University of Moratuwa
Faculty of Engineering
Department of Electronic and Telecommunication Engineering

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BM2102 - Modelling and Analysis of Physiological Systems

Assignement 1

By: Dulsara G.M.L.

220146A

Submitted in Partial Fulfillment of the Requirements for the Module **BM2102 - Modelling and Analysis of Physiological Systems**

1 Objective

The objective of this simulation is to evaluate and compare the mechanical ventilation responses of:

- Healthy (normal) lungs
- Lungs affected by a restrictive pulmonary disease (e.g., pulmonary fibrosis)
- Lungs affected by an obstructive pulmonary disease (e.g., COPD)

2 Simulation Setup

For the simulations the model given in the assignment is used which is the simulator developed by David Leonardo Rodriguez Sarmiento and Daniela Acevedo Guerrero (2020) available at Simulation of Respiratory Mechanics on Simulink with GUI

2.1 Common Ventilator Settings

Across the simulation experiment the BPM is considered as 15 because the normal adult rate for BPM is 12 - 20 and 15 seems like an ideal value. Also, the 1:E ratio is considered as 1:1 to get a balanced inspiratory and expiratory time. This will ensure comparability for all simulations.

2.2 Disease-Specific Parameters

Here for restrictive Pulmonary disease I've considered Pulmonary fibrosis and for the obstructive pulmonary disease I've considered COPD

Condition	PEEP (cmH_2O)	Peak Pressure (cmH_2O)
Normal	5	10
Restrictive (Pulmonary Fibrosis)	5	20
Obstructive (COPD)	10	12

Restrictive lungs have low compliance, needing higher pressure to deliver the same volume. Peak pressure increased to 20 to reflect this.

PEEP raised to 10 in obstructive lungs to counteract airway collapse during expiration. Peak Pressure slightly increased to overcome airway resistance.

3 Results

3.1 Ventilation Graphs

Normal Lungs

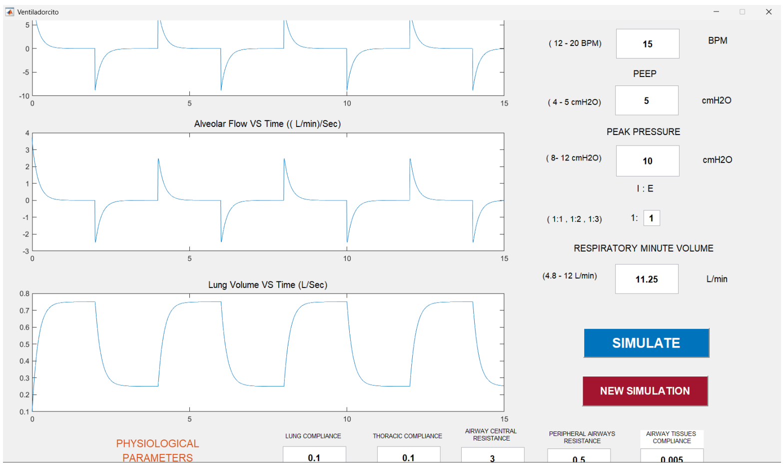

Figure 1: Simulation of normal lungs

In **normal lungs**, ventilation occurs efficiently with standard pressures. A PEEP of 5 cmH_2O is used to prevent alveolar collapse and maintain end-expiratory lung volume.

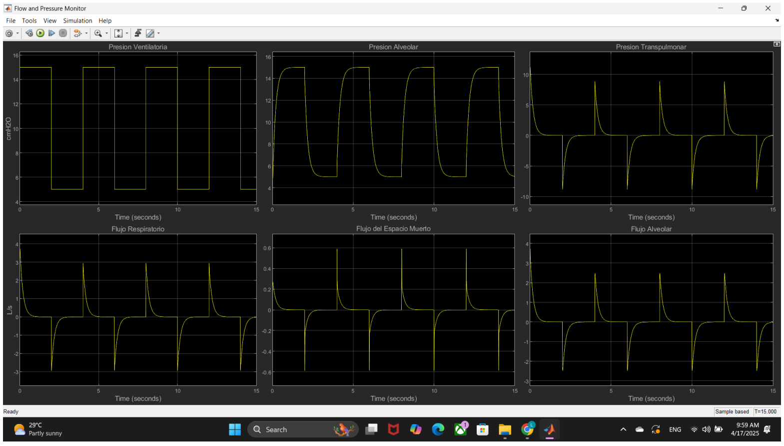

Figure 2: Flow and Pressure Monitor of normal lungs

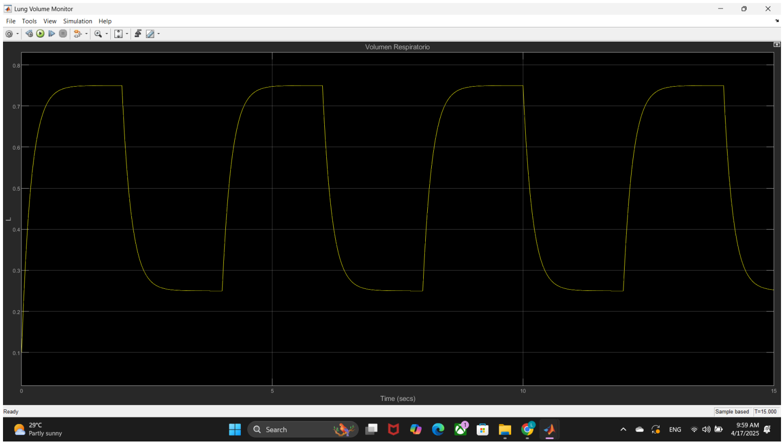

Figure 3: Lung Volume Monitor of normal lungs

Lungs affected by a restrictive pulmonary disease

In **restrictive disease**, such as pulmonary fibrosis, lung compliance is significantly reduced. This necessitates a higher peak pressure (20 cmH_2O) to achieve adequate ventilation, although tidal volume remains lower.

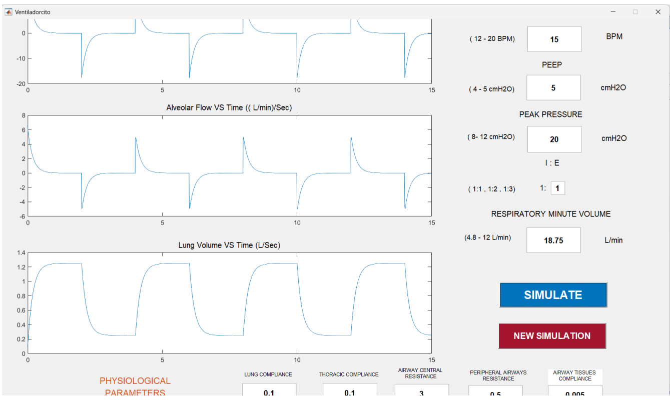

Figure 4: Simulation of lungs affected by a restrictive pulmonary disease

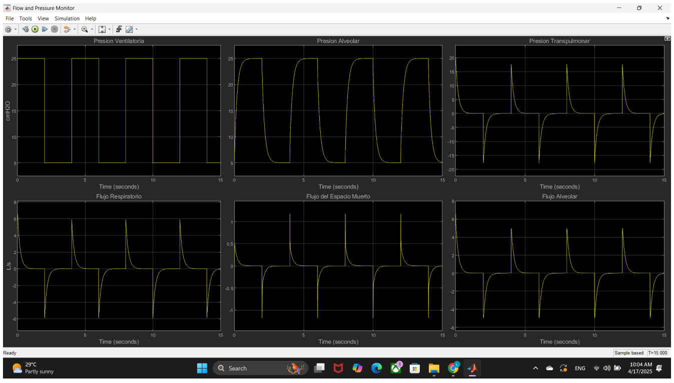

Figure 5: Flow and Pressure Monitor of lungs affected by a restrictive pulmonary disease

Figure 6: Lung Volume Monitor of lungs affected by a restrictive pulmonary disease

Lungs affected by a obstructive pulmonary disease

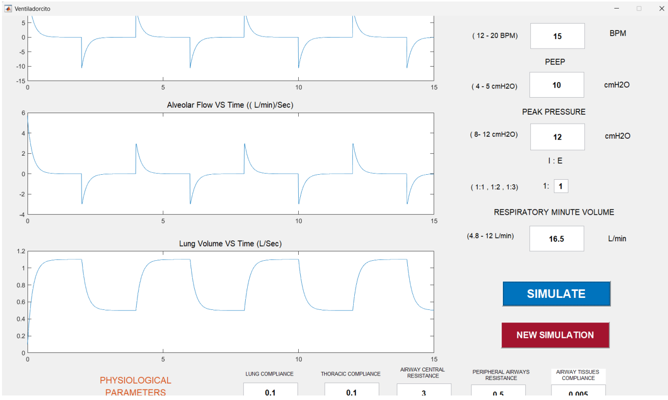

Figure 7: Simulation of lungs affected by a obstructive pulmonary disease

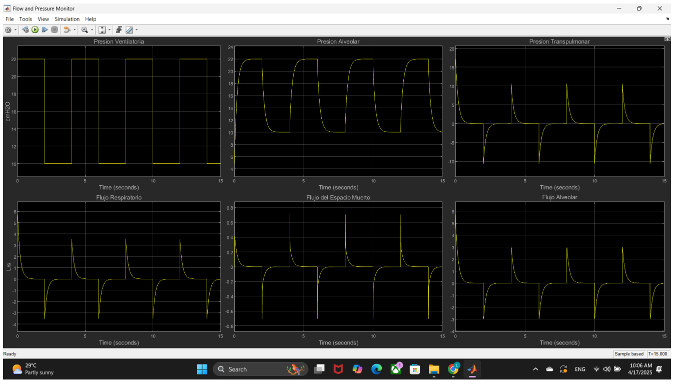

Figure 8: Flow and Pressure Monitor of lungs affected by a obstructive pulmonary disease

Figure 9: Lung Volume Monitor of lungs affected by a obstructive pulmonary disease

In **obstructive disease**, such as COPD, airway resistance is high, especially during expiration. A higher PEEP (10 cmH_2O) is used to prevent dynamic airway collapse. Peak pressure is moderately increased to overcome airway resistance.

4 Discussion

Normal Lung Condition:

In the normal lung simulation, alveolar pressure and lung volume follow smooth, sinusoidal patterns, reflecting healthy breathing. Pressure oscillates slightly around atmospheric levels, while lung volume rises and falls rhythmically. This indicates normal lung compliance and efficient air exchange, with no airway resistance or structural abnormalities affecting ventilation.

Restrictive Lung Condition:

The restrictive lung model shows reduced lung volume despite a similar pressure waveform. More negative pressure is needed during inspiration, reflecting stiff lung tissue with low compliance. The volume curve is flatter, indicating limited expansion and reduced tidal volume—key characteristics of restrictive diseases like pulmonary fibrosis or interstitial lung disease.

Obstructive Lung Condition:

In the obstructive condition, alveolar pressure increases significantly during expiration, and exhalation is prolonged. The lung volume drops slowly, showing incomplete emptying and air trapping. This reflects increased airway resistance, typical of obstructive diseases like asthma or COPD, where narrowed airways hinder airflow, especially during expiration.

5 Conclusion

This simulation demonstrates how identical ventilator settings produce different outcomes depending on lung condition. It emphasizes the importance of tailoring mechanical ventilation to a patient's pulmonary pathology. Proper adjustment of PEEP and peak pressure ensures effective and safe ventilation, particularly in patients with restrictive or obstructive diseases.