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Mechanical ventilator Simulation on LabVIEW to Control the Pressure andVolume of Lung Function

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ABSTRACT

Mechanical Ventilation is a device that is used in irregularities in the respiratory system. It is the supply of oxygenated air to the patient's lungs through an endotracheal tube. It can be done by stimulating the recovery breathing process which could result from diseases and viruses such as pneumonia and COVID-19. It is used in the intensive care unit(ICU). The respiratory system is supported by mechanical ventilation using different modes, such as positive end expiratory pressure (PEEP), volume-controlled ventilation (VCV). The model is implemented using LabVIEW tools and can be used to monitor the breathing per minute, TLC, Vt, pressure-volume control, and also in respiration and flow without any negative effect. LabVIEW is a graphical programming language that helps us in providing a platform to simulate a ventilation process. The main aim is to simulate the mechanical ventilation process by using this software. LabVIEW provides virtual instruments like a PID controller, switches, mathematical components, counters, Timer, etc. The result we get through this process

as PEEP(mm H_2O)-10500, PAW(mm H_2O)-Pmax (mm H_2O)-10350 the range of the pressure and range of volume controls (l/min)-30, flow(l/min)-40, BPM-3, lung rest volume(2-4). The obtained result by the proposed method is precise, acceptable, and good to use.

Keywords: (respiratory,COVID-19, Pressure-volume control, LabVIEW, PID controller**)**

I. INTRODUCTION

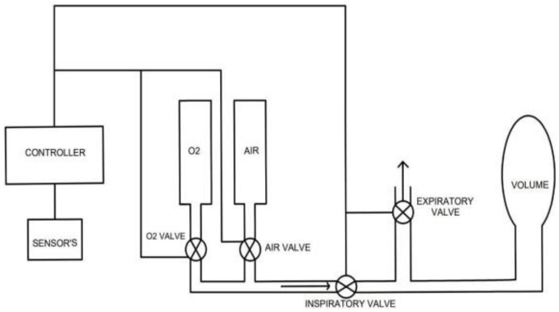
A mechanical ventilator is a device that is used to reduce the work of breathing, improve oxygenation, or correct excessive respiratory acid condition of the body. It is frequently delivered to patients admittedto intensive care units (ICU).

In most cases, the ventilator is set to completely control the patient's ventilation shortly after intubation. The objective is to improve the ability to inhale without causing any damage to the lungs and to put the respiratory muscles at rest. When a patient's condition starts to improve, his/her ventilation is favored by the ventilator until destination. There is no clear consensus about when, how, and at which level the patient's work of breathing should be reduced. Insufficient assistance may induce diaphragmatic fatigue or weakness and force the recruitment of accessory inspiratory muscles, sometimes leading to respiratory acidosis. Excess in assistance may induce respiratory alkalosisand reduce respiratory drive, facilitating the appearance of patient-ventilator asynchronies and sleep disruptions. Mechanically ventilated patients should be evaluated daily for the appropriateness of a spontaneous breathing trial, and the success or failure of the trial should be judged based both on subjective criteria and objective measurements like the rapid shallow breathing index.

II. LITERATURE SURVEY

Basic functionality of mechanical ventilator can be illustrated by the use of oxygenation and air valve Where the lung is connected with their storage and the patient gets air through an inspiratory valve, we can maintain the pressure and volume through the controller and sensor as per the requirement of the lungs. Here is the basic block diagram of workingfig(a):

In the given figure we can see that the inspiratory and expiratory valves are connected to the controller and sensor through which we can control the PCV, VCV, PEEP, Pmax, PAW, BPM, and lung rest volume. The given terminology have their usual meaning which has been described below:



fig(a): Basic functioning of the mechanical ventilation system

III. BASIC TERMINOLOGY OF CONTROL MODES

Some functions have been used for controlling the function of ventilation

PEEP (positive end-expiratory pressure):
It stands for positive end-expiratory pressure which in layman's terms is the pressure at which the lungs must be after completing explorations, This is a crucial parameter as the all behind might collapse if the beep is too low causing inflammation and other complications. The basic function of PEEP is to increase the pressure.

Pmax (Maximum pressure):
It is simply the maximum pressure of the lungs of their inspiration. It can be triggered by the system as per the requirements of breaths.

TLC (Total lung capacity):
It is the total capacity of the lungs (airway) which takes the maximum volume of gas, it may be calculated as:

TLC = Vital capacity + Respiratory volume

VT(Tidal volume):

It stands for tidal volume of the lungs which is the difference of the volume between the breath.

VC (Volume control):
It is the specific mode in which our simulation will be run is intermittent mandatory ventilation (IMV).

BPM(Breath per minute):
It is quite self-explanatory which means the amount of air breathed per minute.

PAW (Airway pressure):
It is a pressure that is applied in positive pressure and can be calculated as the average pressure of the lung during inspiration and expiration.

IV. CONTROL METHODOLOGY:

Breath per minute → Expiratory valve opening

S. NO.	METHODOLOGY	COMPONENTS
1.	Obtain current lung state	Specific double property
2.	Time between breaths	On delay timer
3.	Manual activation of a breath	Toggle switch
4.	Rate limiter on the expiratory breath	Rate limiter
5.	Connecting device	Digital constant and NOT gate

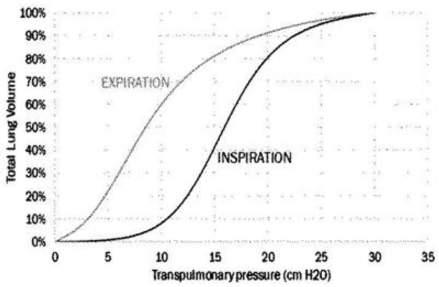
Volume control →Expiratory valve opening

S.NO.	METHODOLOGY	COMPONENTS
1.	Obtain current flow	Specific double property
2	Set required flow	Analog constant
3.	Control flow	PID controller
4.	Check if lungs are breathing	comparator

PEEP → Expiratory valve opening

S.NO.	METHODOLOGY	COMPONENTS
1.	Obtain current lung pressure	Specific double property
2.	Set control for PEEP	PID components
3.	Only activate during the rest state	Toggle switch
		Rate limiter

From the above tabular representation, we can see that different types of control in the ventilation process. In LabVIEW, through this way, we may also calculate the maximum pressure, lung rest volume, tidal volume, etc.



fig(b): lung representation pressure vs volume

V. TABULAR & GRAPHICAL REPRESENTATION

S.NO.	Pressure in(mm H2O)	Time in (sec)
1.	10000	0
2.	10007.88	1.5
3.	10350	5.5
4.	10300	6.2
5.	10200	7.0
6.	10190	11.5
7.	10050	20

Table 1 : PAW (Airway pressure), Where PEEP = 10050 mm H2OPmax= 10350 mm H2O

S.NO.	Flow in(l/min)	Time in (sec)
1.	66.0	0.5
2.	-3.5	1
3.	-16.1	1.5
4.	11.8	1.8
5.	-7.6	2.5

Tabular representation of controls (PEEP, PAW, Pmax, volume control, flow, BPM,Vt, volume, lung rest volume) are given below:

6.	29.3	5.2
7.	-24.2	6
8.	-50.0	10
9.	29.5	15
10.	2.0	20

Table 2: flow where volume control =29 (l/min) BPM= 6

S.NO.	Volume (l)	Time (sec)
1.	4.1	0.2
2.	5.3	2.5
3.	6	5
4.	4.5	6
5.	4.0	10
6.	4.4	12
7.	5.5	13
8.	6.7	15

Table 3:volume, Vt = 2l, lung rest volume = 4l

Note:
(The tabular representation of the airway pressure, Pmax, VCV, Vt, Lungs rest volume, PEEP & BPM that have been obtained by the performance on the platform of LabVIEW. The various results of the given table may be an error of 10% which may be considerable on a software performance basis).

So now we can see the graph of the table which is given below :

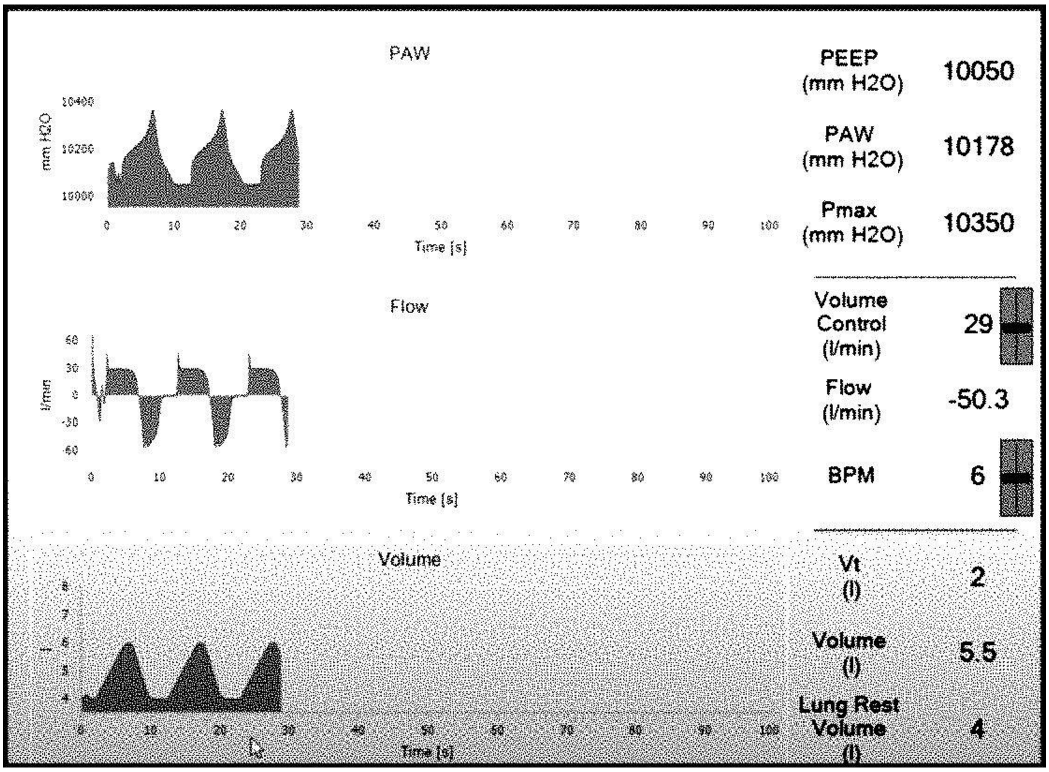
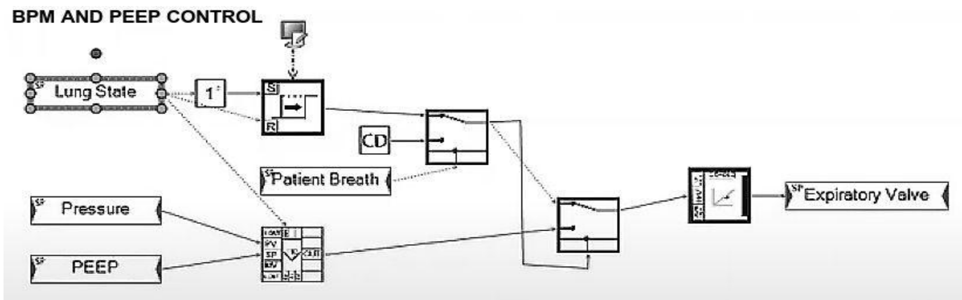
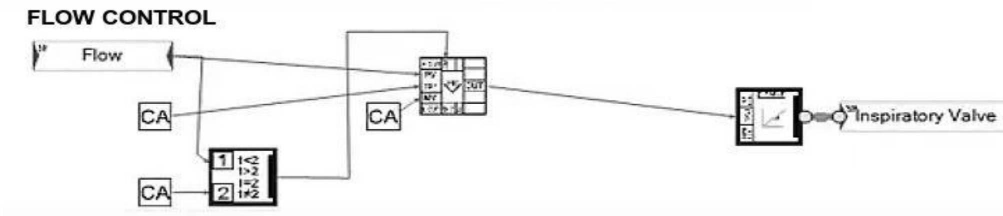


Fig (c) : Graphs of (pressure, Flow, Volume) vs Time respectively

VI. DIAGRAMMATIC REPRESENTATION OF CONTROLS :





VII. CONCLUSION :

Patients on Mechanical ventilators have higher estimated needs. A good understanding of respiratory physiology is required for judicious mechanical ventilation.The equation of motion is the single most useful guide to understanding mechanical ventilation. A registered dietician is needed to make ample tube feeding recommendations for patients. Simulation process is carried out by utilizing the graphical programming language of LabVIEW, the control strategy and signal monitoring can be observed in real-time. The expandable Plug-ins and GUI interface also enable the simulator to further be implemented on a web-base manner for e-learning without the need of installing LabVIEW on the user end. The ultimate goal of this study is to use the simulated process ofthe control model to human respiratory care.

The result we get as PEEP(mm H_2O)-10500, PAW(mm H_2O)-Pmax (mm H_2O)-10350 airway pressure(PAW) is lie between them and the volume controls (l/min)-30, flow(l/min)-40, BPM-3,The lung rest volume(4l)and tidal volume is 2l. The obtained result by the proposed method is precise, acceptable, and good to use and may have an error of 10-20%. In future we will try to use machine learning technology to access the ventilation process.

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