

# Design and fabrication of metal and soil draft force measuring equipment

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**Abstract.** This study aims to develop a test equipment design and prototype for measuring the adhesion of metal with soil, represented by the draft force between metals and soils. The tool is designed to measure the draft force by utilizing the friction system of two distinct items that intersect with each other. A strain gauge is used to accurately measure the magnitude of the force, which is positioned atop a load cell. After constructing the adhesion test apparatus, two soil samples, sand and clay, were subjected to evaluation. The tool is equipped with a Nema 23 stepper motor, motor 57, and a DC 24V 5A converter. The Ardiuno Nano Atmega 328 sensor module was used as its sensor module. The test data results show that clay exhibits a greater frictional force compared to sand due to its significant cohesion value and small soil particles, resulting in a strong binding and high soil resistance. Sandy soil, on the other hand, is characterized by coarse particles, low cohesiveness, abundant voids, and low resistance. It is shown that, the measuring apparatus has been successfully fabricated and able to measure the draft force that occurs in steel metal and soils

## 1 Introduction

Most industries cannot be separated from the use of metal materials. Many industries such as oil drilling, coal mining and even in Indonesia many people who work as farmers use metal tools. For every tool used, there is a possibility that the tool will touch or come into contact with other objects. And when contact occurs between surfaces, several forces will arise, one of which is adhesion force. Soil friction in earthmoving equipment usually occurs between the soil and metal, even if it is coated with plastic [1].

Farmers who hoe rice fields use metal hoes. When the hoe and soil meet, it is possible for the soil to stick to the metal, due to adhesion forces [2]. The adhesion force that occurs in the soil with this metal is one of the causes of the large amount of energy that must be used to cultivate the soil, so it requires a lot of energy sourced from fossils which has a negative impact on the environment, including greenhouse gas emissions. Previous research has stated that adhesion between metal and soil is one of the aspects that influences the level of efficiency of soil processing equipment. This adhesion force is also caused by several factors such as soil water content, soil surface properties and metal [3]. The

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adhesion force between soil and materials such as metal is due to the presence of a thin layer of moisture. The initially high adhesion force will soon decrease with increasing water content.

Adhesion to machines and soil has two forces which must be defined as a form of connection between the two, namely sliding friction and stickiness. When the soil is attached to a different surface, the force required to move the soil parallel to the surface will be different from the force vertical to the ground surface. The adhesion force between soil and materials such as metal is due to the presence of a thin layer of moisture. When soil and metal meet, they will create an adhesion force between them. This adhesion force influences the friction force, the more water content the friction force and adhesion will decrease, this is due to the lubricating effect of moisture. When a tillage tool moves through the soil, shear resistance occurs between the soil and the tool which is referred to as the tangential component of the adhesive force. This resistance is influenced by friction between the soil and the tool, adhesion and the normal pressure exerted on the surface of the tool [4].

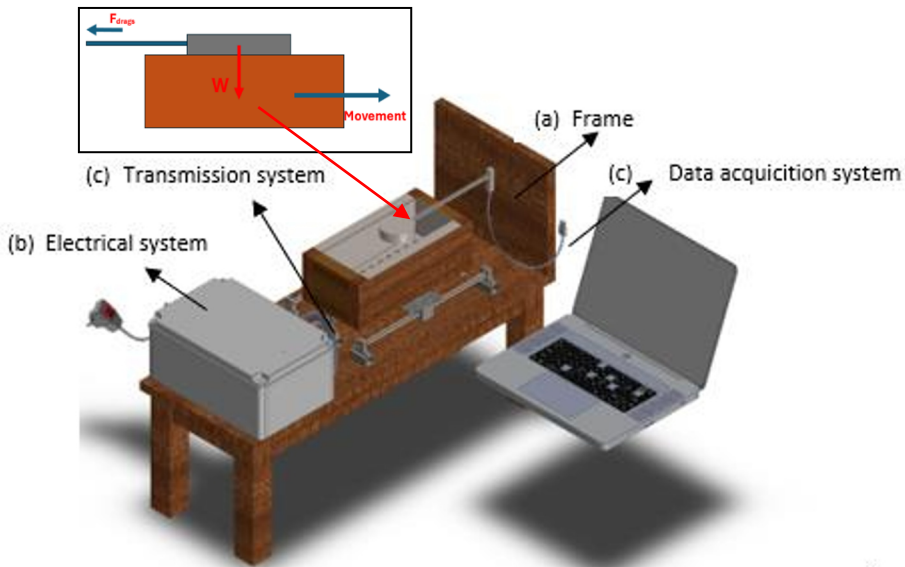
There are several methods for finding adhesion values, including the pull, press, and friction methods. The tensile and compressive methods are usually used to remove soil particles from the surface, and the friction method to move the soil particles on the metal surface. To measure the coefficient of adhesion force, you need a system that can measure the friction of two different objects that are in contact with each other. This system can use a strain gauge to obtain values for the vertical force and friction force. The strain gauge is in the load cell which is placed in one part of this system design, with strain gauge which forms a Wheatstone bridge and consists of four pieces connected in parallel series. Gee et al. [5] have developed a system that can measure the friction coefficient of objects in contact with each other. This system can be used to measure the friction properties of materials in contact with each other. The use of a strain gauge is the main principle of this system. The vertical force and friction force have been calculated with strain gauges installed in the system at certain places and with a series of Wheatstone bridges and the friction coefficients of the contact surfaces of materials such as steel, paper, plastic, glass and some thermoplastic objects are calculated. As a comparison of friction force with normal force. The results of this study show that this system can differentiate between different test materials.

This system successfully measures the friction of two different materials. Due to the absence of the same standards set for measuring soil adhesion test values and the lack of equipment available on the commercial market, it is necessary to design and manufacture such testing equipment. In this design, the focus is only on the adhesion force that occurs between the metal implement and the soil, where metal and soil are two types of materials that contain different elements. When friction occurs, it will create an adhesion force between the metal and the ground.

## **2 Experimental Methods**

The manufacture of this equipment begins by collecting the requirements, then presenting them in the form of a 3D drawing design. This equipment is divided into four main parts, namely: (a) electrical system which provides power sources for electric motors consisting of a DC 24V 5A adapter power supply. (b). transmission system, which converts the rotation of the electric motor into translational motion consisting of a TB6600 4A 9-40 V DC stepper motor driver, a Nema 23 stepper motor, and one set ball-screws transmission system. (c) data acquisition system which read data from a strain gauge or load cell, consisting of a loadcell, Arduino nano microcontroller, HX711 modul as amplifier and Arduino IDE 2.3.1. software, laptop (d). framework, which supports all the main parts. A 3D design of

this equipment can be seen in the Figure 1. The Figure offers a concise and simplified depiction of the various parts of the tensile force measurement apparatus. The design delineates the key components, including the frame, data acquisition system, electrical system, and the tension or force application system. The minimalistic design enables the spectator to concentrate on the practical arrangement of the equipment, free from any distractions caused by superfluous elements like wiring or real-world flaws.

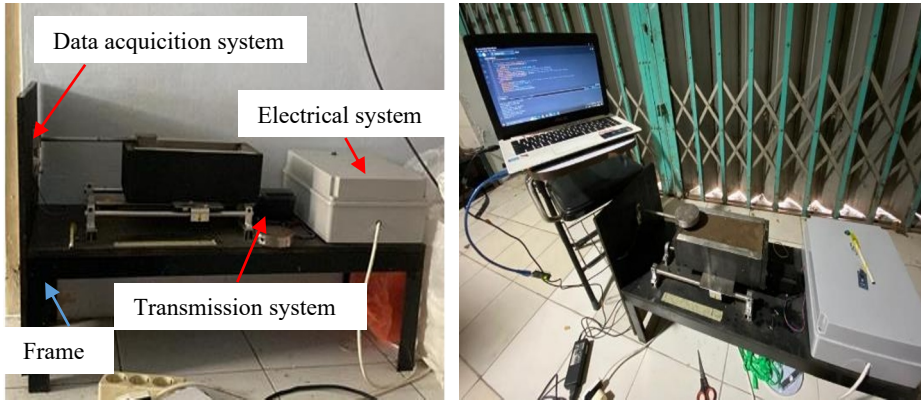


**Fig. 1.** The 3D image of the design of metal and soil draft force measuring equipment

After all components have been set up, including installing the Arduino IDE to the laptop, the load cell calibration is continued to ensure that the weight readings obtained match reality. Place an object of known weight on top of the load cell and note the reading displayed on the Serial Monitor. The next step is to test the equipment with two types of soil, clay and sand. A metal plate with an area of 0.09 m<sup>2</sup> and a downward load of 0.754 kg was used in this experiment, length of the metal path of 14 cm

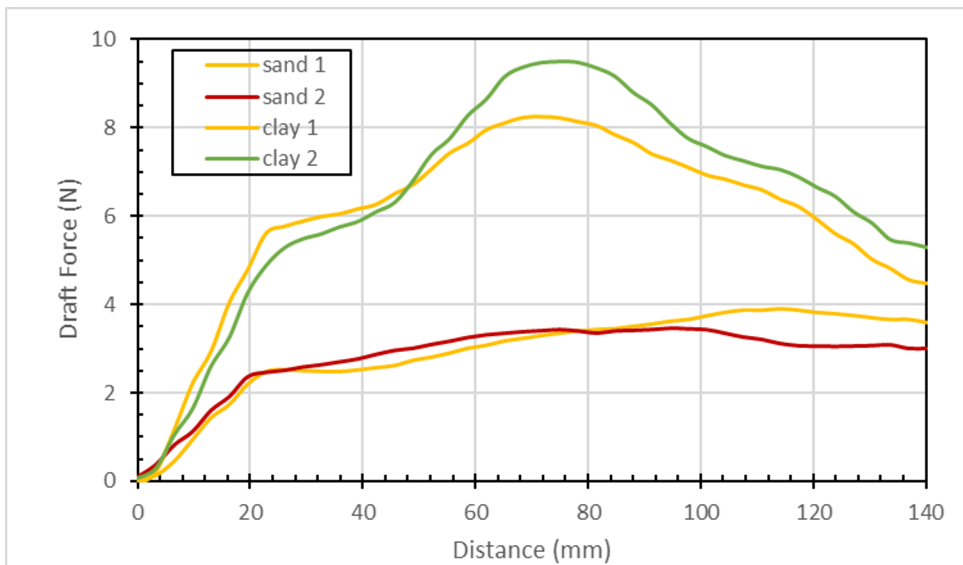
### 3 Result

The Figure 2 a, which depicts the actual equipment, includes all the practical aspects of the constructed apparatus. This includes the materials used for the frame, the actual positioning of components, and additional details like wiring and the workspace environment. The photograph highlights the complexity of real-world fabrication, where factors such as material selection, space constraints, and equipment placement become important. the placement of components mirrors the design closely, but with practical adjustments.



**Fig 2.** a. The fabricated equipment, b. Performance testing

Figure 2.b illustrates the performance testing of a device specifically developed to measure tensile force, particularly the drag force between metal and earth, including sand and clay. The setup consists of a laptop connected to the equipment, most likely for the purpose of acquiring and monitoring data, along with several components of the experimental apparatus. The equipment, situated on a robust platform, comprises elements such as the frame, tensioning system, and sensors. The metal object under examination is typically positioned within the equipment and pulled across the soil sample (composed of either sand or clay), while the ensuing resistance force is quantified by a load cell or a comparable sensor. The several mechanical components are linked to the data collecting system via wire, as depicted on the right side of the figure.



**Fig 3.** Measurement draft force

The graph depicts the resistance encountered when metal is pulled across two soil compositions: sand and clay. The tests were repeated twice for both sand and clay samples, with the y-axis representing draft force and the x-axis indicating time in seconds. The graph

provides insights into the interaction between various soils and a metal object being drafted across their surfaces, providing information regarding their mechanical behavior in such circumstances. The horizontal force is equal to the draft force when the magnitude of the vertical force is very small [6]

The sand samples exhibit a comparatively low and consistent draft force, while the clay samples exhibit considerably greater draft forces. These results are consistent with the results of [7]. The sand samples provide greater opposition as the metal moves the grains, resulting in the generation of frictional resistance. However, once the grains have undergone compaction and rearranged into a more stable arrangement, the draft force diminishes and reaches a steady state. The disparities between "sand 1" and "sand 2" may be attributed to discrepancies in sand density or variances in particle size distribution.

Clay samples, on the other hand, exhibit considerably greater draft forces. They achieve a maximum draft force of roughly 9 Newtons, while "clay 2" achieves around 8 Newtons. The draft force in clay samples does not steady after an initial peak but gradually diminishes after reaching its maximum value. These findings indicate that clay demonstrates greater frictional resistance when a metal object is drafted across it, especially during the beginning phase of motion. The contrasting mechanical characteristics of sand and clay are significant and have notable implications in practical contexts, particularly within industries such as construction and geotechnical engineering. Clay's greater initial resistance, followed by its ability to undergo plastic deformation, allows it to withstand higher loads initially but may result in deformation when subjected to sustained pressure. In contrast, sand exhibits a more consistent and foreseeable behavior, characterized by reduced resistance and minimal deformation over a period.

The graph effectively illustrates the distinct mechanical characteristics displayed by sand and clay when subjected to the drafting of metal. Sand, due to its granular nature, exhibits lower and more consistent draft forces, while clay, being cohesive, experiences larger initial draft forces that gradually decrease as a result of plastic deformation. Birch et al [8] stated that water content and soil type had the greatest influence on the soil-metal sliding resistance forces. These findings are consistent with well-established principles in soil mechanics and have significant implications for engineering applications that need a thorough understanding of how soil behaves when subjected to external forces.

## **4 Conclusion**

The fabricated equipment successfully transitioned from design to reality, maintaining structural integrity and functionality. It performed well in real-world testing, effectively integrating mechanical components with a data acquisition system. The setup demonstrated its capability to accurately measure drag force between metal and soils (sand and clay) in a controlled environment. Practical construction challenges, such as stability and wiring integration, were addressed effectively, resulting in reliable performance and consistent experimental results. Overall, the equipment proves to be a valuable tool for measuring tensile forces in soil-metal interactions.

## **Acknowledgment**

This research was conducted with the generous support and funding provided by Universitas Muhammadiyah Yogyakarta. The authors would like to extend their deepest gratitude to the university for its commitment to advancing scientific inquiry and for providing the financial resources necessary to undertake this study.

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