An Iterative Learning Control Design for Improved Breathing Machine

Anitha T[1*], Gopu G[2]

Abstract

The Ventilator is one of the most important means of saving critical patients, which is commonly used in the fields of ICU and other respiratory therapy. The respiratory control system is a non-linear, multi-output, delayed feedback dynamic system that is constantly disrupted by physiological and pathological factors. Machines providing this control engineering feature have a key role to play in ensuring the secure and precise gas supply to the patient. The proposed work develops a new strategy for adaptive ventilator control, which retains the use of PI, Predictive PI and PID controller can track control signals quickly. Iterative Learning Control can be specified as an intelligent control practice to improve the transient efficiency of functioning systems over a fixed time period continuously. Iterative learning control perceives the process that enforce repeatedly the same work with the aim of sequentially improving accuracy. The pressure of the breathing machine is regulated accordingly. The volume and the breathing time delays also adjust in actual time appropriately. The volume and the breathing time countervail also make corresponding adjustments in actual time. Simulation has shown that the control scenario can persuasively control and alter the domain of the breathing machine according to the patient's breathing state.

KeyWords: Ventilator, PI control, Predictive PI control, PID control, Iterative Learning Control, State space model, Feedback linearization

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Introduction

Intensive modern ventilators provides medical treatment and positive regulation of the patient's airway pressure shown in Figure.1. The flow and exhaust valve delivery system provides cyclical control of pressure or volume which maintains proper ventilation of the lungs of the patient. A mechanical ventilator is a diagnostic device that generates the quantity of air and added oxygen required. Patients suffering from acute respiratory insufficiency.

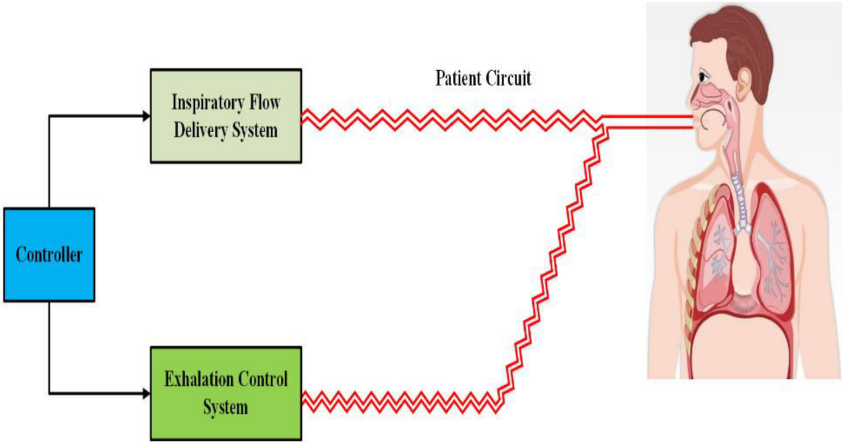

Fig.1.Respiratory system with controller

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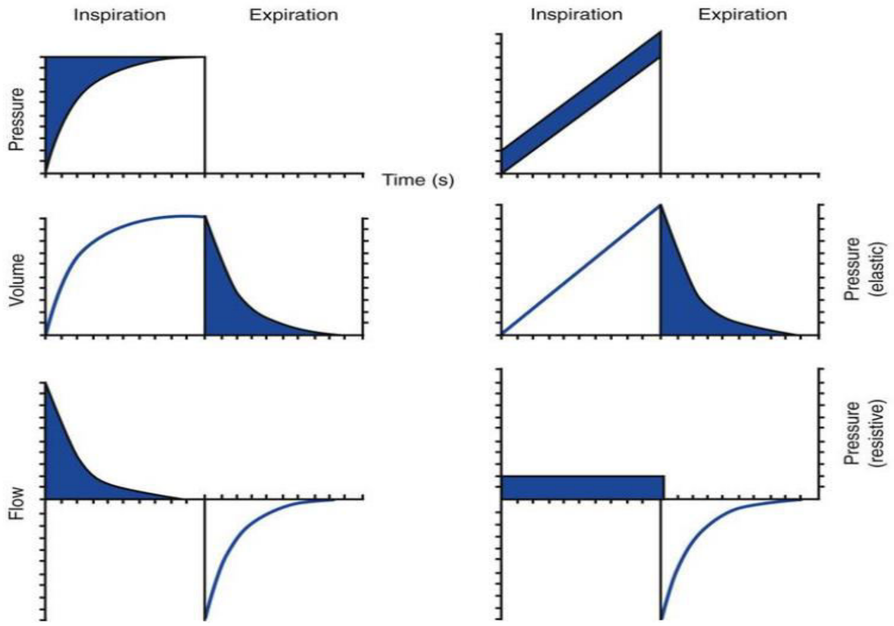

(Wilkins RL, Stoller JK, Kacmarek, RL,2009)
Fig.2. Pressure and Volume control mode for Ventilation

(Naggar.AI et al., 2015) The theoretical model of the respiratory system shows the significant position in role of maintenance and adjustment of the respiratory tract. Ventilators work to facilitate ventilation during the care of patients. The key innovation of this work is the modern MM approach and its simulation. It is also paired with built lung simulator to obtain a simulator for mechanical ventilation systems. This latest simulator is capable of controlling the modelled pressure signal (PCV) and modulated output signal (flow and volume) MaolinCai (2014) as continuous waveforms shown in Figure.2.

(FikretYalcinkaya et al., 2015) in this work various types of lung pressure and volume inhibited ventilation system supplying artificial ventilation has been developed. This analysis varies from the earlier research as it includes transfer functions that describe both pressure and volume regulated type of ventilator.Husam.Y (2020) Evaluation of acute respiratory system signals have also been successfully obtained and observed in the simulation environments used, based on the mathematical model developed and implemented. (Anupama CSS et al., 2018) Mathematical modelling of physiological processes, the cardiovascular system, the lung mechanics and the respiration of normal and congestive heart failure, are designed and simulated. The breathing pattern Cheyne-stokes indicates the stability of the breathing system for those with high altitudes with normal and congestive heart failure. The stability analysis offers prior knowledge on vital patient breathing rates that is helpful in multiple respiratory system-related diagnoses.

(Borrello.M.A, 2005) described components of the scheme was used to model basic lung and lung behaviour. Both airway and gas flow properties in the ventilation system and circuit connecting. The analogy of the linear circuit imparts its well, linear dynamics for tests, but for high fidelity simulations, using static nonlinear relations, components are extended to synthesize models with Linear Parameter Varying (LPV).

(Borrello.M.A, 2001) for the regulation of emergency ventilation, the issue of finding the required pressure path within a patient connecting circuit is solved using indirect adaptive control. The indirect method achieves effective result over a vast variety of conditions for the patient and since air are parameters of physical estimates.The approximate values can be used for diagnostics and further ventilation control measures. (Anitha et al, 2019) experimental outcomes of lungs show significant improvement in mechanical tests in adaptive controller uniform tracking (Nagarajapandian et al, 2019). Currently used conventional PID control method used everywhere in the ventilator industry. (Ioannascu, 2018)

(Akhilesh Swarup et al., 2020) this work describes a new adaptive ventilator control method, which maintain the conventional PID method that can rapidly and completely track the control signals. (Anitha et al, 2018) Anitha.Tetal (2021) PID Control approach allows the breathing machine output pressure to track the theoretical pressure curve.(Germain et al, 2013) The adaptive control approach can automatically adjust the output of the ventilator pressure and time of ventilation according to the amount of change in tidal volume. Due to the lungs low concession and insufficient toughness, accurate tracking is not possible.(He.w.,Huang et al, 2017) The vibration of the flow curve is due to the large flow variation and insufficient sensor accuracy, but it does not affect the experimental results.(Talarsadalla et al, 2017)

(Berndt.A et al., 2015) Positive pressure control is a approach of artificial ventilation. Persons are normally unable to breathe due to respiratory failure, persons are assisted by external ventilation. During the expiration phase, the ventilator produces a positive end expiration pressure (PEEP) and during the inspiration phase, an inspiration positive airway pressure (IPAP). Inspiration and expiration phase determination takes place time-controlled or the patient's respiratory efforts and depends on various modes of ventilation. The major content of this article is the design for mechanically ventilated patients of an iterative learning control.(Chen.P.liu, et al, 2017) Iterative learning control provides a mechanism for decreasing the control error from span to span for cyclically recurring processes.

(Akhilesh Swarup et al., 2020) a mechanical breathing machine that generates the required amount of air and supplementary oxygen required acute respiratory insufficiency for the patient (A.F. de Castro et al., 2019). One of the techniques built on memory, Iterative Learning Control (ILC), can be used to control the system whose tasks are repeated in nature (Mohan et al, 2021)

(Kevin L et al., 2012) ILC is an efficient way to improve the system's transient response performance, which operates regularly over a specified time limit. By improving the inputs based on the calculated errors and updating their efficiency or trajectory, the ILC approach is used to increase the performance of output monitoring. Each path update is generally known as a test or iteration. (Ahn.H.S et al., 2007) and (Alleyne.A.G et al., 2006) (David H. Owens , 2015)author proposed to use a Proportional type ILC layout using state feedback, have certain advantages and ensuring of convergence and stability for linear systems.

(ArunMozhiDevan..P et al., 2020) describes the fractional PI and Predictive PI controller for deadtime process. The process is explained with the setpoint tracking, disturbance tracking and risetime. In this process noise filtering methods are used in a closed loop system. (Devan, P. et al., 2021)(Devan, P. et al., 2022)in this paper the wireless sensors for industrial monitoring was discussed.(Anitha.T. et al., 2021) In this pressure sensors with time-delay and use of PI, Predictive PI controller is used.

(Akhilesh Swarup et al., 2020) Comparing all of this paper's results (A.F. de Castro, 2019) in both instances of this paper, the control effort is minimum, resulting in less risk of actuator saturation. In this paper, the number of iterations shows that the desired response is quickly achieved. The RMS error obtained in the 10-4 range in this paper shows that accuracy is much higher than required in the case of a clinical instrument. The proposed work describes the model equivalent circuit of mechanical ventilator which maintains the pressure and volume of the ventilator according to the transformation in patient breath. In this paper PID controller and Iterative Learning Control is used to regulate the pressure and volume appropriately. The simulation of the patient breath is done at varied parameters.

2. Description Model

Figure 3. Illustrates the ventilated model of the breathing machine. In this circuit RC shows the patience airway resistance, Cc is the primary compliance, P1 is the source of compressor pressure and PEEP is the pressure of water based column, R1 is an atmospheric resistance, C2 is a load pressure reservoir, RptcINSP and RptcEXP are the respiration taking responsibility for airflow measurement during inspiration and expiration, respectively.

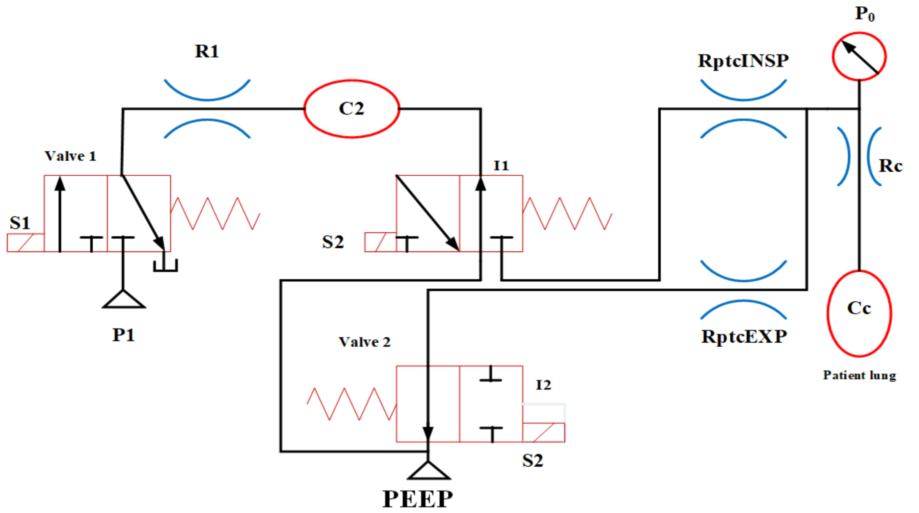

Fig.3. Ventilated model of breathing machine

S0 and S1 are toggle solenoid valves, Po will be the pressure transducer. S0 is three way two position valve constrained for regulation of air flow or pressure during inspiration. S1 adjusts between the termination and starting points of the respiration period the composition is expressed as a three-way two position valve I1 and a two-way two position valve I2, both restrained by the similar signal. The device shows the regulated pressure and volume controlled breathing approach during initial breath. Air flow rate must obey the relation in the volume-controlled case by equation (1)

$$q_{ref} = \begin{cases} \gamma, & if \gamma t < VT and \quad 0 < t < t_{insp} \\ 0, & otherwise, \end{cases} \qquad (1)$$

Here, γ is the relevant airflow during inspiration .

The equivalent electrical circuit shown can be modelled as in figure 4 airflow is designed as current and pressure as voltage, commonly. The solenoid valves are created as resistors regulated by voltage inhibited resistors. The valves are locked, when the resistances for the valves are Rv1max and Rv2max, and valves are open when resistances are Rv1min and Rv2min.A solenoid valve can be operated using PWM, the average pressure can be interpreted as a repeatedly changing signal with a sufficiently high switching frequency.

The process concede that valve S1(t) as a continuous variables so the Rv1a(t) and Rv1b(t), it will be substituted by Rv1(t)=(1−xv1(t))Rv1max+xv1(t)Rv1min, where xv1(t)ϵ[0;1] is an supporting variable similar to the valve deployment S0 by a pure time lag, such that xv1(t)=S1(t-0.45 Tresp), where an standard delay of 45% of the valve response time Tresp was assumed.

3. Problem Description

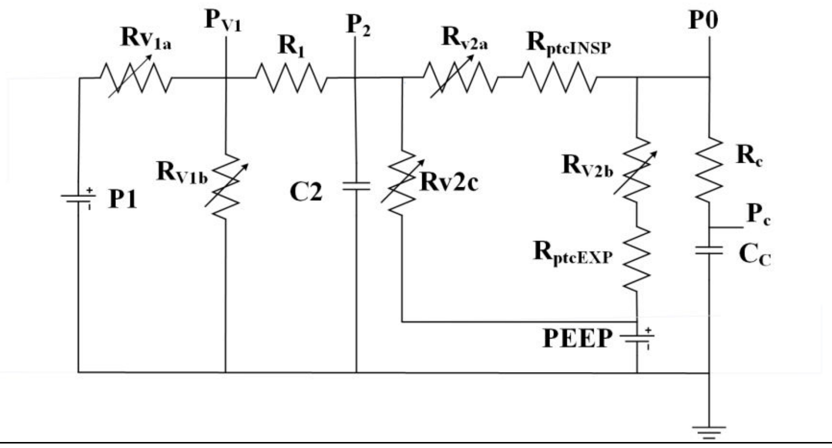

Fig.4. Identical circuit of breathing machine

The system should be consciously monitor only during inspiration, the circuit can be considered by simplified model.

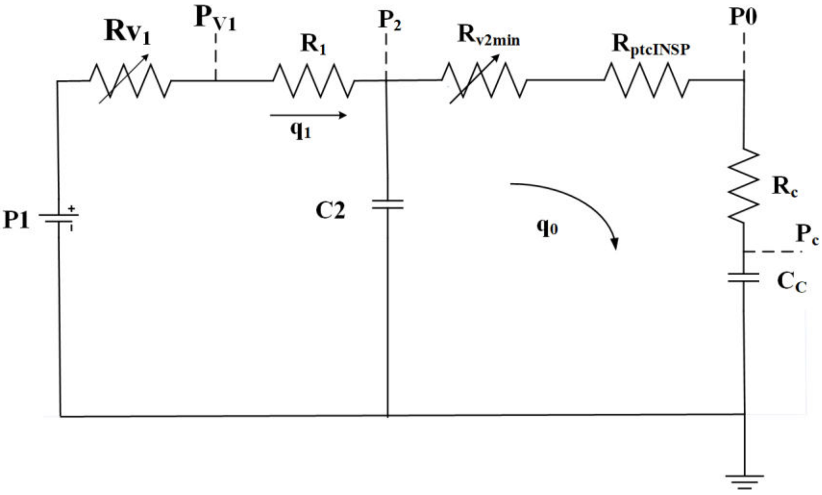

Fig.5. Inspiration circuit of breathing machine

Valve S2 is open to creativity and thus to pathways like Rv2b and Rv2c should be considered to be open models for functional goal. Figure.5 shows the inspiration circuit of breathing machine

4. State Space Model

From figure.3 the structure changes in the breathing machine is described by equation (3)

$$\dot{x}_1 = \frac{P_1 - x_1}{C_2(u+R_1)} + \frac{x_2 - x_1}{C_2(R_{v2_{min}} + R_{ptc_{insp}} + R_C)} \tag{2}$$

$$\dot{x}_2 = \frac{x_1 - x_2}{C_2(R_{v2_{min}} + R_{ptc_{insp}} + R_C)} \tag{3}$$

With P2 as x1, Pc as x2 and Rv1 as u. The previous dynamics can be linearized by feedback by considering a virtual control input v equal to the current flowing through R1

$$\mathrm{v(t)} = \mathrm{q1(t)} = \frac{P_1 - x_1(t)}{u(t)+R_1} \rightarrow u(t) = \frac{P_1 - x_1(t)}{v(t)} - R_1 \tag{4}$$

By doing this, singularity when v=0, interrelated to an unbounded pneumatic resistance. To overcome this trouble by describing actual control input is the conductance

$$\mathrm{g_{v1_t}} = \frac{1}{\mathrm{u(t)+R1}} \epsilon \left[\frac{1}{\mathrm{Rv1_{max}+R_1}}, \frac{1}{\mathrm{Rv1_{min}+R_1}}\right] \tag{5}$$

By this step, the feedback linearized dynamics be reformed as,

$$\begin{bmatrix} \dot{x_1} \\ \dot{x_2} \end{bmatrix} = \frac{1}{R_{2c}} \begin{bmatrix} -1/C_2 & 1/C_2 \\ 1/C_c & -1/C_c \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1/C_2 \\ 0 \end{bmatrix} v \tag{6}$$

$$\begin{bmatrix} q_0 \\ p_0 \end{bmatrix} = \frac{1}{R_{2c}} \begin{bmatrix} 1 & -1 \\ R_c & R_{v2_{min}} + R_{ptINSP+} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} \tag{7}$$

With $R_{2c} = R_{v2_{min}} + R_{ptc_{insp}} + R_c$.

The analogous transfer function for the air flow is

$$G_1(s) = \frac{Q_0(s)}{V(s)} = \frac{C_c}{C_c C_2 R_{2c} s + C_c + C_2} e^{-0.45 T_{resp} s} \tag{8}$$

5. Controller Design

5.1 PI Controller

The proportional plus integral controller generates an output that is the sum of the proportional and integral controllers outputs.

$$\mathrm{u(t) = K_P\, e(t) + K_I \int e(t) dt} \tag{9}$$

When employing laplace transform on both sides,

$$\mathrm{U(s) = (K_p + \frac{K_i}{S})\, E(s)} \tag{10}$$

$$\mathrm{\frac{U(s)}{E(s)} = K_p + \frac{K_i}{S}} \tag{11}$$

As a result, the proportional integral controller's transfer function is

$$\mathrm{K_p + \frac{K_i}{S}} \tag{12}$$

A pole at the origin is an integrator and a finite zero are thus added to the feedback loop by the PI controller. Because the integrator in the loop forces the error to a constant input to go to zero in steady-state, the PI controller is widely utilised in servomechanism design. In the complex s-plane, the controller zero is usually close to the origin. A closed-loop system pole with a large time constant is added when a pole–zero pair is present. The zero location can be changed to keep the slow mode's impact to the overall system responsiveness to a minimum.

5.1.1 Predictive PI Controller (PPI)

Predictive PI control is widely recognised by the existence of a downtime in the control loop restricts the enforcement that can be achieved and, by computing phase lag, adds to the destabilisation of the control system, requiring the controller's gain to be reduced. As a result, control performance for processes with substantial inherent inertias and long time delays can be quite low. In this section, PI controller with a predictive function shown in Figure.6 that's good for deadtime compensation but lacks some of the properties of the Smith control.

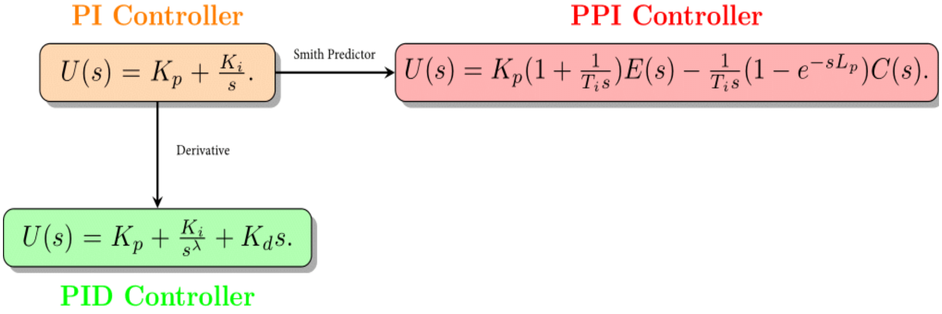

Fig.6. PPI controller Block

$$u(t) = Kp[e(t) + Ki \int_0^t e(t)\,dt - K_{pred} \int_{t-L}^{t} u(t)dt \quad (13)$$

In this e(t) is a error with respect to the time. L is the process deadtime estimate, K_{pred} is predictive gain and these are the parameters of the predictive controller. From control error e to control signal u, the PPI controller (13) can be expressed as a transfer function

$$u(s) = \left(K_p + \frac{K_i}{s}\right)e(s) - \frac{K_{pred}}{s}\left(1 - e^{-Ls}\right)u(s) \quad (14)$$

$$u(s) = \frac{s}{s + K_{pred(1-e^{-Ls})}}\left(K_p + \frac{K_i}{s}\right)e(s) = K_{ppi}(s)e(s) \quad (15)$$

The PPI transfer function can be

$$K_{ppi}(s) = \left(K_p + \frac{K_i}{s}\right) = f(s, K_{pred}, L)\, K_{pi}(s) \quad (16)$$

5.1.2 PID Controller

A standard layout of a system of PID control is shown in figure 4 PID controller have the error signal $e(t)$ benefit to achieve the proportional, integral, and derivative actions, the appearing signals are combined together to form u(t) signal related to plant system. It is Process independent. A steady-state error for a phase comparison is zero. It can be used to better monitor the response characteristics than other controller types. For most cases, it leads to a reasonable solution when tuned. Without a large amount of experience needed, it can be tuned

$$u(t) = Kp[e(t) + \frac{1}{Ti}\int e(t)dt + Td\frac{de(t)}{dt}] \quad (17)$$

$Kpe(t)$- In a control loop, usually the main drive, Kp eliminates a significant portion of the overall error. $\int e(t)dt$ —A drive signal large enough to shift the device towards a smaller error is created by summing up even a small error over time.$Td\frac{de(t)}{dt}$, it helps to minimize overshooting and ringing.

5.2 Iterative Learning Control

Iterative learning control (ILC) is based on the premise that the output of a machine that observes the repeated test several chances can be enhanced by observing from before trial. The goal of the ILC is to enhance efficiency by integrating error monitor knowledge for future iterations. ILC varies from alternative control techniques like adaptive control, neural networks, and repetitive control. In this ILC, L and Q filter was designed from the cut-off frequency of the plant transfer function by using bode plot frequency response analysis. Figure 7 shows the structure of ILC with ventilator system.

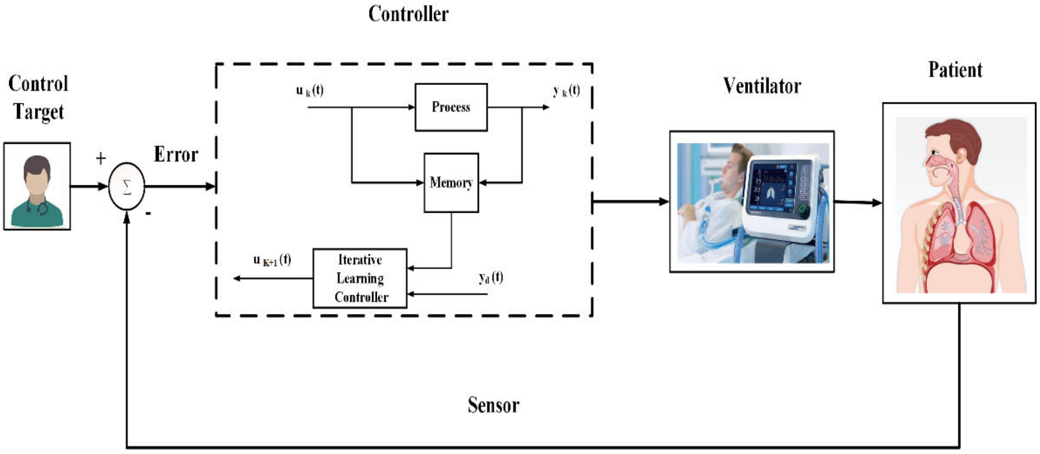

Fig.7 Iterative Learning Control Design for Improved Breathing Machine

Let us assume a scalar linear system with input. U(s) and output Y(s) is expressed by

$$U(S) = F_f(S)Y_D(S)$$
(18)

Where $G(S)$ denotes the transfer function of the system and $V(S)$ is load disturbance. The goal is to pick the $U(S)$ input signal so that the output signal matches as closely as possible the desired $YD(S)$ output signal

$$U(S) = F_f(S)Y_D(S)$$
(19)

$F_f(S)$ is a transfer function

$$E(S) = Y_D(S) - Y(S)$$
(20)

Equation (20) implies the error is described by

$$E(S) = \big(1 - G(S)F_f(S)\big)Y_D(S) - V(S)$$
(21)

Open loop control is bonded with feedback to have

$$U(S) = F(S)\big(Y_D(S) - Y(S)\big) + F_f(S)Y_D(S)$$
(22)

$F(S)$ is the transfer function of the feedback regulator. Equation (22) denotes the error signal described effects by

$$E(S) = S(s)\big(1 - G(s)F_f(S)\big)Y_D(S) - S(s)V(S)$$
(23)

Where,

$$S(s) = \frac{1}{1+F(S)G(S)}$$
(24)

It is the sensitivity function. The control signal can be used along with the feedback reg0ulator error signal

$$E(S) = F(S)(Y_D(S) - Y(S))$$
(25)

The error signal of the PD regulator is a combination of position and velocity error, properly scaled into a torque.

$$E(S) = G_c(s)G^{-1}(S) - F_f(S)Y_D(S) - F(S)S(s)V(s)$$
(26)

Where,

$$G_c(s) = \frac{F(s)G(s)}{1+F(s)G(s)}$$
(27)

5.3 ILC Design Guidelines

(Bristow et al., 2006) (5), the process coincides to rigid upon u* the condition if ρ (Q (I-LG)) <1.

If the above one is fulfilled, then the asymmetric error is

$$e_\infty = \{I - G[I - Q(I - LG)]^{-1}QL\}\big(y_{ref}\big)$$
(28)

Let $\bar{\sigma}(.)$ be the higher singular value and let $\|.\|_2$denote the Eucliden norm.

(Bristow et al., 2006). If the system with algorithm satisfies $\gamma 1 := \bar{\sigma}(GQ(I - LG)G^{-1}) < 1$, then
(29)

$$\|e_\infty - e_{j+1}\|_2 < \gamma_1 \|e_\infty - e_j\|_2 \forall j = 1,2, \dots ..$$
(30)

The computing of γ_1 is unconditioned, if G,Q and L are toeplitz and lower triangular, the error convergence rate can be described as

$$\gamma_2 = \|Q(z)[1 - zL(z)G(z)\|_\infty \forall j = 1, 2, \dots .$$
(31)

In a given system T(z), $\|T(z)\|_\infty$ is defined as sup$sup_{\theta\epsilon[-\Pi,\Pi]}\big|T(e^{i\theta})\big|$.

The principle of the system is the portability of the operation of a given target system and the ability to enhance the check input on the basis of prior physical operational data.

A controller which has the tracking of zero errors when command repetitions or learns to remove the issues of repetitive disruption on a control system.

In order to sequentially increase accuracy, ILC considers systems that perform the same task repetitively.

ILC is intended to use system recurrence as experience to enhance the efficiency of system control even under inadequate system control information.

ILC controller helps to implement recursive action in developing greater certainty and the error is also reduced to increment the output efficiency.

6. Results And Discussion

The simulations for this improved breathing machine were executed in MATLAB. Initially the experiment were done for under -respiring lungs with respect to the parameters pressure, flow and volume. The Proportional Integral(PI),Predictive Proportional Integral (PPI), Proportional Integral Derivative (PID) and Iterative Learning Control (ILC) controller were designed for the system for its enhanced output. Figure 8 shows the response of the under-respire lungs with the input pressure 15 psi or 15 cm of H2O.This under respiring pressure is difficult for the human to breath.

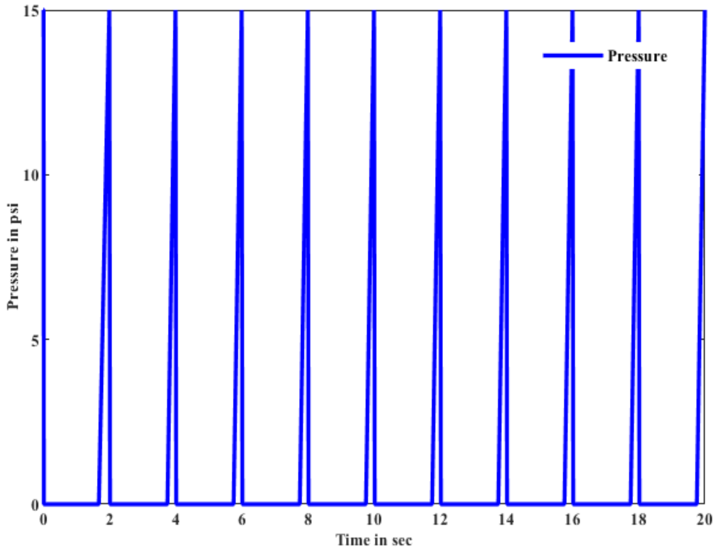

Fig.8. Response of pressure for under expire lung

The obtained tidal volume shown in Figure.9 is smaller than expected. Figure.10 shows the flow pattern changing for artificial ventilation. Figure.11 shows the united response of under expire lung with a amplitude of 15 cm of H2O.

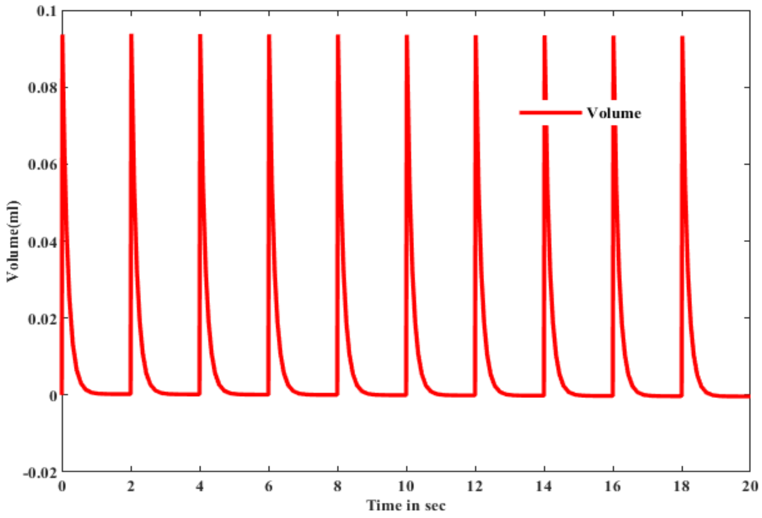

Fig.9. Response of volume for under expire lung

The machine shows that the muscle of the lungs is unable to generate adequate negative pressure, the flow into the lungs. Flow retrieved at this pressure is also low for the human to breath. The flow can be increased by using appropriate controller.

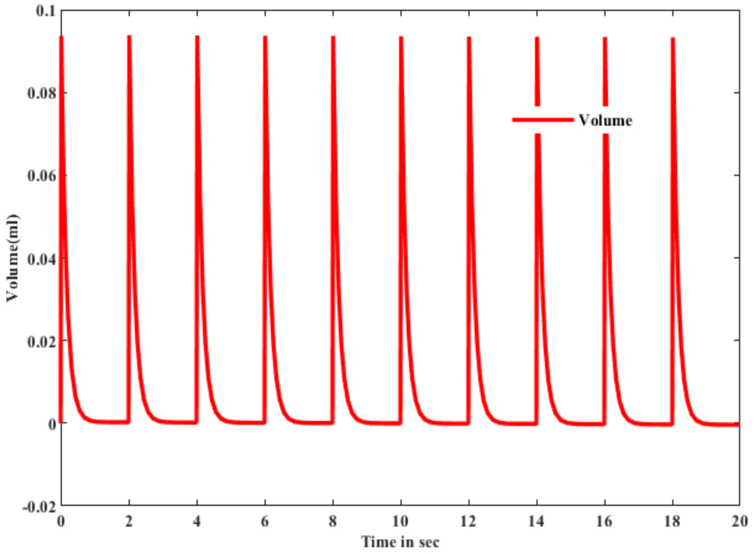

Fig.10. Response of flow for under expire lung

The corresponding volume and flow of the lungs are shown. When a sick person is suffer to breath to the necessary tidal volume, an external ventilation aid is needed.

In a normal case, inside the lungs, these lung muscles produce a minimum pressure that forces the air into the lungs. The ventilation would sustain will establish positive pressure away to force air into the lungs. With the use of PI controller Figure 12 shows the pressure increase of 21 cm H2O for the input lung pressure 15 cm H2O.

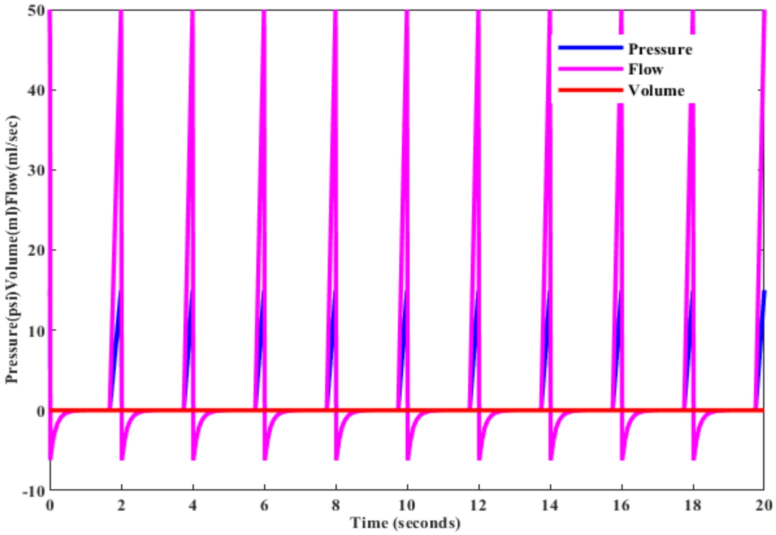

Fig.11. United response of under expire lung with a pressure of 15psi.

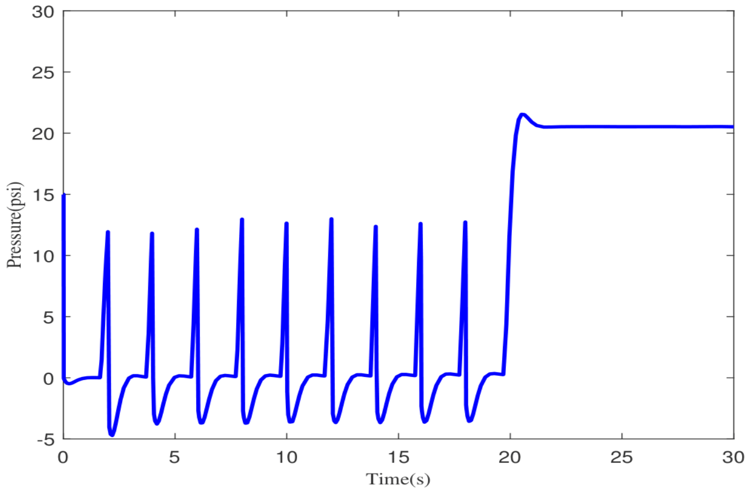

Fig.12. Response of PI controller for pressure

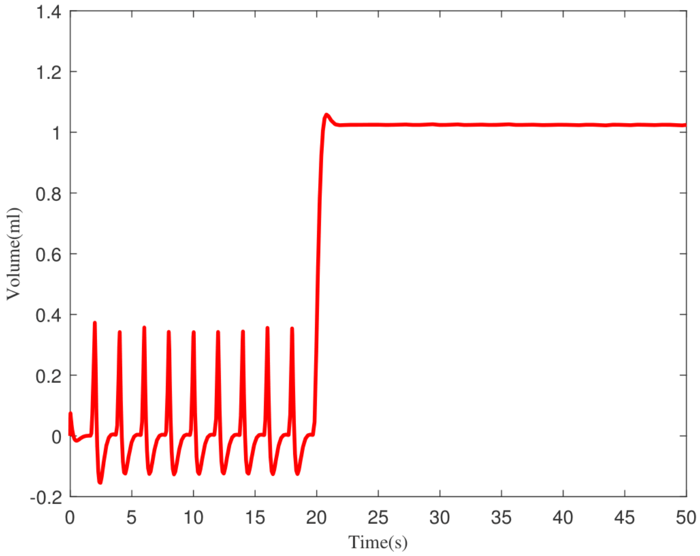

Fig.13. Response of PI controller for volume

Figure.13 volume also increased 0.4 ml to1 ml. Figure.14 shows the good ventilation flow to 4ml/sec.Figure.15 indicates the united response of pressure, flow and volume using PI controller. In this pressure, volume and flow gets elevated.

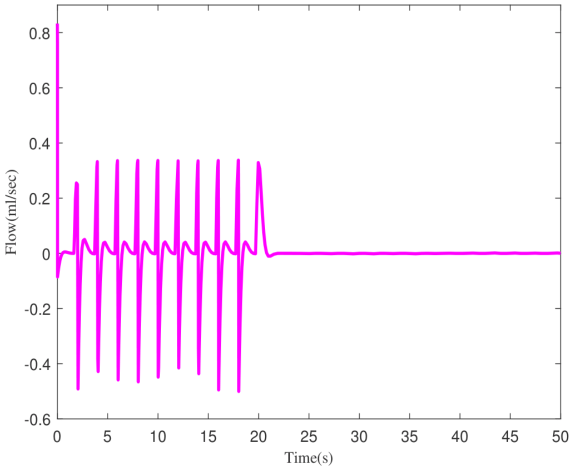

Fig.14. Response of PI controller for flow

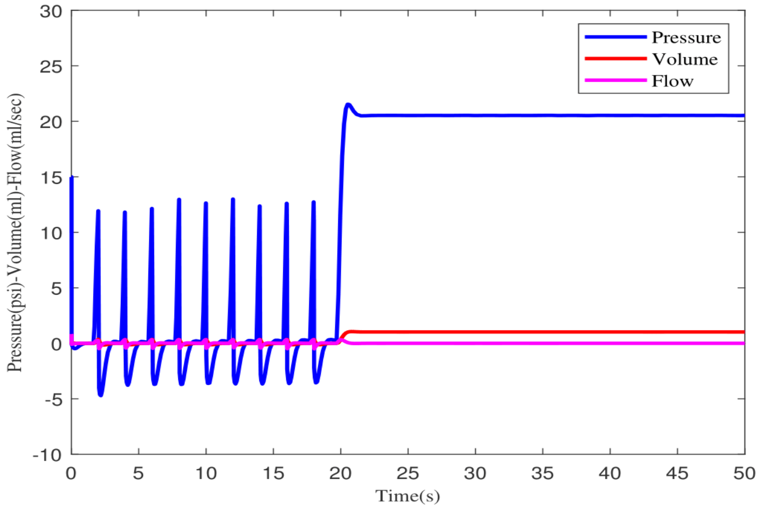

Fig.15. United response of pressure, flow and volume using PI controller

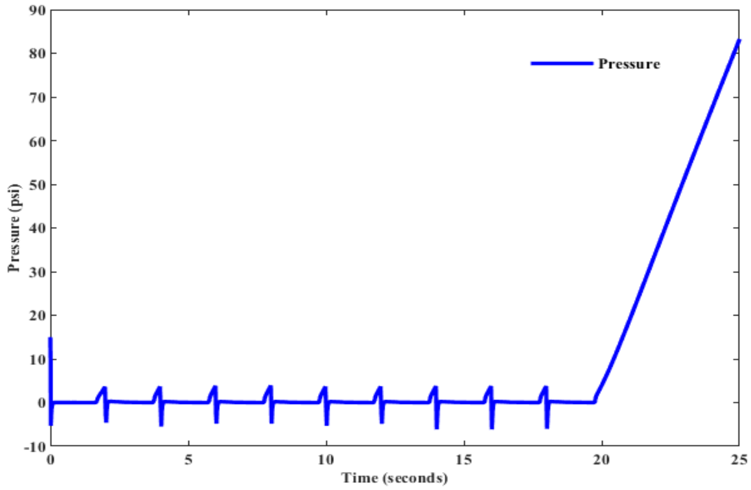

Fig.16. Response of PPI controller for Pressure

Figure.16 indicates the pressure increasing 20 cm of H2O in the alveoli. Figure.17. shows the lung volume remains the same to 0.4ml/sec.Figure.18 shows the lung exchange volume increased to 1.1 ml.

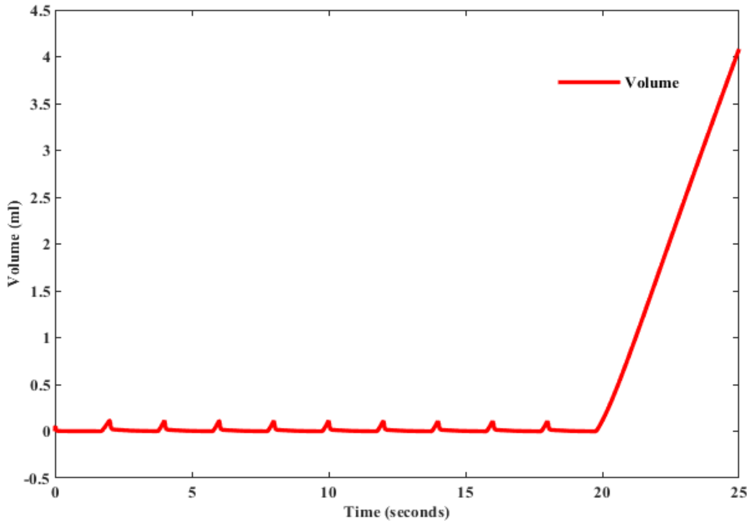

Fig.17. Response of PPI controller for volume

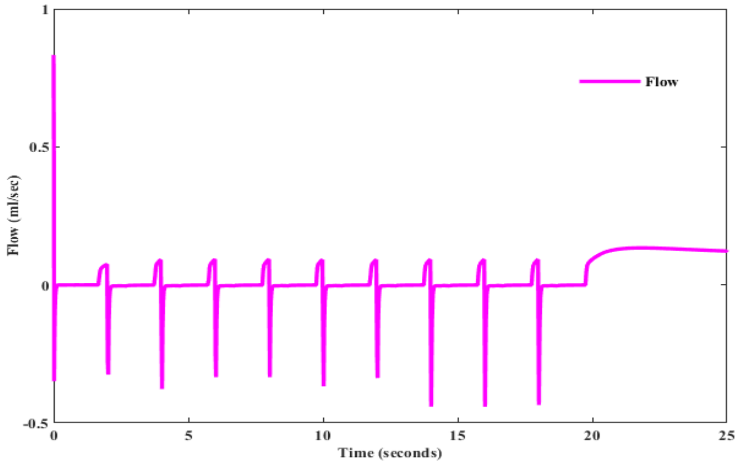

Fig.18. Response of PPI controller for flow

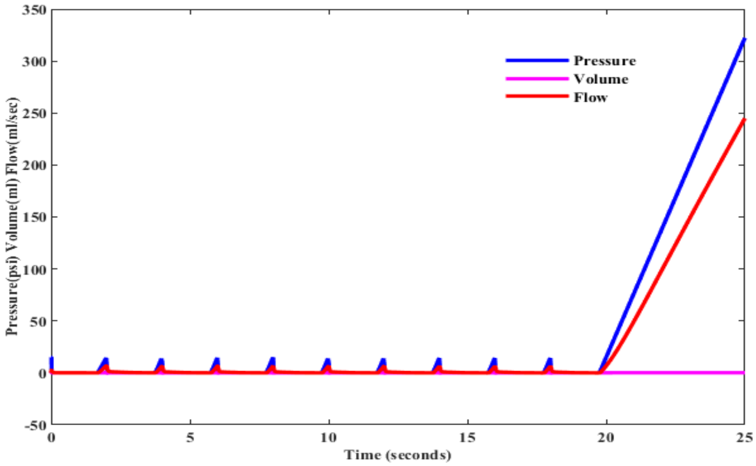

Fig.19. United response of pressure, flow and volume using PPI controller

Figure.19 United response of pressure, flow and volume using PPI controller. Figure 20 shows the proposed a breathing support system into the lungs. The breathing support systemprovides a tidal volume reference from the ti dal volume data recommended or required for normal lungs. By involving a ventilator system under the respiratory lungs along with a PID controller. This PID controller can be used to enhance the pressure to 23 cm H2O.

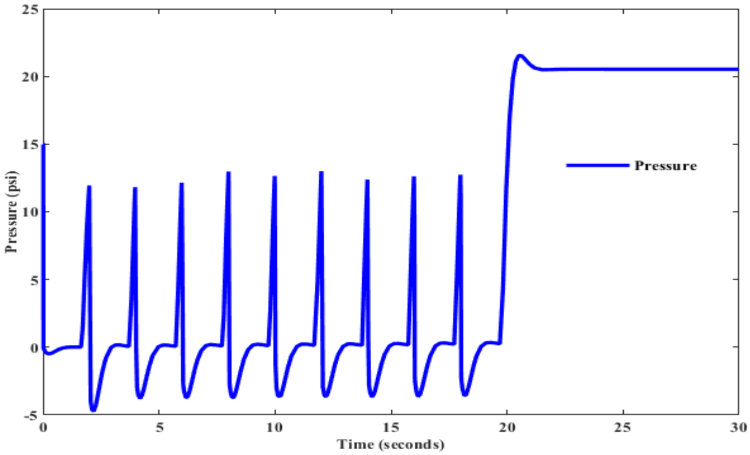

Fig.20. Response of PID controller for pressure

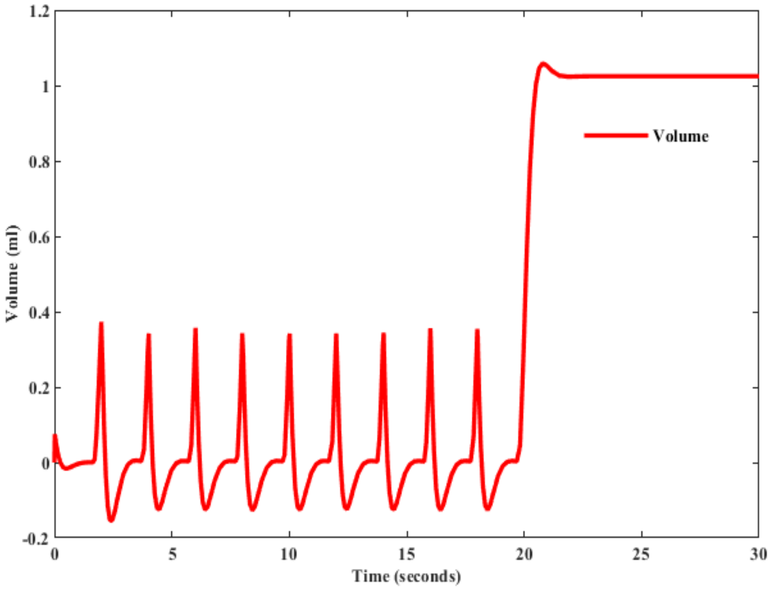

Fig.21. Response of PID controller for volume

Figure 21 shows the breathing support system along with PID controller. The obtained tidal volume is increased to 1.1 ml with the use of PID controller.

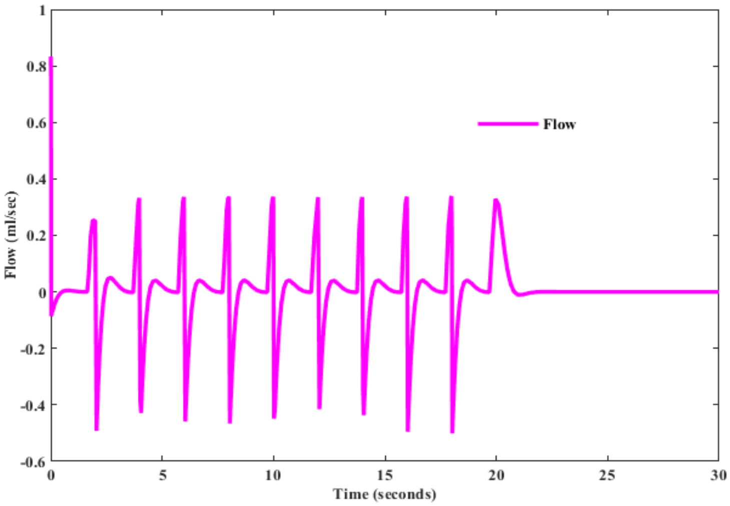

Fig.22. Response of PID controller for flow

Figure 22 shows the response of flow with the PID controller. The response shows that the muscle of the lungs is unable to generate adequate negative pressure, the flow into the lungs. The flow is decreased with the apply of PID. By considering that with the shift in the constants, the results changed.

Figure 23 shows the response of the pressure, volume and flow of the breathing support system with the usage of PID Controller.

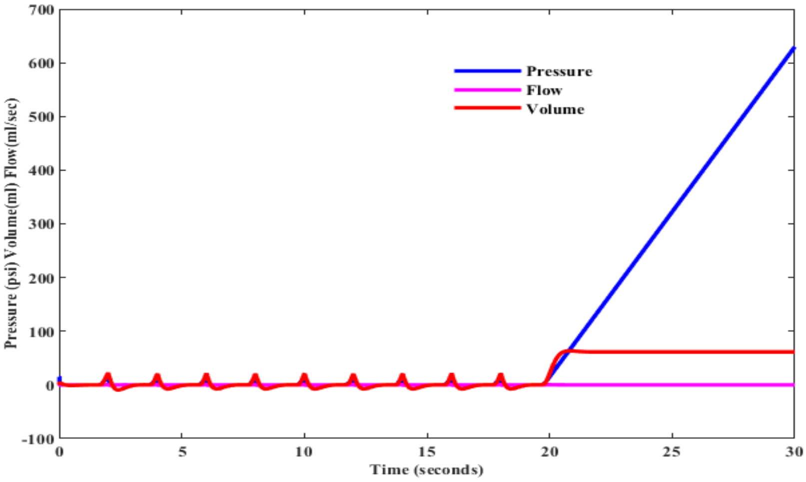

Fig.23. United response of pressure, flow and volume using PID controller

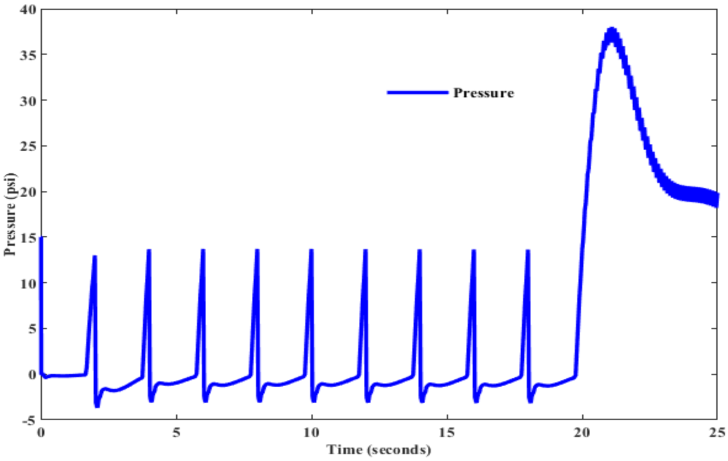

Fig.24. Response of ILC controller for pressure

Table 1 Performance index for various controllers

Under expired lung parameters	PI	PPI	PID	ILC
Pressure =15 cm H2O	20	22	23	40
Volume =0.09 ml	1	1.1	1.1	2
Flow=50 ml/s	0.2	0.4	0.4	0.4

Figure 24 shows the response obtained using ILC controller. This ILC benefits to achieve the high pressure. The pressure is elevated to 38 cm of H2O or psi. ILC supports the breathing machine to gain the required pressure to breath of the human.

Figure 25 shows the volume obtained using the ILC controller. ILC supports breathing system to produce the volume increased in the level. In this the tidal volume gets increased to 2 ml.

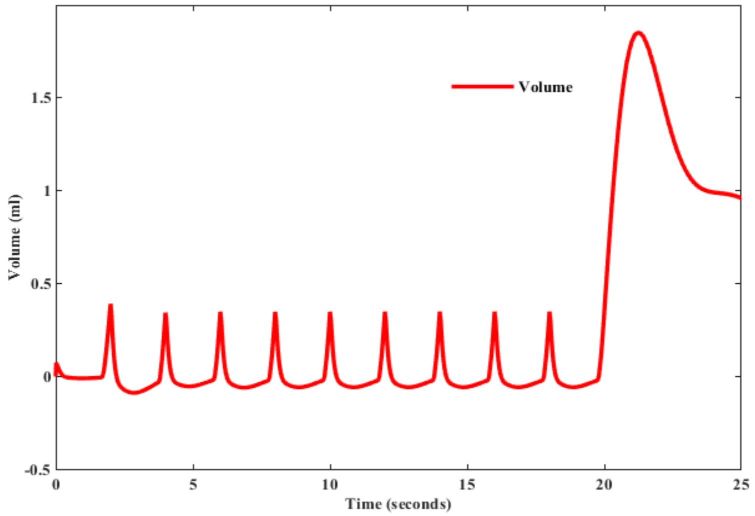

Fig.25. Response of ILC controller for volume

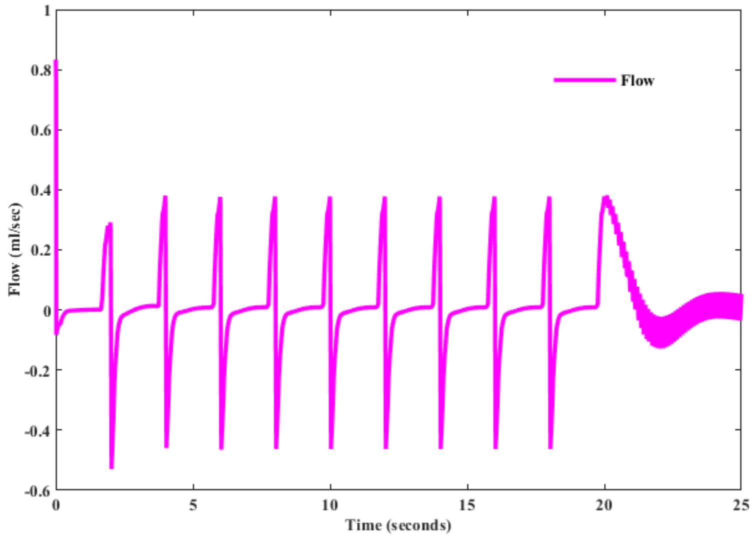

Fig.26. Response of ILC controller for flow

Figure 26 shows the response of ILC controller for flow. The controller does not take much effort in increase of flow. The values of ILC controller can be further tuned to get improved response. Table.1 gives the performance indices of several of various controllers with respect to flow, pressure and flow parameters accordingly.

7. Conclusion

The results were obtained for the breathing machine or ventilator. In this proposed work the results were compared with the PI,PPI,PID,ILCcontroller. At first the results were taken with PI controller. The lung pressure value obtained is 21 cm H2O the comparably flow and volume increase. There is only few change in parameter values. Then predictive PI controller is intended to be used for breathing machine. With the use of PID controller it is viewed that the pressure for the under expire lung gets increased from 15cm of H2O to 23 cm of H2O. Correspondingly, the volume also incremented to 2ml/.When working with controllers like PI,PPI,PID controller there is only less variation in the pressure ,volume and flow. The primary concept of ILC is to recursively find an input sequence such that the device output is as close to the desired output as possible. ILC controller provides improved response with respect to pressure and volume for the breathing machine while analysing with the PI,PPI,PID. Further developments in the ILC trials and more advanced controllers for the breathing machine will give better results in future.

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Appendix A: Simulation Parameters

Software used	Type of Controller used			
MATLAB 2017a	Proportional Integral Control (PI)	Predictive Proportional Integral Control (PPI)	Proportional Integral Derivative (PID)	Iterative Learning Control (ILC)
Input Parameters				
Constraints	Assessment	Constraints	Assessment	
C2 (pressure reservoir)	0.465ml/cm H2O	Rv2min (valve command)	1.062*10-4 cmH2O/ml/s	
Cc (pulmonary compliance)	0.075ml/cm H2O.	Rc (patient airways resistance)	0.377cmH2O/ml/s	
Tresp (Breathing Cycle of time Period)	2*10-3s	RptcINSP (Device for breathing rate recording during the inspiration cycle)	0.7Rc	