

E-BOOK OF EXTENDED ABSTRACT

THE 14TH INTERNATIONAL INVENTION, INNOVATION & DESIGN COMPETITION 2025



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HORSE-RIDING SIMULATOR USING A PNEUMATIC ACTUATION SYSTEM FOR REALISTIC MOTION REPLICATION AND TRAINING APPLICATIONS

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ABSTRACT

This project focuses on the design and development of a horse-riding simulator that uses compressed air pneumatic actuation to replicate the actual motions of horseback riding. The simulator aims to provide a realistic training experience for beginner and professional riders, enabling them to practice posture, balance, and coordination in a controlled environment. The use of a pneumatic system ensures smooth, adjustable, and repeatable motion profiles. The project includes mechanical design and pneumatic system integration with electrical technology. Traditional mechanical simulators often lack realism in motion replication, leading to the exploration of pneumatic actuation systems for smoother and more dynamic movements. Research and development of this project was conducted at Sekolah Kebangsaan Kampong Salang in collaboration with the Faculty of Mechanical Engineering and Technology, Universiti Malaysia Perlis.

Keywords: Horse riding simulator, horse riding simulator using pneumatics

1. INTRODUCTION

Learning to ride a horse takes a lot of practice and can be dangerous or expensive if using real horses. For this reason, we decided to build a horse-riding simulator that can move like a real horse. This way, beginners can learn how to balance and ride safely indoors, without needing a real animal. Our simulator uses pneumatic cylinder to copy how a horse moves during walking, trotting, and galloping to make the ride feel realistic. Through prototype testing and commissioning of the project, we observed that the simulator closely mimics the motion of actual horse riding. Various test data were collected and are explained in detail in the results section. When students used the simulator, their balance and riding posture showed noticeable improvement. The simulator is safe and offers an effective way to learn horse riding without the need for a real horse. Simulators help riders practice without live horses, reducing risks and costs [1]. Pneumatic systems offer advantages such as high force-to-weight ratio, compliance, and precise motion control [2]. Project objective consists of design a pneumatic actuation system for realistic horse gait replication, develop a control system to simulate different riding modes (walk, trot, canter, gallop) and last one to validate the simulator's effectiveness through user testing.

1.1 Literature Review

The development process started with 6-DOF motion measurement of the dynamics of the rider's saddle while riding. Six-dimensional measurements during riding are required to fully understand the character of the saddle dynamics during different gaits [3]. In addition, a rider can experience the feeling of real horse riding by controlling the movement of the horse, such as start, stop, and change of the riding pace, and with the aid of an image of the horse's riding course displayed on a screen in front of the rider [4]. A systematic review of the literature on horseback riding therapy as an intervention for children with cerebral palsy (CP) was carried out. The terms horse, riding, hippotherapy, horseback riding therapy, equine movement therapy, and cerebral palsy were searched in electronic databases and hand searched [5]. Research has demonstrated that pneumatic systems significantly enhance motion realism in various applications, such as flight and driving simulators, where precise and responsive actuation is critical for

immersive user experiences. By leveraging the unique properties of Pneumatic Artificial Muscles (PAM), motion simulators can offer more natural and dynamic feedback compared to traditional mechanical actuation methods [6].

2. METHODOLOGY

2.1 Mechanical Structure System Design

The design of the system begins with a stable base platform featuring three to six degrees of freedom (DOF), providing a dynamic foundation capable of replicating the complex, multi-directional motion associated with horseback riding. To achieve realistic and fluid movement, pneumatic actuators are strategically arranged to mimic the intricate motions of a horse's pelvis and spine, allowing for smooth transitions, rhythmic gait patterns, and naturalistic motion feedback.

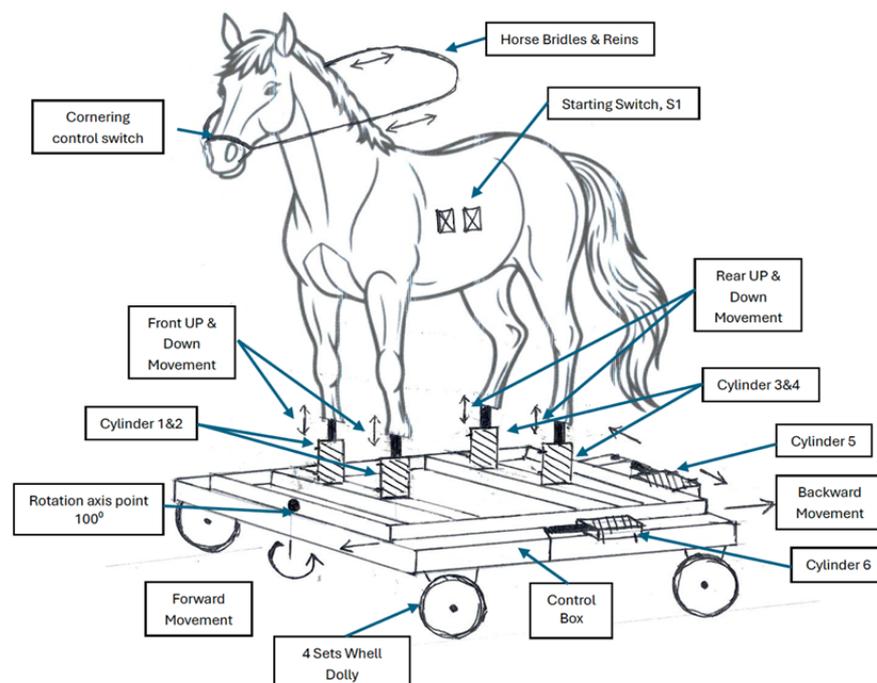


Figure 1 Detail concept design for Horse Riding Simulator using Electro-Pneumatic System

2.2 Pneumatic System

Movement is achieved using six double-acting cylinders: four control vertical (up and down) motion, one handles forward and backward movement, and another manages left and right turning, collectively enabling a full range of simulated motions using 4-6 bars of air pressure. Airflow to these actuators is regulated by five 5/2-way single solenoid valves and one 5/3-way double solenoid valve, allowing for precise control and smooth transitions between different motion states. Additionally, the speed of cylinder actuation is finely regulated using one-way flow control valves, allowing for smooth transitions and safe operation by adjusting airflow rates according to movement requirements.

2.3 Safety Benefits

One of the primary advantages of using a pneumatic horse-riding simulator is the significant reduction in the risk of injury commonly associated with real horse riding. Traditional horseback riding involves exposure to potential hazards such as falls, kicks, or bites, and riders must constantly adapt to the unpredictable behavior of the animal. In contrast, the pneumatic simulator provides a controlled and predictable environment, eliminating the inherent dangers posed by live animals.

3. FINDINGS

3.1 Comparative Summary Table: Simulator vs. Real Horse

Table 1 below highlights the key differences between the pneumatic horse-riding simulator and real horse riding, emphasising aspects such as safety, cost, accessibility, and motion accuracy. This comparison illustrates the simulator’s strengths as a safe, cost-effective, and accessible training tool, while also acknowledging the unique authenticity offered by real horse riding.

Table 1 Key differences between the pneumatic horse-riding simulator and real horse-riding performance.

Factor	Pneumatic Simulator	Real Horse Riding
Safety	No injury risk; emergency stops	Risk of falls, kicks, or spooking
Cost	Low maintenance (~RM100/year)	High (RM6000+/year for upkeep)
Consistency	Perfectly repeatable gaits	Horse-dependent variability
Muscle Activation	80–90% of real riding	100% natural engagement
Accessibility	No animal or weather dependency	Requires a horse, space, and suitable conditions

3.2 Caloric Expenditure Comparison (Simulator vs. Real Riding)

A test involving 10 participants, including 8 beginners and 2 experienced riders, was conducted to compare the caloric expenditure during 15-minute sessions on both the pneumatic simulator and real horse riding across different gaits (walk, trot, and canter). Table 2 below summarises the average calories burned and the percentage difference between the two activities.

Table 2 Average calories burned and the percentage difference between the two activities.

Activity	Avg. Calories Burned (Simulator)	Avg. Calories Burned (Real Horse)	Difference (%)
Walk (30 min)	45 kcal	60 kcal	15%
Canter (30 min)	110 kcal	134 kcal	24%

4. CONCLUSION

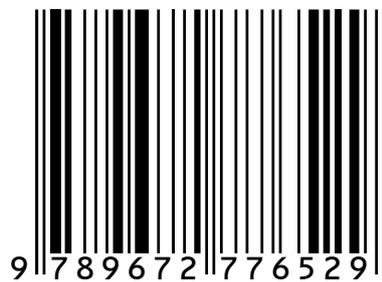
Our pneumatic air-powered horse simulator showed that we can use ‘air power’ to make a safe and realistic horse-riding simulator. It is a good way for beginners to learn riding skills, especially in places where horses are not available. It also works well for people who need physical therapy or want to improve their balance and helps people practice riding in a safe and fun way. It is a great tool for schools, training centers, or therapy programs. In the future, we could add virtual reality to make the experience even more exciting.

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