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Full Length Research Paper

Simulation and analysis of innovative hand tool harvester

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There is a real need to develop a hand tool harvester since harvesting tubers of *Dioscorea hispida* (*ubi gadong*) is time tedious and consuming. The tubers were surrounded by roots, which were well gripped to the soil which made harvesting process difficult. Therefore, a new tool equipped with cutting device to cut the roots of *D. hispida* is required. The information from the experiments is used to model and simulate the tool in Computer Aided Design (CAD) environment. The solid modeling software solidworks was used for the design, modeling and simulation of the equipment and the finite element analysis to determine the stress, force and displacement were also conducted.

Key words: Simulation, solidworks, agriculture mechanization, *Dioscorea hispida* (ubi gadong).

INTRODUCTION

Dioscorea hispida, locally known in Malaysia as *ubi gadong,* is one of the most economically important agriculture products in yam species, which serves as a fast food for millions of people in both tropical and subtropical countries (Bradbury, 1988; Udensi et al., 2008; Hudzari et al., 2011). During harvesting, a hand tool is required to replace the traditional method of manual harvesting using a hoe where it required high force to operate especially in cutting the scattered roots of tubers. The farmers, when harvesting *Dioscorea hispida,* used a hoe to plow soil around the stem at a radius a bit larger than the tuber area. Sometimes the farmer had to cut the roots of the tubers using a hoe, they had to push manually. This process requires them to wear leather gloves. This process was repeated many times before the tubers were harvested. Figure 1 show tubers of *ubi gadong*. This plant is classified as a wild creeping and climbing plant which can grow up to the height of 20 m (Bradbury, 1988). *D. hispida* trees are commonly found in the secondary forests and grow under shaded areas and near river streams (Nashriyah et al., 2010).

MATERIALS AND METHODS

Reverse engineering concept was applied where it initially involved extraction of the design layout of the machine, development of schematic drawing and wireframe model, design modification in Computer Aided Design (CAD) environment, design simulation and finally, the complete drawing for fabrication purposes (Hudzari et al., 2011; Darius et al., 2003). Conceptual designs of the tools were developed and these designs are important in product development (Sarah, 2008; Sapuan et al., 2006; Sapuan et al., 2005; Sapuan and Maleque, 2005). Figures 2a-c shows the schematic design drawn using solid modeling software namely solidworks. The design consists of a T-shaped handle connected to a stepping bar and a fork. The use of the fork is for penetrating the soil easily and yet reducing resistance when pushing harvest out. A large stepping bar gives more power to push and penetrate the fork into the ground and also acts as a fulcrum as shown in Figure 3.

Material and fabrication process

The development of innovative hand tools were carried out at

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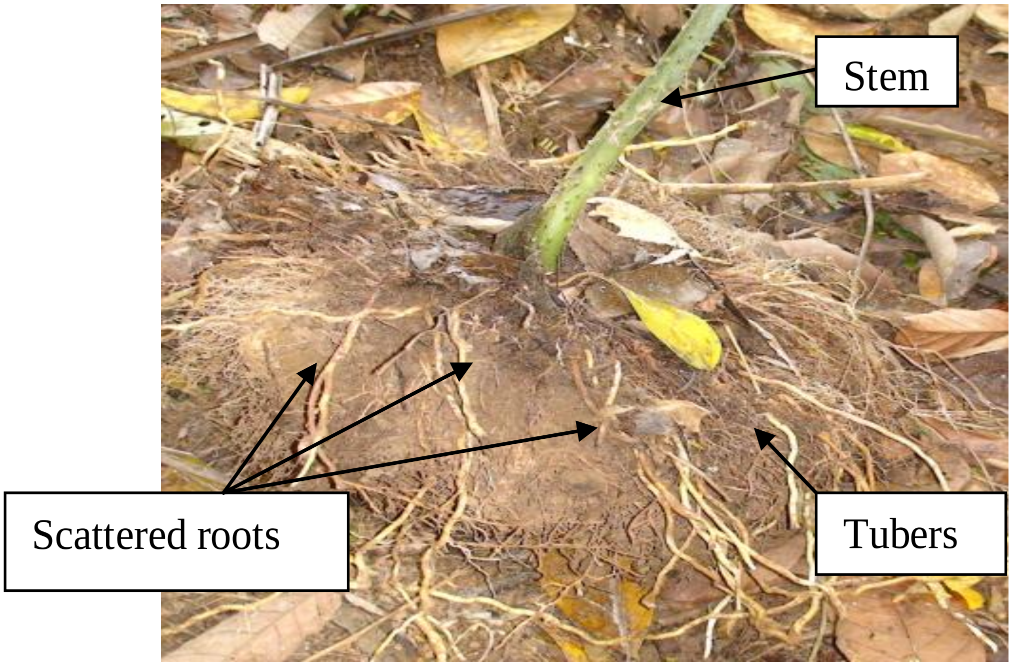


Figure 1. The tubers and stem for *Dioscorea hispida.*

Workshop Unit at the Faculty of Agriculture and Biotechnology and Faculty of Innovative Design and Technology, University Sultan Zainal Abidin, Terengganu Malaysia. The material used for the entire top part of the tool like pipe holder and press pad was mild steel. They are welded to one another and the forks comprise of sharp pointed stem and the length of them is the depth of *D. hispida* tubers. They were separated from each other by the width of about 3/8th of the width of *D. hispida*. The points are sharp and pointed downwards. The grinding and hydraulic shearing machines were used to refine the press pad, the edge of the forks and to cut the iron plate for the press pad and forks. The Tungsten Inert Gas (TIG) welding was used to join various components.

Field test and actual work

Ten *D. Hispida* plants were selected during the preliminary trial at Kg Kudat, Ajil, and Terengganu, Malaysia. The harvesting time of fruits took about 10 min. Sharpe edge or knife was required for cutting the *D. Hispida* tubers (Amir et al., 2011). Figures 4 and 5 show the hand tool set used during harvesting of the *D. hispida*.

RESULTS OF MODELING AND SIMULATION

The dimensions and properties of hand tool were defined and input into the solidworks software and relevant force data were also inserted as indicated in Table 1. The acting forces are chosen from 100N to 600N and the resulting stresses were shown in the middle part of press base indicated as A in Figure 6. The data result on the straight type of hand tool was not measured. Table 1 only show the results of minimum and maximum stress, displacement and strain for the bend and fulcrum hand tools. Otherwise the simulation and the actual designed for straight type of hand tool show that there is similarity indicating the most critical force area as indicated in Figure 6.

Figures 6 and 7 shows the results of simulation indicating the stress and displacement during harvesting process. As shown in Figures 6 and 7, the stress point is shown at the joint indicated A. This point should be modified to enhance the strength of the components such as by welding with reinforced bar. The conceptual design and simulation have a high impact on agricultural equipment especially in extracting the technology for adoption as given in (Morteza et al., 2010). For simulation on displacement distribution of hand tools, all three types of hand tools show the same point (point B) in top holder has the highest value of stress (Figure 7).

The simulation results using CAD modeling software was compared with actual field test. The stress point was not affected during field test since the tool was made of mild steel and it was strong enough to pull the *D. Hispida* tubers. The use of mild steel are acceptable for many applications such as for structural steel containing 0.16 to 0.29% carbons; therefore, it is neither fragile nor ductile with relatively low tensile power, but it is cheap and flexible for development as in this project (Peter, 1987).The actual forces required for harvesting process varied due to the differences in soil types and age of tubers and forces at different conditions must be measured. The force required during harvesting came from many directions surrounding the tubers instead of one direction used in simulation work (Yulfian, 2011). The

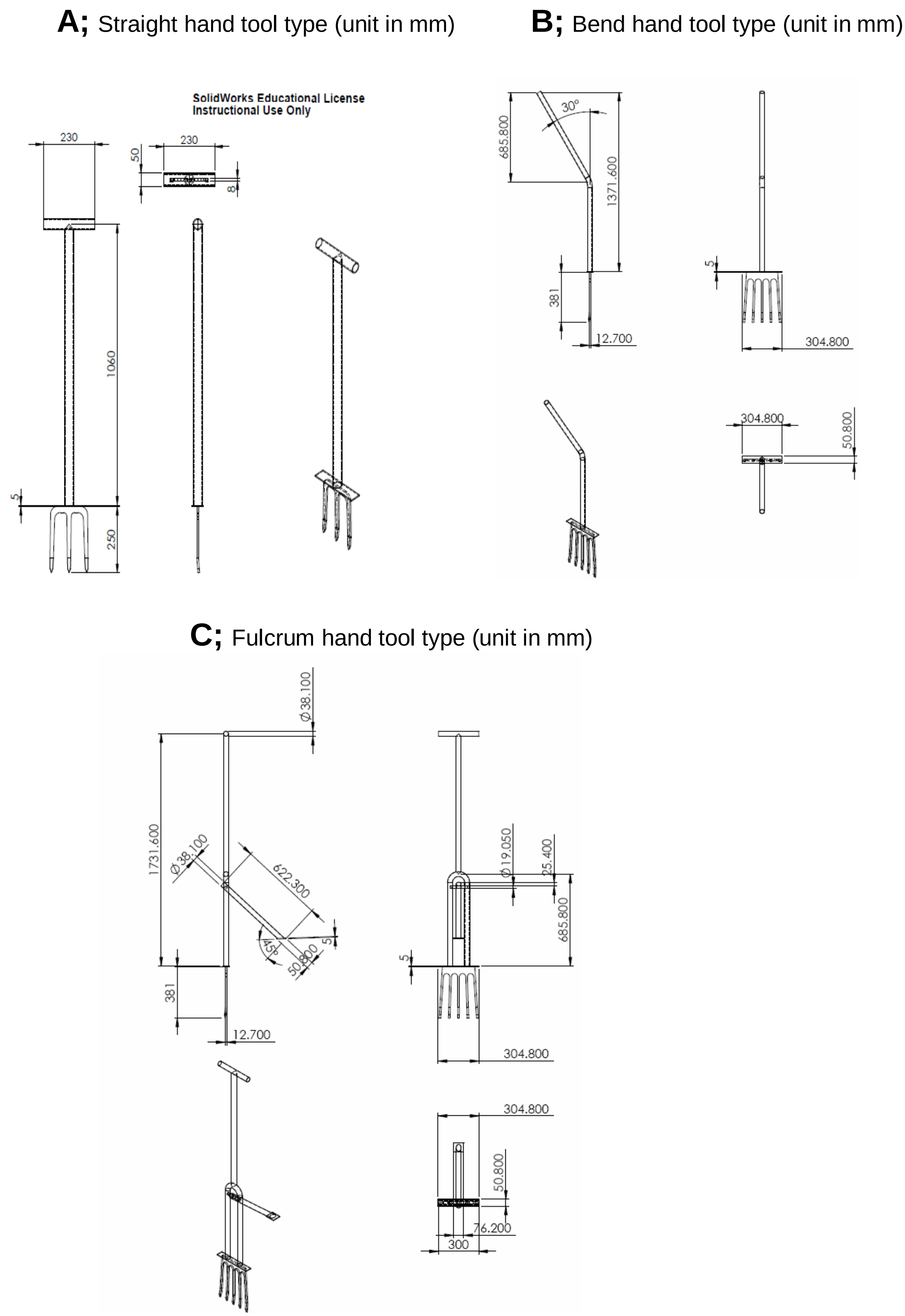


Figure 2. Three types of hand tool harvester; (a) straight, (b) bend and (c) fulcrum type.

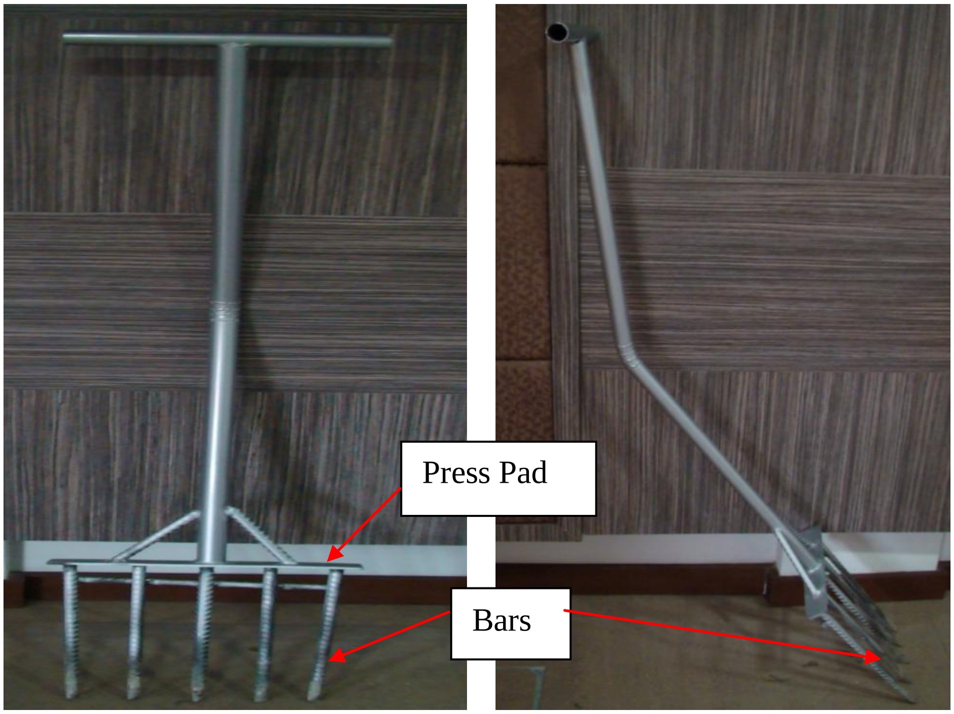


Figure 3. Design of bend type hand tool showing press pad and penetration bars.

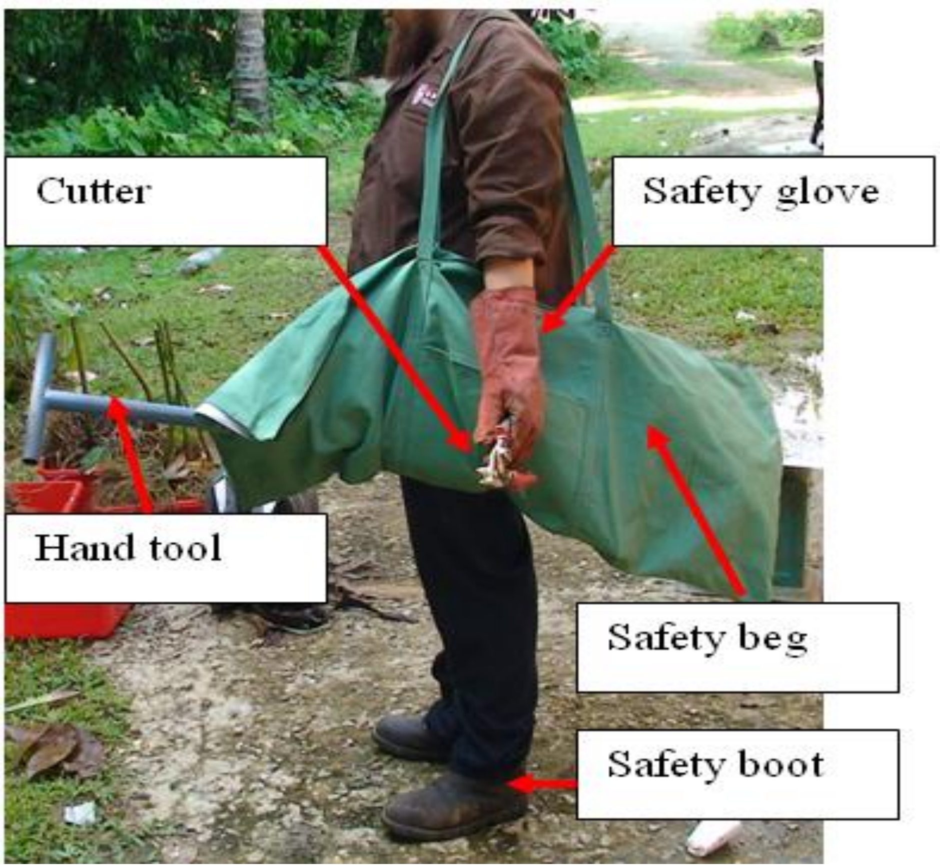


Figure 4. Tools set for manual harvesting of *Dioscorea hispida.*

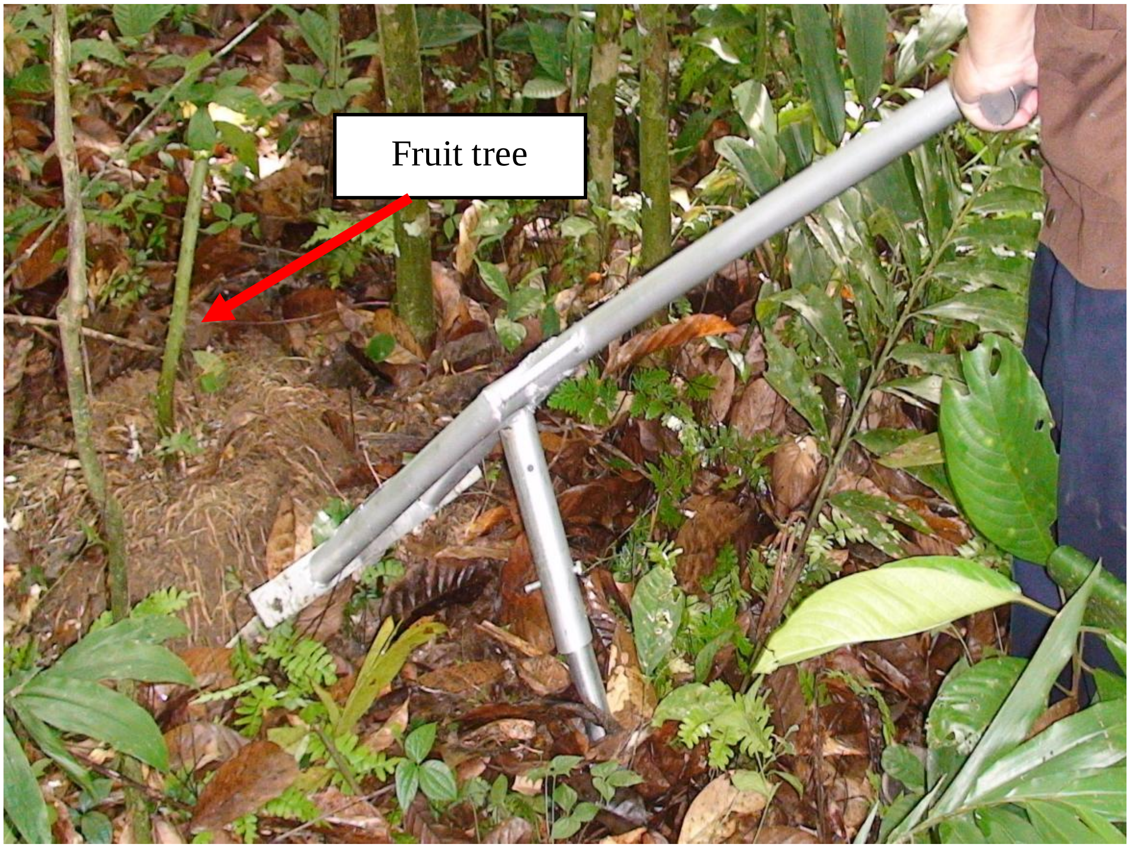


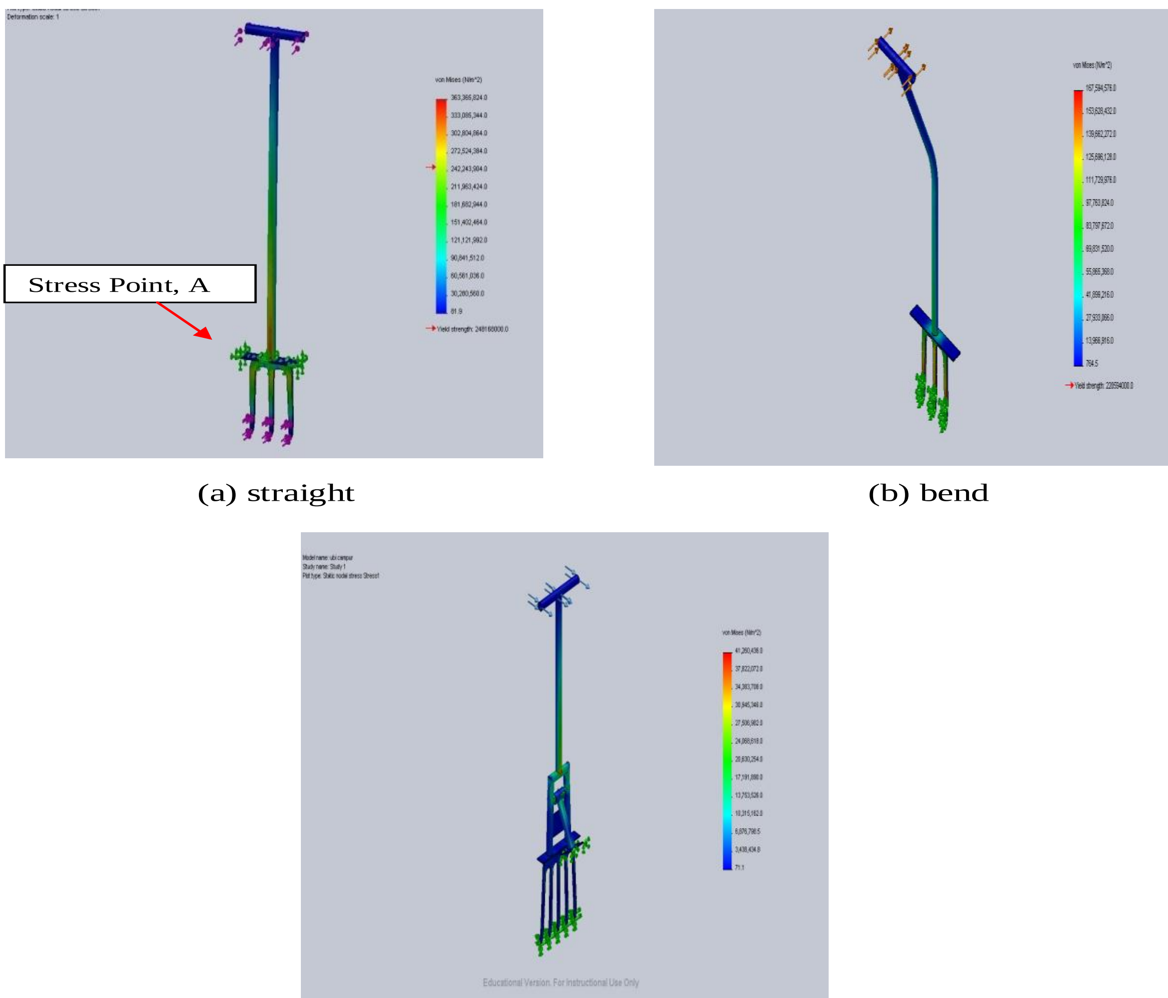
Figure 5. Penetrating and harvesting *Dioscorea hispida* plant using fulcrum type tool.

Table 1. Results of minimum and maximum stress, displacement and strain (Straight, bend and fulcrum hand tools).

Type of hand tools	Load (N)	Stress (N/m^2)		Displacement (mm)	
		Max	Min	Max	Min
Straight hand tool harvester	100	1.02E+08	7852.28	37.9718	0
	150	1.53E+08	12206.4	57.0185	0
	200	2.03E+08	16305.4	76.0251	0
	250	2.54E+08	20411.7	95.0154	0
	300	3.04E+08	23662.3	113.993	0
	350	3.54E+08	28794.7	132.914	0
	400	4.04E+08	33012.6	151.8	0
	450	4.54E+08	37337.7	170.634	0
	500	5.03E+08	41664.8	189.403	0
	550	5.52E+08	46081.3	208.103	0
	600	6.00E+08	50561.8	226.717	0
Bend hand tool harvester	100	1.68E+08	764.509	34.2407	0
	150	2.54E+08	12206.4	52.0597	0
	200	3.39E+08	1220.01	69.6902	0
	250	4.25E+08	1531.44	87.4403	0
	300	5.12E+08	1931.85	105.291	0
	350	5.98E+08	2299.15	123.23	0
	400	4.04E+08	33012.6	151.8	0
	450	4.54E+08	37337.7	170.634	0

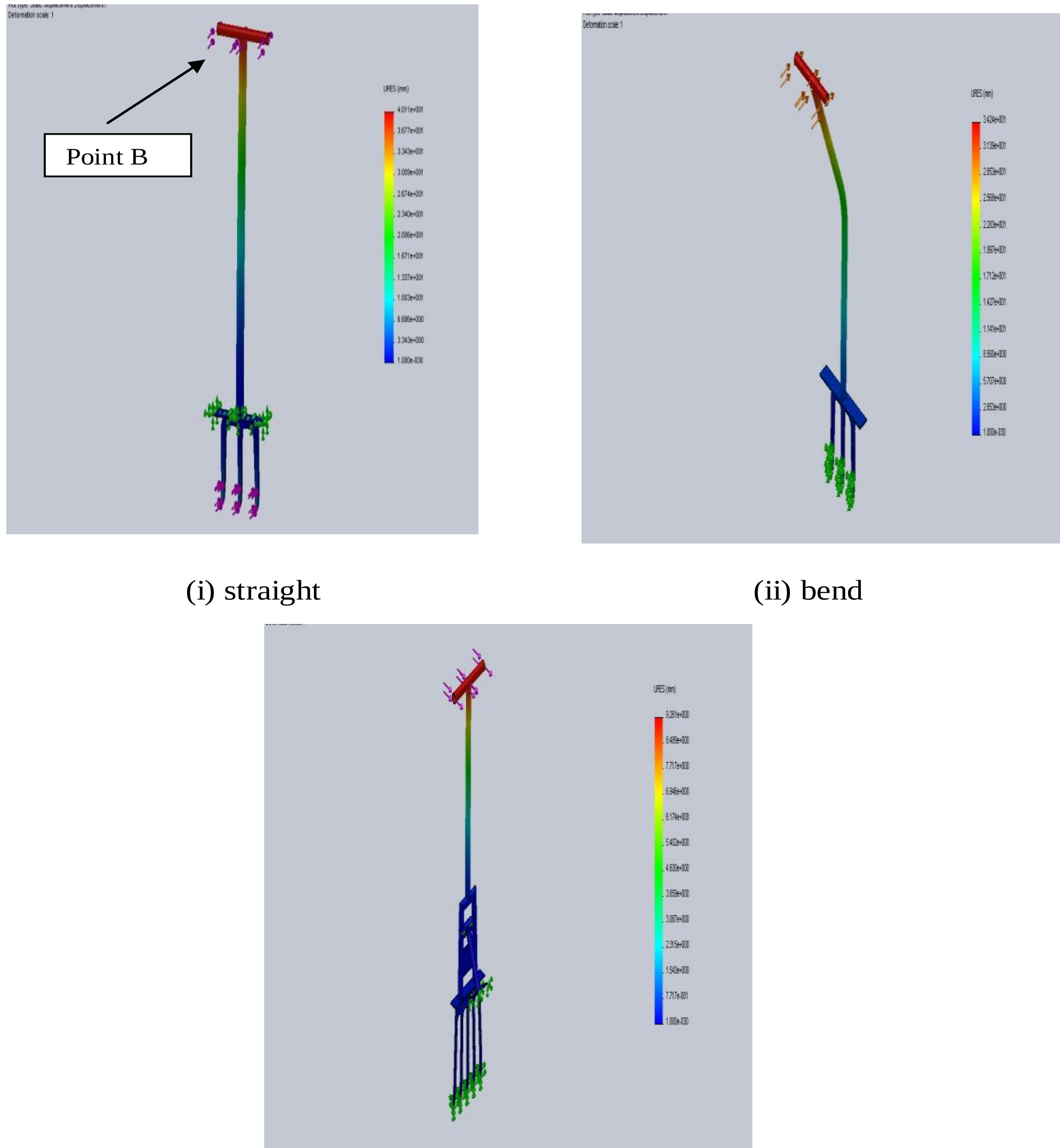
Table 1. Contd

	500	8.58E+08	3286.47	177.423	0
	550	9.44E+08	3621.72	195.558	0
	600	5.98E+08	2299.15	226.717	0
	100	4.13E+07	71.1018	2.64591	0
	150	6.19E+07	105.897	3.96887	0
	200	8.25E+07	142.204	5.29182	0
	250	1.03E+08	194.832	6.61478	0
	300	1.24E+08	211.795	7.93773	0
Fulcrum hand tool harvester	350	1.44E+08	290.574	9.26069	0
	400	1.65E+08	284.407	10.5832	0
	450	1.86E+08	342.811	11.9066	0
	500	2.06E+08	389.664	13.2296	0
	550	2.27E+08	391.414	14.5525	0
	600	2.48E+08	423.589	15.8755	0



(c) fulcrum

Figure 6. Stress distribution on hand tool; (a) straight, (b) bend and (c) fulcrum.



(i) straight (ii) bend

(iii) fulcrum

Figure 7. Displacement points at top holder of all designed hand tools.

concept of getting actual result from simulation work should cover from laboratory data which requires traditional method of analysis (Razali et al., 2008)

The simulation shown in Figure 7 reveals that the hand holder (top portion) gives the highest value of displacement which results in the user having to push the tool to a laying down flat on the surface of the ground and this actually happens during the field test. To solve this problem, the bend and fulcrum hand tool harvesters can be used. The bend and fulcrum types were further analyzed using solidworks parametric software and the simulation is very useful in the design stage before arriving at the correct fabrication of the final product (Sapuan et al., (2007).

Conclusions

It is important to replace the traditional method with hand tool harvester during harvesting of the tubers of *D. hispida* in the jungles. The solid modeling software is useful in design, modeling and simulation of such harvester. The application of technology in area of composite material and automation should be involved in product commercilization. The concept of easy handling and friendly user are the priorities in overcoming the customer target and the researcher in the university where the *D*. *hispida* research is conducted.

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