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Improvement of Portable Mackintosh Probe Extractor

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Abstract: This paper presents a design improvement of the Portable Mackintosh Probe Extractor. This tool was used to pull out the probe rod from the ground after Standard Penetration Test (UPS). UPS is Soil Investigation (SI) technique used in civil engineering as a fundamental step, which is held before any construction activity on site. Previous probe extractor has limitations such as unfriendly to user, large size, weight and not being adjustable, and difficult to store in the vehicle. The improvement design was established and simulated using SolidWorks 2019 software. The parts and assembly in the design process were done to identify the weight and overall size by applying mild steel material properties. Improvements were made by adding an adjustable part on the vertical section, minimize frame thickness to reduce material consumption, and change the holder from slot pin to cylinder to be fit while holding the mackintosh probe. The maximum force of critical area on adjustable vertical and cylinder holder section was identified from stress and equilibrium force calculation. The result is 19.231 kN and 9.615 kN respectively. Finite element analysis (FEA) simulation is conducted on adjustable vertical and cylinder holder section with variable force (2,4,6,8,10,12,14,16,18,20,22) kN and (1,2,3,4,5,6,7,8,9,10,11) kN to identify the profile, graph of force against stress and displacement value. The result of each section was found the displacement change in small value at 5.516×10^{-3} mm during an increase of 2 kN and 5.411×10^{-4} mm for each 1 kN increase of force respectively. All graph shows the force directly proportional with stress and displacement. Finally, movement of animation has been run also by this software to

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determine its functionality in virtual. Based on the results, the improved design of the Mackintosh Probe Extractor can be further to the fabrication stage.

Keywords: Improve, Tool, Mackintosh, Probe, Extract, Design

1. Introduction

Mackintosh Probe is a lightweight portable penetrometer device used in the Standard Penetration Test (SPT) [1]**.** Standard Penetration Test (SPT) is a soil parameter estimation as the main step performed before any construction activity is carried out at a location. It also aims to obtain all the soil parameters required before planning the foundation or site to accommodate the load on the building to be constructed. The soil parameters obtained can help in planning the construction phase of the building so that the structure is more quality, economical and safe [2]. This test method is carried out by inserting a probe connected with a metal rod (probe-rod) into the soil through the method of mass impact continuously from the soil surface to the last penetration depth [3]. After this study was conducted, there was difficulty in removing the probe-rod from the ground due to the strong soil structure and gripping the probe-rod and preventing them from coming out of the ground. The device that can remove the probe-rod is named Mackintosh Probe Extractor [2]. However, the existing Mackintosh Probe Extractor is exhausting in terms of weight, large size and it is difficult to store in the vehicle. Therefore, an improvement to the design of the Mackintosh Probe Extractor needs to be made to make it easier for land surveyors to use it without reducing the effectiveness in terms of tool capabilities. This tool is named Portable Mackintosh Probe Extractor. Appropriate design modifications were developed using SolidWorks 2019 software [4],[5]. The analysis of the reaction forces was carried out through the principle of force balance. The value of the reaction force on the critical part of this tool is used to run Finite Element Analysis (FEA) simulation using SolidWorks 2019 to determine the maximum force and displacement allowed on this tool in determining its strength and capability.

2. Methods and Materials

2.1 Part design using SolidWorks 2019 software

Parts of the Portable Mackintosh Probe Extractor were drawn using SolidWorks 2019 software as in **Figure 1.** The design started with the extractor site part. The base section is drawn using a rectangular shape and expanded according to the predetermined thickness as well as extruded cut features to make a rectangular-shaped hole. Then, use the round shape and extruded cut features to make the latch holes as in **Figure 1 (a)**. The next part is vertical. The vertical part is drawn using a rectangular shape then expanded according to a predetermined thickness. The section uses a round shape and extruded cut features to make a 10 mm diameter slot hole as in **Figure 1 (b).** Next, the presser section is drawn using lines then expanded and using command extruded cut features. This section also uses rectangular and round shapes as in **Figure 1 (c).** After that, the handle part is drawn using a round shape then expanded according to a predetermined thickness to produce a cylindrical shape. This section also uses a rectangular shape then expanded as in **Figure 1 (d).** Next, the cylindrical part of the handle is drawn using a round shape and then expanded using the command extruded cut features as in **Figure 1 (e)**. The supporting components were drawn using rectangular and round shapes then expanded as well as using the extruded cut command to make a 20 mm diameter slot hole as in **Figure 1 (f)**. The wheel components are drawn using a straight line according to the predetermined measurements than using revolved base features to produce the round shape of the wheel as in **Figure 1 (g)**. The 20 mm diameter bolt section is used as a latch to connect the handle components with the presser. This part is drawn using a polygon and round shape then expanded according to the size and size of 30 mm × 10 mm and using command extruded cut features to make a hole in the middle of the latch as in **Figure 1 (h)**. Next, the pin section is drawn using straight and curved lines according to the predetermined measurements and using the swept boss command as in **Figure 1 (i)**. The bolt components were drawn using a polygon and round shape of 10 mm diameter then expanded according to a size of 90 mm × 10 mm as shown in **Figure 1 (j)**. The 20 mm diameter shaft components were drawn using polygonal and round shapes and then expanded and using extruded cut features to produce holes as in **Figure 1 (k)**. The pin slot components for connecting the wheel brackets are drawn using a round shape then expanded and using the fillet icon as in **Figure 1 (l)**.

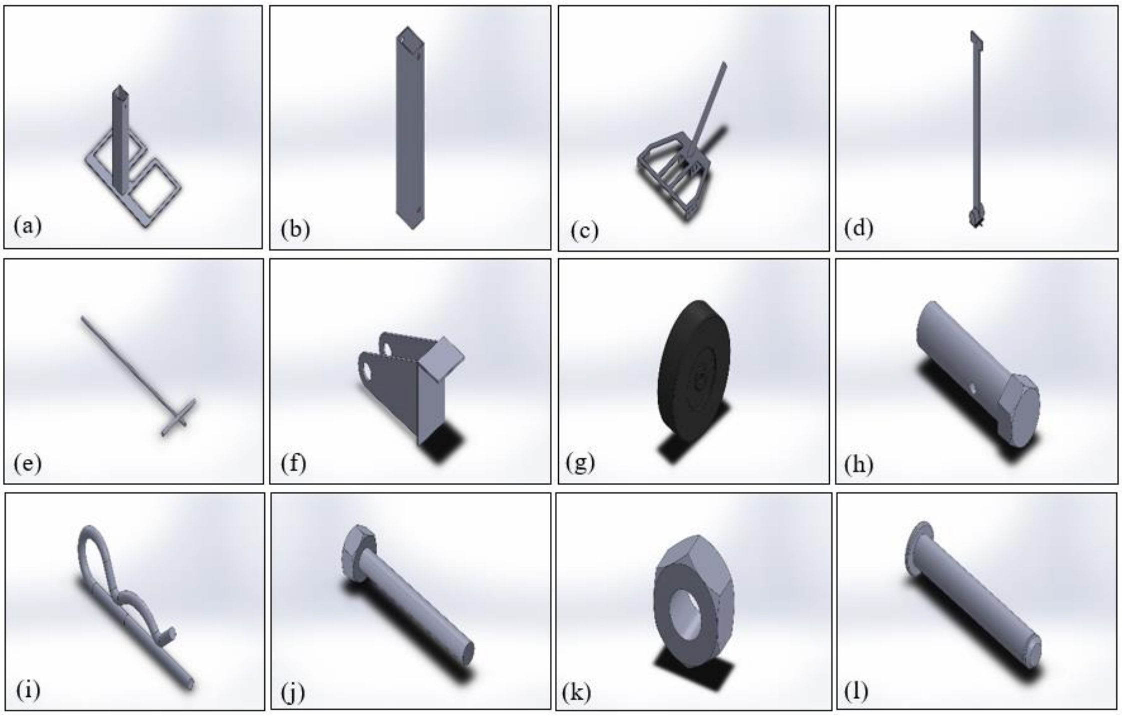

Figure 1: Part design using SolidWorks 2019 software, (a) Base, (b) Vertical, (c) Presser, (d) Handle, (e) Cylinder handle, (f) support, (g) Wheel, (h) Bolt size 30 mm × 10 mm (i) Pin, (j) Bolt size 90 mm × 10 mm, (k) Shaft, (l) Pin slot

2.2 Assembly design using SolidWorks 2019 software

Figure 2 (a) shows the assembly design of the Portable Mackintosh Probe Extracto*r* uses SolidWorks 2019 software. The assembly process begins with the base section, followed by the adjustable vertical then the presser section. The presser section will be connected to the cylinder lever and Mackintosh probe (cylinder holder). Base components and wheels are mounted on the base section. Figure 2(b) show Portable Mackintosh Probe Extractor in exploded view

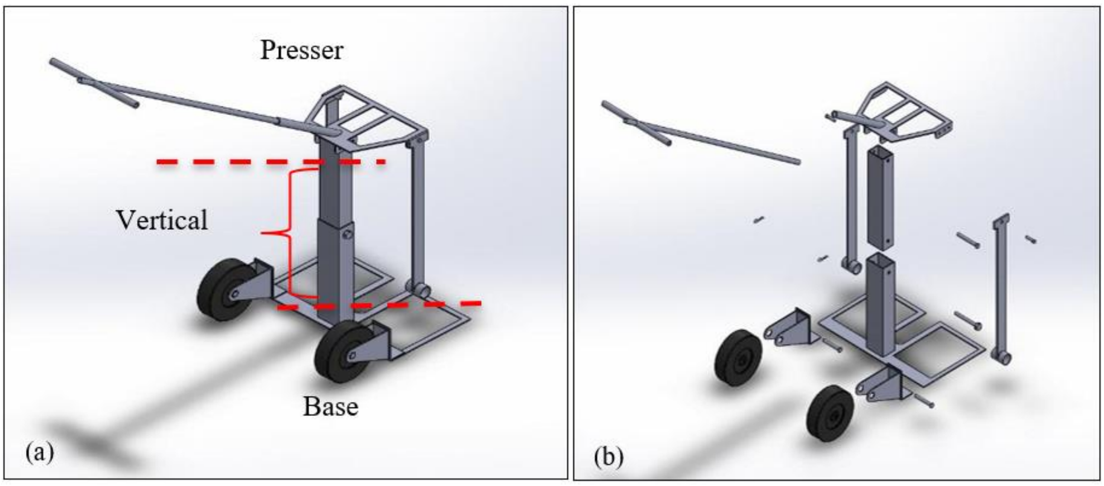

Figure 2: (a) Assembly design and (b) Exploded view Portable Mackintosh Probe Extractor using SolidWorks 2019 software

3. Results and Discussion

Reaction force analysis in the calculation, Finite Element Analysis (FEA) in SolidWorks simulation, and Mackintosh Probe Extractor after improvement comparison has been shown in this section.

3.1 Analysis of the reaction force on the Portable Mackintosh Probe Extractor

The reaction force was obtained from equilibrium force analysis between cylinder lever, adjustable vertical, and Mackintosh Probe holder. **Figure 3** shows the free body diagram (FBD) of reaction force that occurs from the cylinder holder F_1 to the Mackintosh Probe holder representing F_2 and F_3 as well as an adjustable vertical which is F_4. The distance between F_2 and F_3 is 280 mm from F_4, while the outer and inner diameters of the hollow cylinder on the handle side are 2cm and 17cm. These force values are the maximum limits allowed acting on each part.

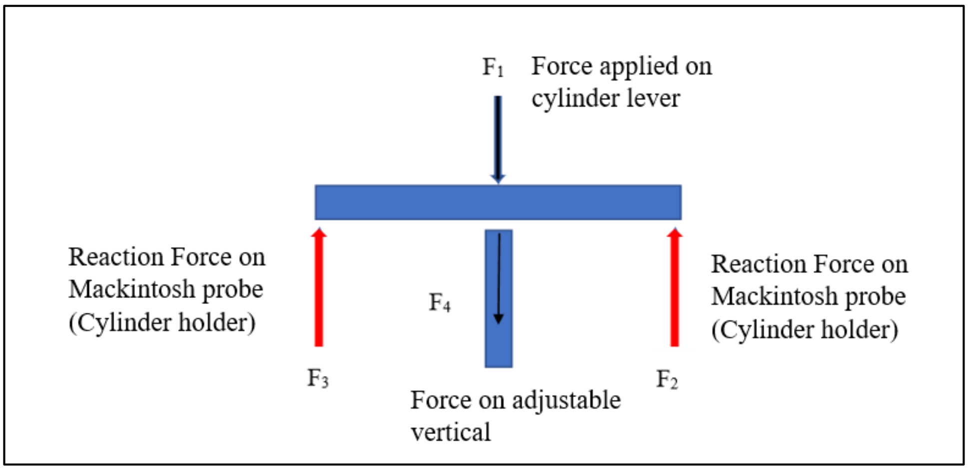

Figure 3: Free body diagram (FBD) for Portable Mackintosh Probe Extractor

Table 1: Parameters for mild steel material

Item	Properties name	Value	Unit
1	Yield strength	220.594	MPa
2	Tensile strength	399.836	MPa
3	Shear Modulus	79000	MPa
4	Modulus of elasticity	210000 MPa	MPa
5	Poisson ratio	0.28	

The hollow diameter value of the cylinder lever at the presser section is 0.02 m of inner and 0.017 m of outer. By **Eq.1** the value of the cross-sectional area of the cylinder is 8.72×10^{-5} m^2 has been obtained. The yield strength value of the material 220.594 MPa in **Table 1** is used in **Eq.2** to obtain the force applied. The result found, applied force F_1 is 19.231 kN. F_1 value is the same as F_4 because of the force in the same direction and position. Reaction force and moment equilibrium from **Eq. 3** and **Eq. 4** is used to calculate the F_2 and F_3 against their respective distances with F_4 being 280 mm. The result reaction force F_2 and F_3 is 9.615 kN.

$$A = \frac{\pi {d_1}^2}{4} - \frac{\pi {d_2}^2}{4} \quad \textbf{Eq.1}$$

$$\sigma = \frac{F_1}{A} \quad \textbf{Eq.2}$$

$$\sum M_3 = 0 \quad \textbf{Eq.3}$$

$$\sum Fy = 0 \quad \textbf{Eq.4}$$

3.2 Simulation of Finite Element Analysis (FEA) using SolidWorks 2019

Figure 4 shows the profile stress distribution image of Finite Element Analysis (FEA) simulation using SolidWorks 2019 software when the force is applied on the cross-section area of the vertical section with variable (2,4,6,8,10,12,14,16,18,20,22) kN. From observed, the maximum stress distribution has occurred at the area of the pinhole where it is the connection part of the adjustable vertical component. Pinholes usually work under complicated conditions. Heat, deformation and contact all can fail pinholes. Fatigue fracture is the main failure mode of the pinhole [6-7]. **Figure 4 (j)** and **Figure 5** show the maximum force limit at 19.231kN produces a stress of 104.3 at the pinhole area. The force applied is directly proportional to the stress as shown in **Figure 5**.

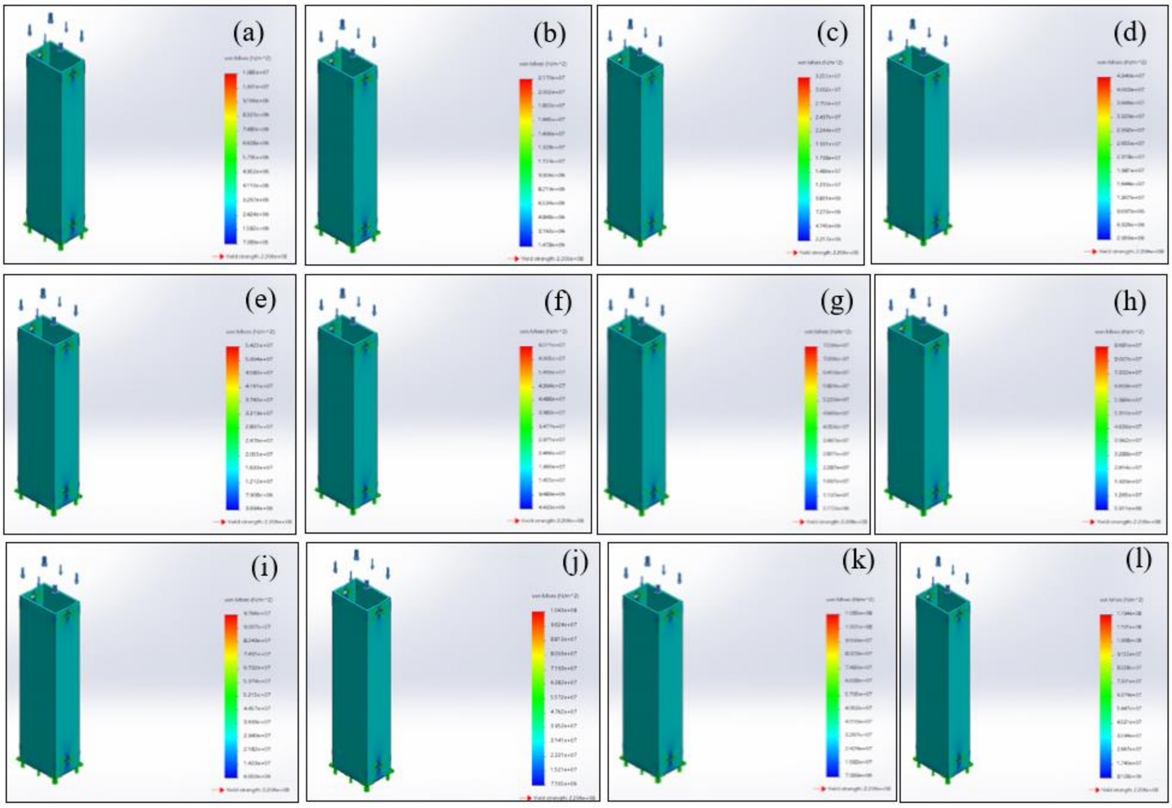

Figure 4: Stress distribution of force changes on adjustable vertical components, (a) 2kN, (b) 4kN, (c) 6kN, (d) 8kN, (e) 10kN, (f) 12kN, (g) 14kN, (h) 16kN, (i) 18kN, (j) 19.213 kN, (k) 20kN, (l) 22kN

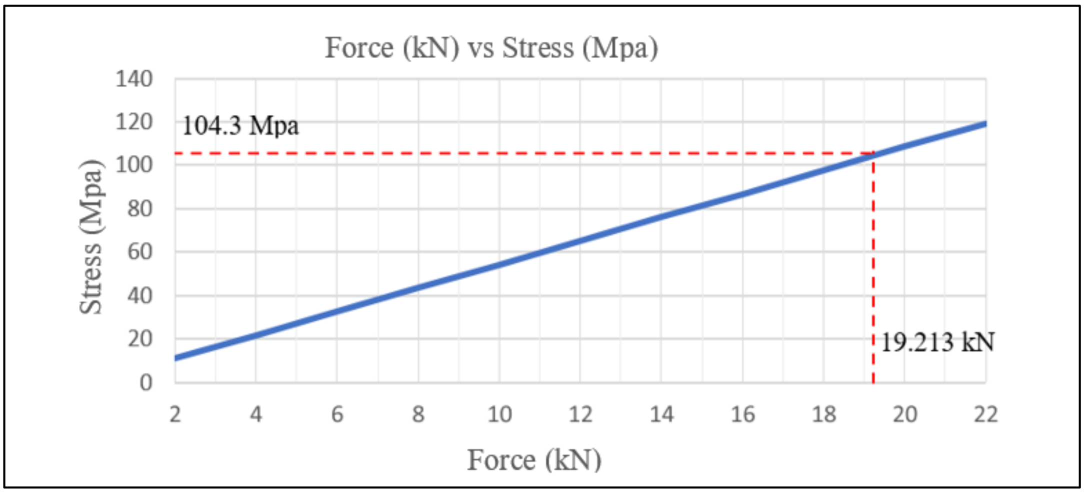

Figure 5: Graph of force against pressure for the vertical component

Figure 6 shows the displacement profile against force change is maximum at the top and decreases uniformly downwards for the adjustable vertical component. A limit force of 19.213 kN applied to the cross-sectional surface of the adjustable vertical component produces a slight displacement of 5.008×10^{-2} mm as shown in **Figure 6 (j)** and **Figure 7**. **Figure 7** also shows the graph is directly proportional between the force applied and displacement. The elongation of 5.516×10^{-3} is a small value while force changes every 2 kN increase.

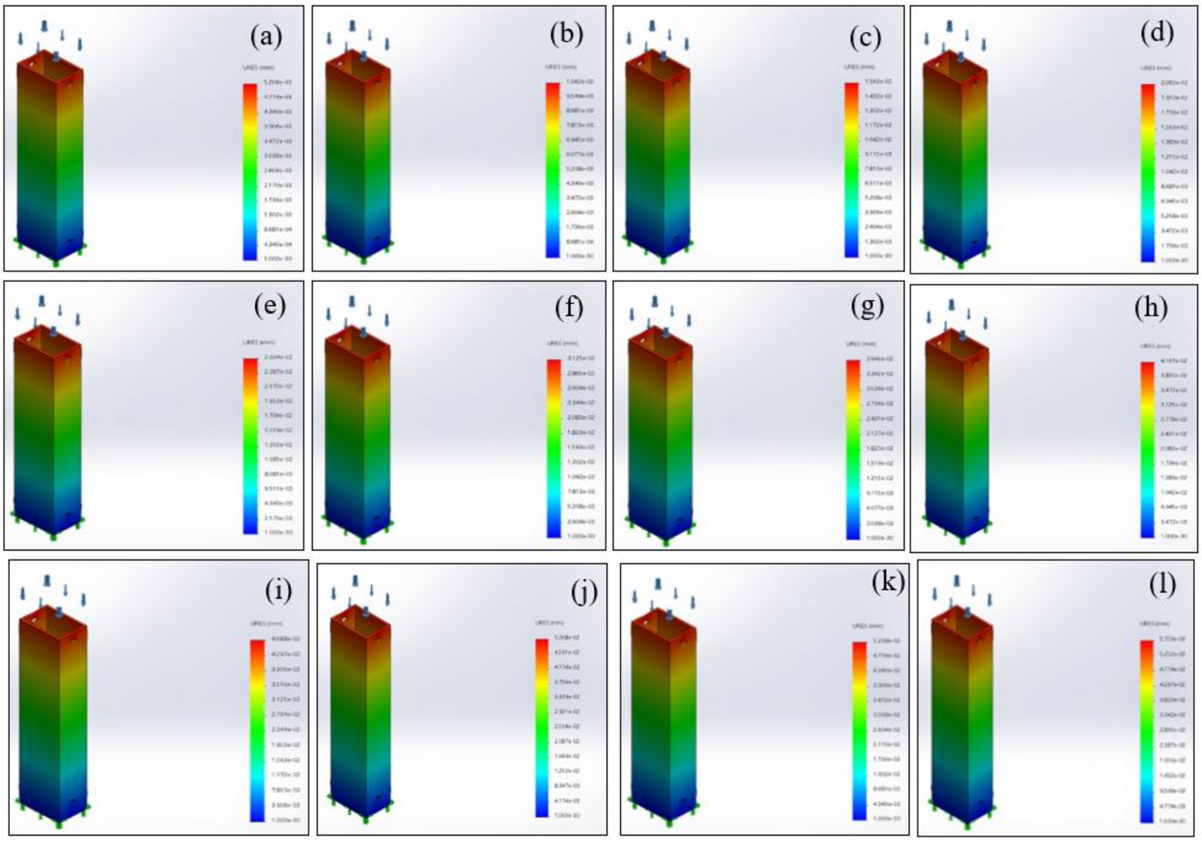

Figure 6: Displacement analysis of force changes on adjustable vertical components, (a) 2kN, (b) 4kN, (c) 6kN, (d) 8kN, (e) 10kN, (f) 12kN, (g) 14kN, (h) 16kN, (i) 18kN, (j) 19.213, (k) 20kN, (l)22kN

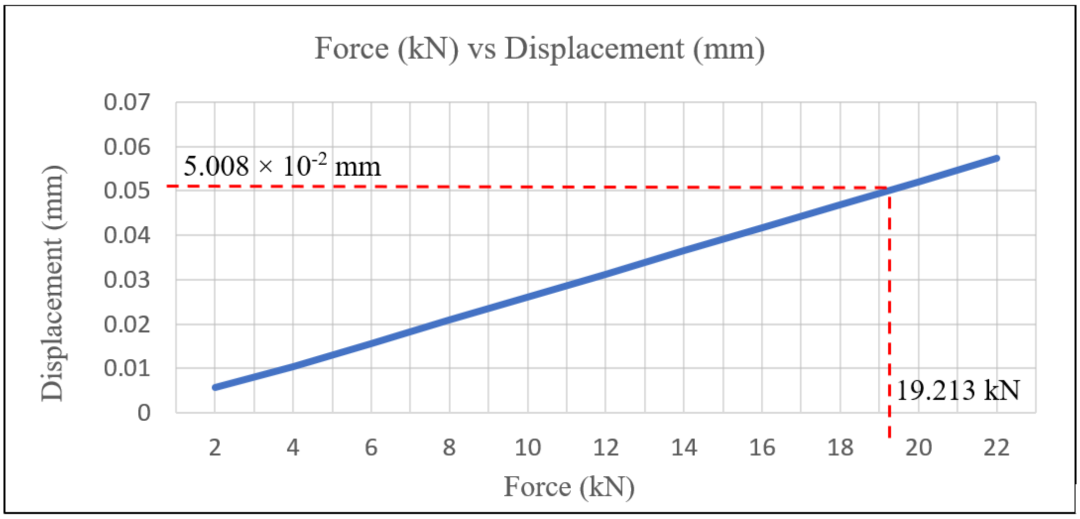

Figure 7: Graph of force against displacement for an adjustable vertical component

Figure 8 shows the profile stress distribution image of Finite Element Analysis (FEA) simulation using SolidWorks 2019 software when the force applied on cross-section area of Mackintosh probe holder cylinder holder with variable (1,2,3,4,5,6,7,8,9,10,11) kN. From observed, the maximum stress distribution has occurred at the end of the inner half-cylinder area of the Mackintosh probe holder. Then, the pressures are longitudinally visible more clearly due to the force acting in the vertical direction. The large internal in the cylinder produces high tension hoop stress along the inner surface of the cylinder and eventually may result in the nucleation of the internal surface cracks due to cyclic action of high-pressure loads which it is starting at the surface of the bore, expanding into a longitudinal or radial cracking [8]. **Figure 8 (i)** and **Figure 9** show the force limit at 9.615 kN that applied in-cylinder holder has produced maximum stress of 54.15 MPa that known as the hoop stress. This hoop stress value is less than mild steel's yield strength of 220.549MPa. Consequently, it can prevent the cylinder holder from bending or breaking. It has been proven based on hoop stress analysis that is influenced by the yield stress of the material used to design a compound cylinder [8[,[9].

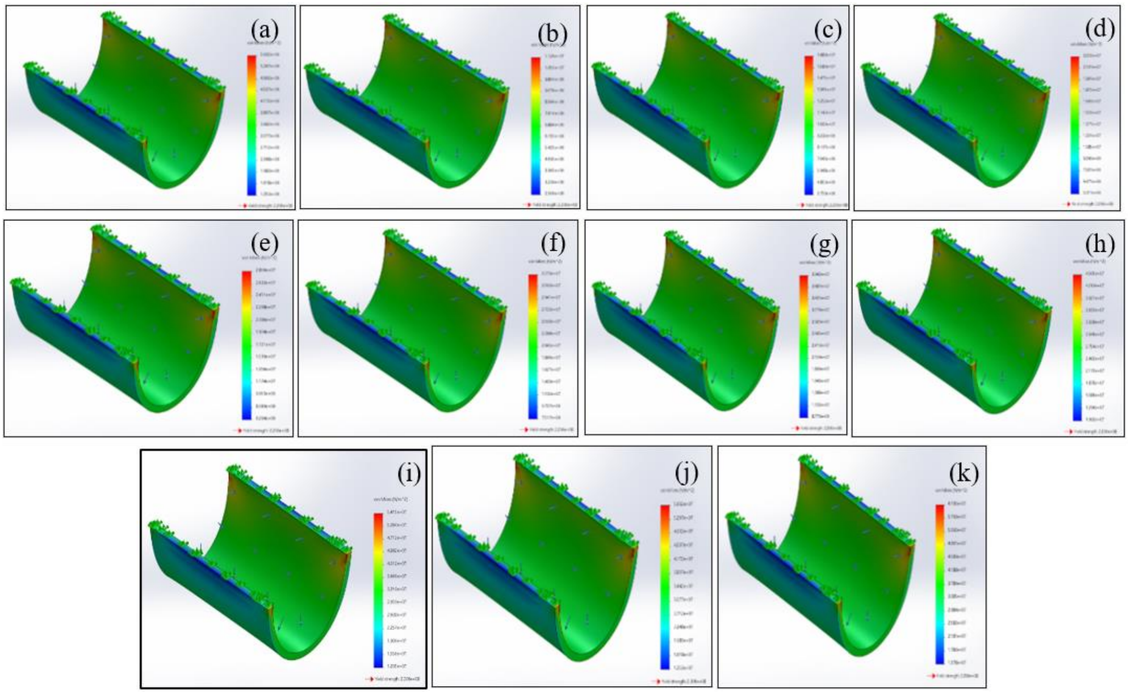

Figure 8: Stress analysis of force changes on handle components, (a) 1kN, (b) 2kN, (c) 3kN, (d) 4kN, (e) 5kN, (f) 6kN, (g) 7kN, (h) 8kN, (i) 9.615kN, (j) 10kN, (k) 11kN

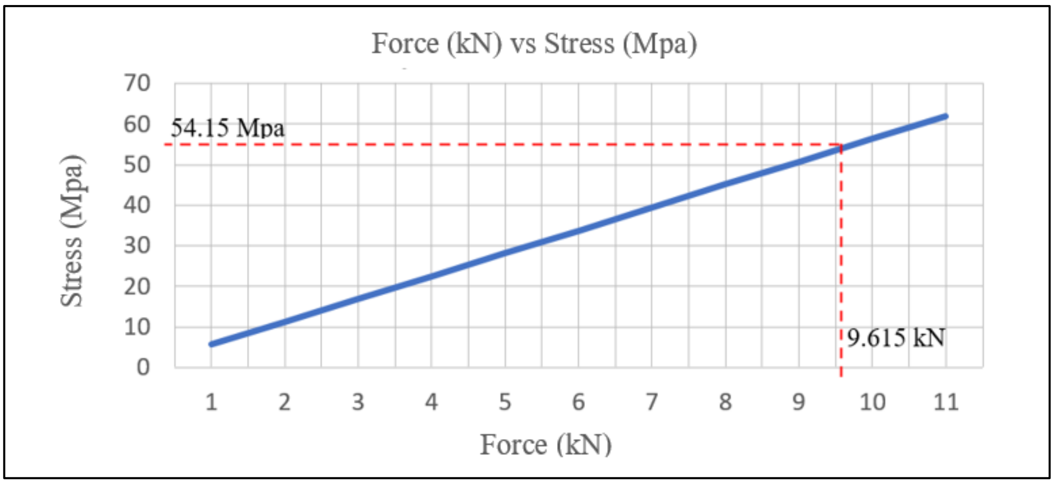

Figure 9: Graph of force against the stress of mackintosh probe holder

Figure 10 shows the displacement profile against force change is maximum at the contact area between of Mackintosh probe and the inner side of the cylinder holder. A limit force of 9.615 kN applied to the cross-sectional surface of the cylinder holder produces a slight displacement of 5.199×10^{-3} mm as shown in **Figure 6 (i)** and **Figure 11**. **Figure 11** also shows the graph is directly proportional between the force applied and displacement. The elongation of 5.411×10^{-4} is a small value while force changes every 1 kN increase.

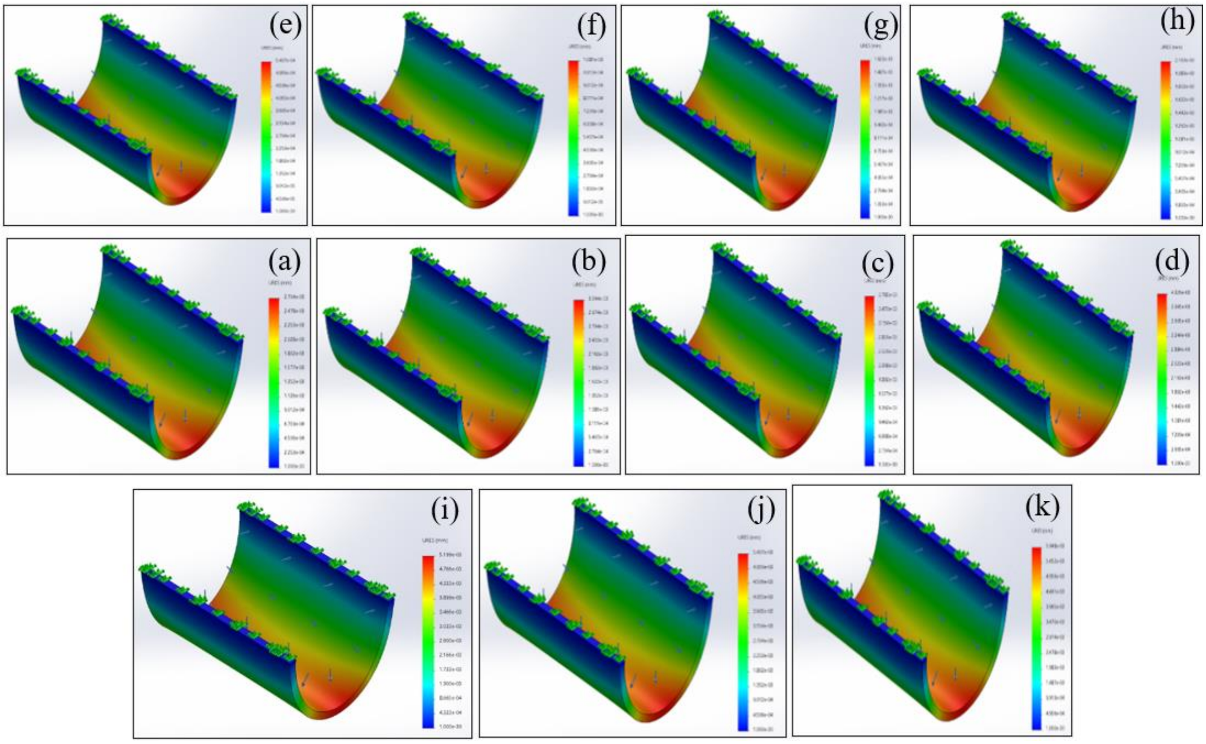

Figure 10: Displacement changes of cylinder holder in variable force;, (a) 1kN, (b) 2kN, (c) 3kN, (d) 4kN, (e) 5kN, (f) 6kN, (g) 7kN, (h) 8kN, (i) 9.615 kN, (j) 10kN, (k) 11kN

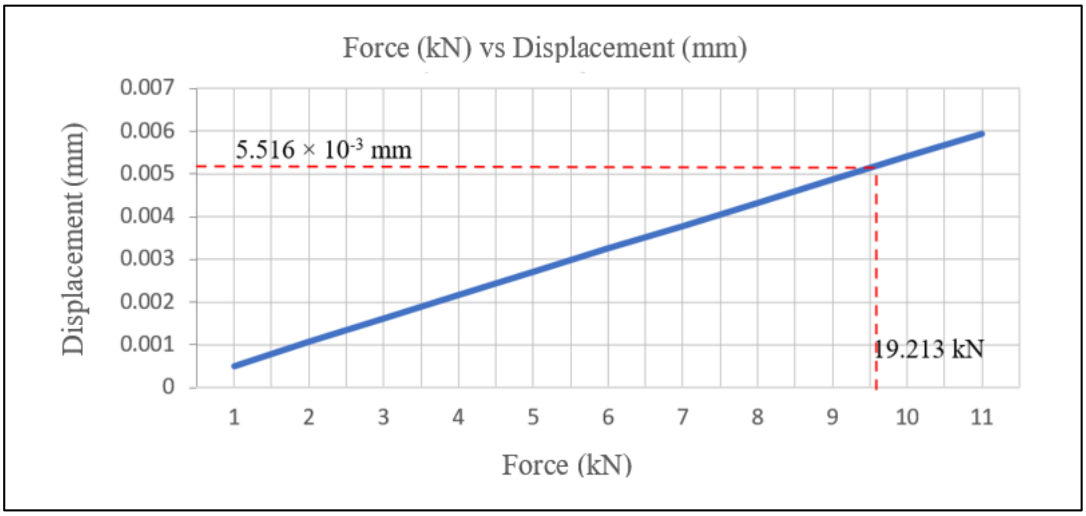

Figure 11: Graph of force against displacement of the mackintosh probe holder

3.4 Working principle of Portable Mackintosh Probe Extractor

Figure 12 shows the working principle of the Improvement of Portable Mackintosh Probe Extractor. Before conducting the process of removing the probe rod from the ground, the vertical part should be adjusted to the maximum height and the lever released in the free state. Then, the installed mackintosh probe holder (cylinder holder) should hold the probe rod firmly. Next, the lever will be pull down using human force and in turn, this movement will cause the mackintosh probe holder to move upwards. Then, the lever is pressed down several times to remove the probe rod from the ground gradually. The step will be continued until the entire probe rod can come out from the ground.

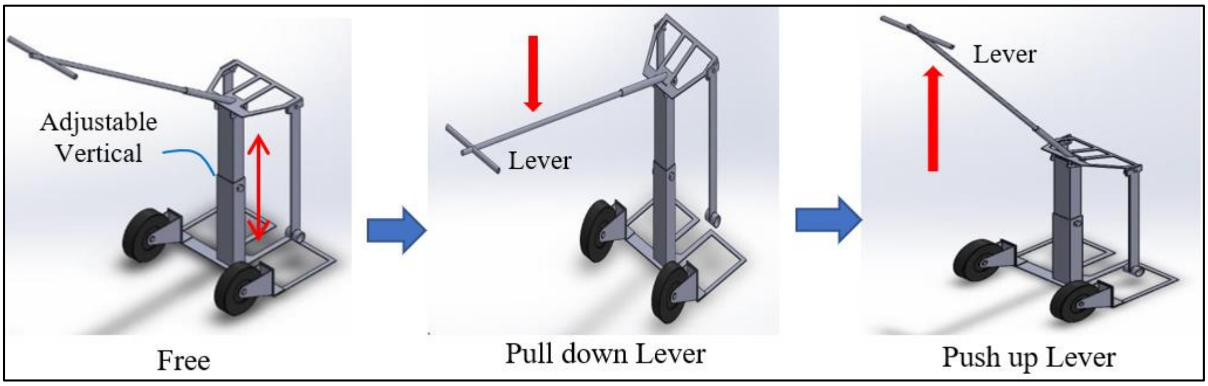

Figure 12: Working principle of Improvement of Portable Mackintosh Probe Extractor

3.5 Comparison of Mackintosh Probe Extractor after improvement.

Figure 12 shows comparisons before and after the improvement can be seen on the vertical section, where the permanent vertical is replaced by an adjustable vertical for ease of storage. Moreover, on the presser and base component, the material consumption is reduced by changing the design from a solid plate to a frame. At the holder component, the shape of two parallel bars that are connected to the slot pin has been changed into a thin bar that is connected to the cylinder to make it lighter and the extractor probe is easier to install.

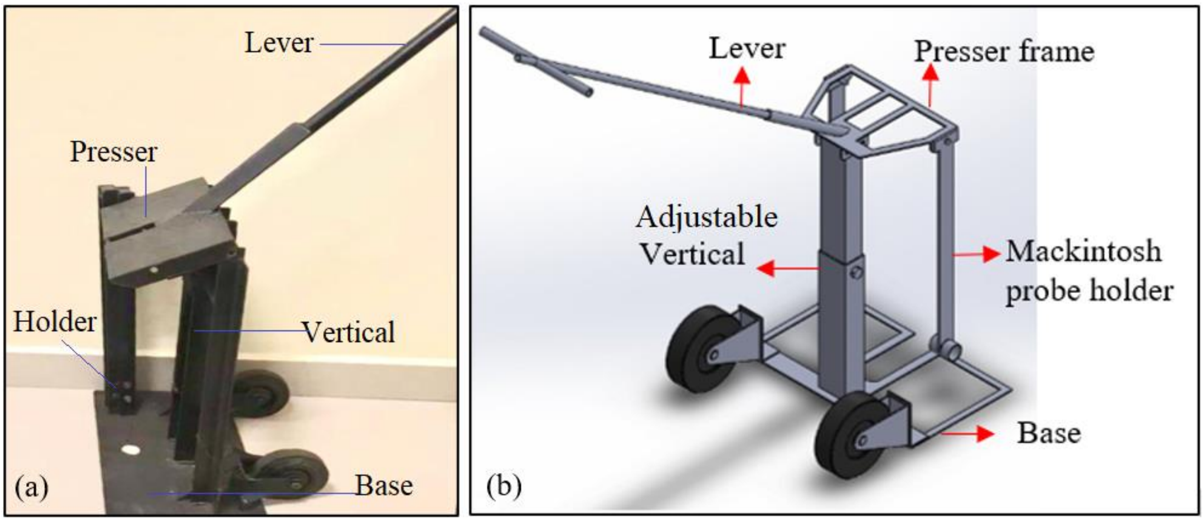

Figure 12: Comparison of Mackintosh Probe Extractor (a) before and (b) after improvement.

Table 2: Specification of mackintosh probe extractor before and after improvements

Item	Part component	Before	After
1	Probe holder	Tough operated	Easily operated
2	Vertical	Not adjustable	Adjustable

3	Base	Weight	Lighter
4	Roda	Easy to handle	Easy to handle
5	Presser	Weight	Light
6	Lever	Difficult to install	Easy to install
7	Weight	12.0 kg	9.0 kg
8	Size	40.5 cm × 25.5 cm × 60 cm	45 cm × 22 cm × 58 cm

Table 2 shows the mackintosh probe extractor after improvement is easier to operate. Adjustable vertical makes this tool can be stored in a minimum of space. Base and pressure lighter after re-design and reduced the material used. Weight and size were determined from observation of mass properties of SolidWorks 2019.

4. Conclusion

In this conclusion, improvements of design for the previous mackintosh probe extractor were made by adding an adjustable part on the vertical section, minimize frame thickness to reduce material consumption, and change the holder from slot pin to cylinder to be fit while holding the mackintosh probe. The maximum force of critical area on adjustable vertical and cylinder holder was identified from the stress and equilibrium force equation. Finite element analysis (FEA) simulation on adjustable vertical and cylinder holder section with variable force was found the displacement change in small value at during increase of force. Finally, movement of animation has been run also by this software to determine its functionality in virtual. Based on the results that have been obtained, the improved design of the Mackintosh Probe Extractor can be further to the fabrication stage.

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References

[1] J.A. Lukiantchuki, G.P. Bernardes, E.R. Esquivel, “Energy Ratio (ER) for the Standard Penetration Test Based on Measured Field Tests,” Soils and Rocks, São Paulo, vol. 40, no. 2, pp. 77-91, August 2017.

[2] N.K.A. Rahman, M. Kaamin, A.K. Suwandi, S. Sahat, and M.J. Kesot, “Development of Mackintosh Probe Extractor,” IOP Conference Series: Materials Science and Engineering, vol.160, 2016,pp. 012-015, doi:10.1088/1757-899X/160/1/012012016

[3] Adminjkr. (n.d.), “Penyelidikan Tanah,” PerkihdmatanMedia Sosial: Jabatan Kerja Raya Besut. [Online]. Available: http://jkrbesut.terengganu.gov.my/index.php/7-blog/276-penyelidikan-tanah. [Accessed July. 4, 2021]

[4] K. Noraniah, M.N. Hafsa, L.M.X. Bernadette, A.R. Hashim, M.A.M. Fadzir and T.M. Hafeez, “A study on a new design of semi-automatic crepe machine to improve Small Medium Enterprise (SME) productivity.” Multidisciplinary Applied Research and Innovation vol. 2 no. 1, pp. 255-265, 2021.

[5] K. Noraniah, M.N Hafsa, M. Noraini, M.Huzairi, Z. Ilyas and W. Naiem. “Alat Penyandar Belakang Mudah Alih untuk Pesakit.” Multidisciplinary Applied Research and Innovation. vol. 2, no. 2, Pp.132-141, 2021, e-ISSN : 2773-4773.

[6] W. Qin, J. Li, Y. Liu, J. Kang, L. Zhu, D. Shu, P. Peng, D. She, D. Meng, Y. Li. Effects of grain size on tensile property and fracture morphology of 316L stainless steel. Mater. Lett., vol.254, pp. 116-119, 2019

[7] W. chen Tang, Z. yu Piao, J. Zhang, S. ying Liu, L. jun Deng, “Effect of trace elements on the pinhole fatigue-resistance of gasoline Al-Si piston alloy,” Eng. Fail. Anal, Vol.108, pp.104-340. 2020

[8] R. Reghunath and S. Korah, “Analysis of Internally Pressurised Thick-Walled Cylinders,” Journal of Basic and Applied Engineering Research, vol.1, no.2, pp. 88-93. ISSN: 2350-0077, 2014, Online ISSN: 2350-0255.

[9] S. A. Patil, “Finite element analysis of optimized compound cylinder,” Journal of Mechanical Engineering Research. vol. 5, no. 5, pp. 90-96., 2013, doi:10.5897/JMER10.059