Time Graph of Pressure Controller with Tuned and Blocked Values at 7bar set point

Figure 14 shows the amplitude of response robustness of the controller to achieve the desired responses. The controller showed rise time within 1.22 seconds but remained unstable till after 7 seconds when it attained the set point. The controller was put on automatic mode to run the process without manually manipulating the PID values. PID values were selected accurately by the controller to achieve stability. The response of the controller was smooth from beginning till it attained stability after 8 seconds. On the contrary, the manipulated PID values (1.076, 0.878/s, 0.1966s) initially showed a huge overshoot above the set point and remained very unstable and later stabilized at the set point after 6 seconds. However, it eventually achieved the required stability after 10s, having attained the set point. Furthermore, manual mode process response was fast to correct the overshoot bringing it to attain stability when compared to the automatic mode operation of the controller. Both mode of error manipulation of the process achieved stability after 10s hence no real advantage judging by the response of the controller.

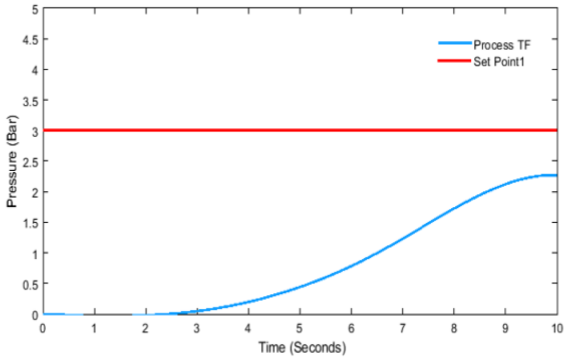

Figure 15: Pressure vs Time Graph of the Controller with PID Values of 1.5, 1/s, 2.5s

Figure 15 shows the simulation result of the PID controller using PID values of 1.5, 1/s, 2.5s with pressure set at 3bar. This was achieved by manually manipulating the controller the PID values to correct the error to get the desired response. The graph showed a gentle rise time with significant damping when compared to the set point, showing that there was no stability after 10s. The output achieved did not give the desired response, hence it requires further tuning of the controller with a new set of PID values.

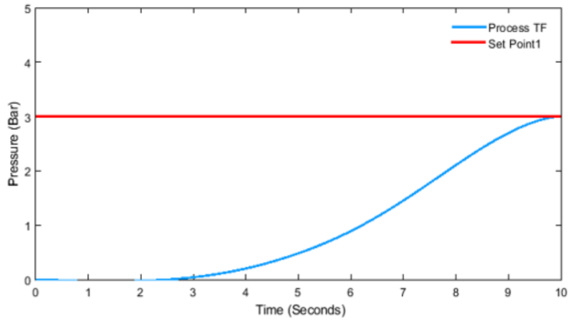

Figure 16: Pressure vs Time Graph of the Controller with PID Values of 1.5, 1.5/s, 2.5s

Figure 16 shows the simulation result of the PID controller using PID values of 1.5, 1.5/s, 2.5s with pressure set at 3bar. This was achieved by manually tuning the controller PID values and manipulating the error to get the desired response. The graph showed a gentle rise time with no significant damping when compared to the set point, indicating stability after 10s. The output gave the desired response and does not require further tuning of the controller with a new set of PID values.

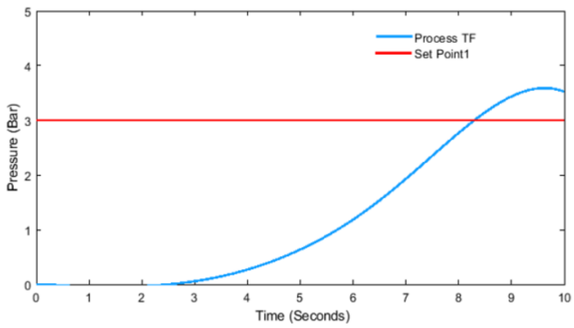

Figure 17: Pressure vs Time Graph of the Controller with PID Values of 2.5, 1.8/s, 3s

Figure 17 shows the simulation result of the PID controller using PID values of 2.5, 1.8/s, 3s with pressure set at 3bar. A manual manipulation of the controller was done with a desire to achieve set value. The graph showed a gentle rise time with significant overshoot above the set point after 8s, indicating the control process did not attain stability. The output achieved did not give the desired response as compared to the set value, hence it requires further tuning of the controller with a new set of PID values.

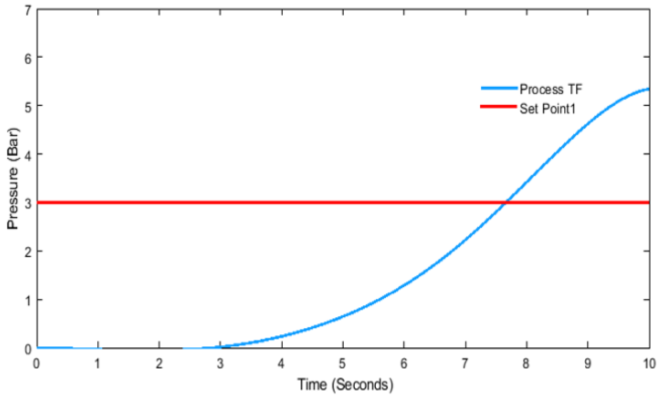

Figure 18: Pressure vs Time Graph of the Controller with PID Values of 3, 2.54/s, 1.52s

Figure 18 shows the simulation result of the PID controller using PID values of 3, 2.54/s, 1.52s with pressure set at 3bar as the operating parameter. A manual manipulation of the PID controller was carried out with a desire to achieve the set value. The graph showed a gentle rise time with significant overshoot above the set point after 7.7s. The performance achieved did not give the desired response as compared to the set value, hence it requires further tuning of the controller with a new set of PID values.

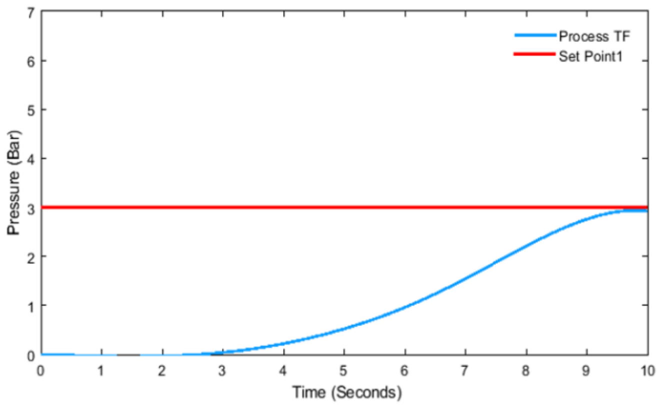

Figure 19: Pressure vs Time Graph of the Controller with PID Values of 2.5, 1.2/s, 2.5s

Figure 19 shows the simulation result of the PID controller using PID values of 2.5, 1.2/s, 2.5s with pressure set at 3bar. This was achieved by manually tuning the controller PID values and manipulating the error to get the desired response. The graph showed a gentle rise time with no significant damping when compared to the set point, indicating there was stability after 10s. The output gave the desired response, hence it does not require further tuning of the controller with a new set of PID values. Figure 20 shows the amplitude of response robustness of the controller to achieve the desired responses. The controller showed rise time within 2 seconds but remained unstable till after 8 seconds when it attained the set point. In this case, the controller was put on automatic mode to run the process without manually manipulating the PID values. PID values were selected accurately by the controller to achieve stability.

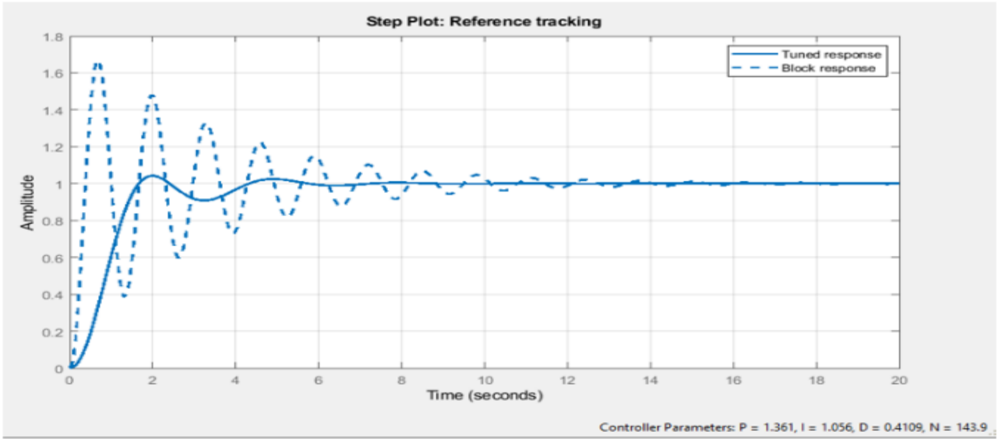

Figure 20: Transient Response Amplitude vs Time Graph of Pressure Controller with Tuned and Blocked Values 1.361, 1.056/s, 0.4109S a 3bar set point

Table 3: Controller Parameters for Automatic and Manual Pressure Control set at 3bar

Controller Parameters	Tuned	Blocked
P	1.3608	12
I	1.0562	8
D	0.41093	5
N	143.924	100
Performance and Robustness	**Tuned**	**Blocked**
Rise time	1.06 seconds	0.245 seconds
Settling time	5.19 seconds	12.5 seconds
Overshoot	4.24 %	66.9 %
Peak	1.04	1.67
Gain margin	20.2 dB @ 4.56 rad/s	10.7 dB @ 8.5 rad/s
Phase margin	69 deg @ 1.26 rad/s	8.07 deg @ 4.78 rad/s
Closed-loop stability	Stable	Stable

Table 3 shows the corresponding input data of the controller to achieve the desired response with 3 bar pressure as the control variable. The performance of the controller was compared using data generated by the system and those manually selected. The rise time was 1.06 seconds for the tuned data whereas 0.245 seconds for the manually selected PID data. The settling time was 5.19 seconds for the tuned data whereas 12.5 seconds for the manually selected PID data. This shows that it took more time for the process to reach the desired output with manually selected PID data and less time with automatically selected PID data. Table 4 shows various sets of PID data manually selected to operate the controller at various pressure set points of the solid-liquid separation system and control process stability response analysis. The analysis gives indication of data to be applied to monitor the system performance in order to achieve response stability.

Table 4: PID data of the controller at the different pressure set points

Iteration Number	P Value	I Value (/s)	D Value (s)	Remarks
12 Bar Pressure Set point				
1	2.5	1.25	1.55	Response showed overdamping after 10 seconds without stability
2	3	1.05	2	Set point was achieved in 9 seconds but process did not stabilize.
3	4	1.25	2.3	Set point was achieved without process stability
7 Bar Pressure set Point				
1	**3**	2.25	1.52	Underdamped response within 10 seconds of operation and no stability
2	2	1.5	3	Process overdamped after 10 seconds without attaining set point and no stability
3	2	1.2	3	Process highly overdamped after 10 seconds and no stability
4	4	2.95	3.15	Highly underdamped response within 10 seconds of operation and no stability
3 Bar Pressure set Point				
1	1.5	1	2.5	Set point achieved and process stabilized minimally within 10 seconds
2	1.5	1.5	2.5	Set point attained in 10 seconds with minimal stability
3	2.5	1.8	3	Underdamped response within 8 seconds operation and no stability
4	3	2.54	1.52	Highly underdamped response within 10 seconds of operation and no stability
5	2.5	1.2	2.5	Process stabilized minimally within 10 seconds below with set point at 2.9 bar operating pressure

CONCLUSION

The efficiency of the hydrocyclone was successfully determined with various particle sizes with pressure as the operating parameter. The PID controller response analysis was carried out considering 12 bar, 7 bar and 3 bar set points. Table 1 shows the result of the controller performance with 12 bar pressure as the control variable while Tables 2 and 3 are for 7 bar and 3 bar respectively.

Two sets of data were presented which indicate the performance of the PID controller, those generated by the system i.e. the tuned values and the manually selected, being the block values to monitor the PID controller performance. With 12bar as set point the rise time which is the time required for the output of the controller to increase from 0.1 to 0.9 of its final value was 1.35 seconds for the tuned data and 0.213 seconds for the manually selected PID data. The settling time was 5.53 seconds for the tuned data whereas that for the manually selected PID data was 7.96 seconds. The PID values were 0.09518, 0.1438/s, 0s for automatic mode operation and 13, 8/s, 7s manual. This shows that it took more time for the process to reach the desired output with manually selected PID data. Both operating modes show desirability in selecting the performance monitoring process of the multiphase desander.

Similarly with 7 bar as pressure set point the rise time was 1.22 seconds on automatic mode and stability attained in 4.7 seconds with a peak of 1.05mm amplitude. On manual mode operation the rise time was 0.271 seconds and stability attained within 4.79 seconds with a peak of 1.48mm amplitude. The settling time was 4.7 seconds for the tuned data whereas that for the manually selected PID data, it was 4.79 seconds. This shows that it took about same time for the process to reach the desired output with manually selected PID data. With 3 bar set point and manually manipulated PID values (12, 8/s, 12s), the controller initially showed a huge overshoot of 1.67mm which was 66.9% above the set point and gradually stabilized to the set point after 12.5 seconds. Furthermore, the tuned process response with PID values (1.361, 1.056/s, 0.4109s) was quick to correct the overshoot making it faster to attain stability when compared to the manual mode operation of the controller.

The rise time for the automatically manipulated process was within 1s with little overshoot of 4.24% above set point. Stability of the control process was achieved in 5.19 seconds with pressure set at 3bar and controller operating on automatic mode. Under same mode of operation and pressure set at 7 bar, stability was attained in 4.7seconds whereas 12bar set point recorded 5.53 seconds. Similarly in manual mode of operation, stability of the control process when operating at pressure set point of 3bar was 12.5 seconds and at 7 bar 4.76 seconds whereas 12 bar was 7.96 seconds.

REFERENCES

Azimian, M. & Bart, H. J. (2016). Numerical Analysis of Hydroabrasion in a Hydrocyclone. *Petroleum Science*, *13,* 304-319.

Hisham, B., Van, H. L. & Yuli, L. (2019). Sand Production: A Smart Control Framework for Risk Mitigation. *Department of Petroleum Engineering Journal, 66*(12), 13-31.

Hongyan, L., Qing, Y., Qingshan, H., Shujun, G., Taobo, H. & Aqiang, C. (2021). Experimental Investigation on Interaction of Vortex Finder Diameter and Length in a Small Hydrocyclone for Solid-Liquid Separation. *Separation Science and Technology, 57*(5), 733-748.

Marvin, D. C., Jose, M.G., Brittany, N. & Andres, G. M. (2020). CFD Modeling of Desanders: A Study of Efficiency of Hydrodynamic Reservoirs. *Fluids, 5*(3), 118-120.

Rawlins, C. H. (2002). *Application of Multiphase Desander Technology to Oil and Gas Production.* Kvaerner Process Systems US, Presented at the 3rd International Conference on Multiphase Technology in Banff, Alberta, 3-5 June.

Rawlins, C. H. (2013). *Design of a Cyclonic Solids Jetting Device and Slurry Transport System for Production Systems.* Paper 166118 presented at the SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, 30 Sep-02 Oct.

Tamunobere, A. A., Sodiki, J. I., Lebele-Alawa, B. T., & Nkoi, B. (2023). Performance Monitoring of a Multi-Phase Desander with a Flow Control System. *European Journal of Science, Innovation and Technology, 3*(6), 241-248.

Tamunobere, A.A., & Sodiki, J. I. (2024). Multiphase Desander Performance Monitoring with Pressure Control Mechanism. *ISJ Theoretical & Applied Science*, *10*(138), 1-8.

Zhang, Y., Jiangbo, G., Yang, M., Jiang, L. & Yang, X. (2021). The Influence of Height-to-Width Ratio of Feed Inlet on Flow Field Characteristics and Separation Performance of the Hydrocyclone with Spiral Inlet. *International Journal of Coal Preparation and Utilization, 2*(7), 1-18.