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Improvement of Lifting Mechanism of an Intelligent Additional Track System for a Swamppeat Tracked Vehicle

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Abstract: This study presents the improvement of lifting mechanism of an intelligent additional track system for a tracked vehicle. The lifting mechanism is attached to the additional track system at the middle frame of tracked vehicle. It is used to lift the additional track system upwards and downwards depend on the condition of ground surface. In previous study, a tracked vehicle with an intelligent additional track mechanism has been developed to full fill the demand of swamp peat vehicle. However, the design of link mechanism is used to move the additional track is not effectively functioning as it causes the delay and misalignment during the operation. Hence, four different concepts would be generated through morphological method in order to find a proper link mechanism. For each concept, there would be different prospects and functions of their own. Those concepts would be illustrated in design sketches and simulated through morphological diagram. Finally, the best model would be chosen and analysed.

Key words: Downwards, causes, morphologic, delay, diagram, simulated

INTRODUCTION

Development of swamp peat vehicle has been rapidly increased recently as the demand of machinery for agriculture, housing scheme and military increased due to the increasing of world population (Mohd *et al*., 2009). The vehicles need to be specifically design and can adapt the surrounding needs and requirement (Luo *et al*., 2003). Several designs have been introduced in previous research to overcome the limitation of movement in swamp peat and contribute to the related area. However, to come out with a vehicle that can survive on 7 kN/m bearing capacity of soil is a big challenge for the researchers and peoples in automotive industries as the vehicle tend to sink and stuck in that soil (Jaya, 2002). Design such as segmented rubber tracked vehicle, air-cushion semi-tracked vehicle and intelligent air-cushion tracked vehicle cannotwork effectively on the swamp peat due to the high ground contact pressure, slippage and high power consumption (Luo *et al*., 2003; Hossain, 2010; Rahman *et al*., 2005). Hence, a tracked vehicle with an additional track mechanism has been introduced to satisfy the demand of the swamp peat vehicle.

A small custom build of the vehicle has been developed for this design. Equipped with the ball-screw lifting mechanism and fuzzy logic expert system as the vehicle controller, the tracked vehicle is expected to move smoothly in the swamp peat as the additional track mechanism is used to support the vehicle from being sunk in the swamp peat (Iqbal *et al*., 2015). The additional track mechanism is designed to be unfolded on normal ground surface area and folded when the vehicle experiencing the sinkage. But some how, the lifting mechanism of the additional track is not working accordingly. It causes the delay and misalignment during the lifting process as it tends to stick on the half way and does not move smoothly. In this study, a proper link mechanism is developed to replace the existing lift mechanism in order to reduce the operation time and misalignment and improve the movement of the additional track. Based on the design requirement, morphological method has been applied in the development of the conceptual design for the new lifting mechanism. This method involved design consideration, concept design development and concept design selection. At the end of the process four conceptual designs of the lifting mechanism have been produced and the best concept design has been selected (Mansoor *et al*., 2014).

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MATERIALS AND METHODS

Design consideration: Figure 1 show the ball-screw design concept, Fig. 1 shows the design of the previous lifting mechanism for the additional track mechanism. In this design, a DC motor would drive the ball screw in clockwise and anti-clockwise direction thus initiated the movement of the lifting mechanism upwards and downwards. The ball-screw is acted as the holder for the additional track mechanism and drive mechanism at the same time. Since, there is no other support between the vehicle frame and additional track system, it causes misalignment and the movement sticks on the half way. This situation has caused the delay of the additional track movement. Hence, the new design of lifting mechanism must be strong enough to support the weight of the additional track has the ability to move upwards and downwards without much difficulty can be perfectly fitted in the middle frame of the tracked vehicle and consumes less power. Table 1 shows the list of more specific requirement in term of engineering and customer needs as a guide in developing and choosing the best concept design for the lifting mechanism.

Concept generation: The concept generation process has been carried out by using morphological method. About 12 conceptual designs have been successfully generated in order to obtain the possible upcoming design of the lifting mechanism. In order to shortlist the various designs, those designs were screening by analyzed each function or features of the lifting mechanism option as listed in Table 2 of morphological diagram. Thus, 4 concept designs left for the possible lifting mechanism design. Each of them has specific features which make them more or less desirable for different applications. The key difference is the drive mechanism which propels the working platform to the desired location.

Based on the concept generated four concept design sketches were illustrated with their specific feauters in Fig. 2:

Table 1: Engineering requirements and customer requirements

Engineering requirements	Customer requirements
Quality	Reliability
Construction of transfer device	Safety
Weight	Cheap (Cost)
Dimension	Size
Portability	Efficiency
Environment factor	Stability and flexibility
Movement	User friendly and green tech
Comfortability	Maintenance
Performance	Types
Useful life	Design

Table 2: Morphological diagram

	Product: additional track lifting mechanism			
Design features	Option 1	Option 2	Option 3	Option 4
Shape/type	Flat 45° turn	Scissor movement	Straight going up down	One side cylindrical support
Movement type	Piston	Hydraulics	Screw gear	Pneumatics
Attachment holder type	Two holder for left and right	One base holder at a point	One cylinder in middle at a point	Side holder connected

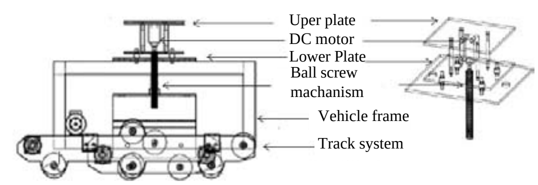

Fig. 1: The ball-screw design concept

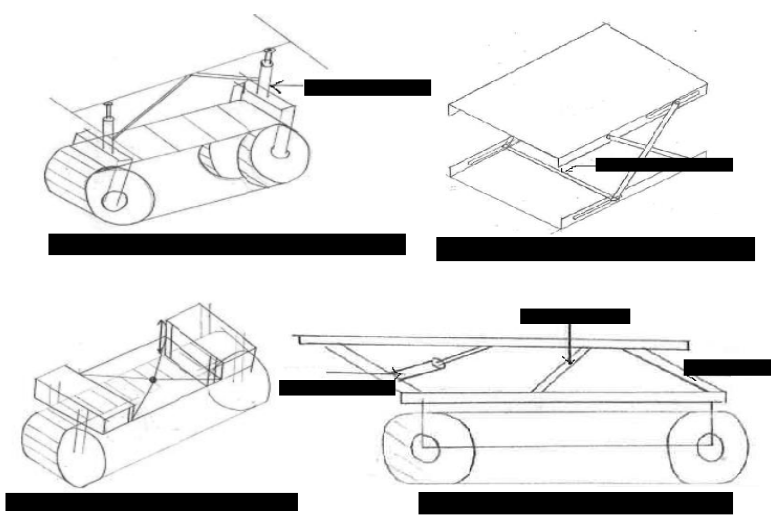

Fig. 2: Conceptual design sketches

- Conceptual design 1 illustrated two single pistons of hydraulic shafts that are vertically attached at each edge of the additional track platform
- Scissors lift mechanism between the vehicle body and the additional track platform used for the conceptual design 2
- In the 3rd concept, the electric motor would drive the trapezoidal threaded screw through a step down gearbox into a fixed nut on the lift mechanism
- In the 4th concept, fluid is controlled directly or automatically by control valves and distributed through hoses and tubes

Pugh matrix: Pugh method has been chosen as the final method to select the final design. The calculation included in this method has made it convenient for an analysis to select the final design. In this phase, concept design 1 has been chosen as the datum or benchmark for the other designs. The weight concern on particular operating condition, functional safety, working place configuration and mobility become the major key-point for the selection. Table 3 of pugh concept selection matrix shows the analysis on the design weighted score for all concepts. Based on the table, concept 2 takes up the first choice in the selection, followed by concept 4 and 3. Therefore, conceptual design 2 has been selected as the best design for the lifting mechanism of the additional track system.

Table 3: Pugh concept selection matrix

		Design concept			
Performance criteria	Weightages	1 datum	2	3	4
Portability	9	0	+1	0	-1
Reliability	9	0	+1	-1	0
Weight	9	0	+1	+1	0
Useful life	9	0	0	0	-1
Size	9	0	+1	0	0
Maintenance	8	0	+1	+1	+1
Stability and flexibility	10	0	+1	-1	+1
Maximum weight capacity	7	0	-1	-1	+1
Cost	8	0	0	+1	+1
Material	8	0	-1	0	-1
Easy to assembly	8	0	0	+1	0
Mechanism advance	6	0	-1	-1	+1
Sum of positives	-	0	6	4	5
Sum of Negatives	-	0	3	4	3
Weighted sum of positives	-	0	54	33	39
Weighted sum of negatives	-	0	21	32	26
Overall weighted score	100	0	33	1	13

RESULTS AND DISCUSSION

Finale concept design: After selecting the conceptual design 2, 3D Model of the design was generated as shown in Fig. 3. Conceptual design 2 was comprised of actuator motor and scissor lift mechanism. The actuator used hydraulic power to elevate the lift mechanism upwards and downwards. The actuator is mounted at the upper part of the lift platform to control the movement of the mid-cross bar. As for the lift platforms, two rectangular steel plate of (274×15_210 mm) was designed so that it can support up to 80 kN load. The upper plate is attached to the middle frame of the tracked vehicle while the lower plate is directly attached to the additional track system. This design also consists of four link bar that is assembled to provide the lifting movement towards the additional track.

Stress-strain analysis: Stress-strain analysis was carried out for the cross-bar of the final design concept. This stage is important to obtain the most suitable size and material for the cross-bar. This part was chosen to be analyzed as it experiences the maximum stress during the operation. In this analysis, three different materials; steel AISI 1020, aluminum 1060 alloy and brass with three different thickness of link bar: 5 10 and 20 mm were used.

Figure 4 shows an example of the stress analysis done on the 5 mm thickness of link bar. The colors in this analysis represent the level of stress experienced by the link bar when a certain value of load applied on the lifting mechanism. The maximum stress experienced by the link was illustrated in red color while the minimum stress experienced by the link was represented in blue color. Figure 5 and 6 shows the simplified analysis done in

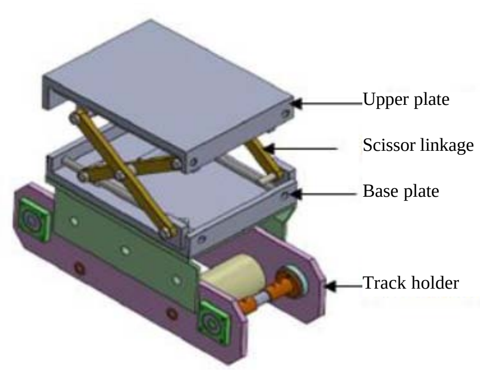

Fig. 3: The assembly drawing of scissor lifting mechanism based on concept 2

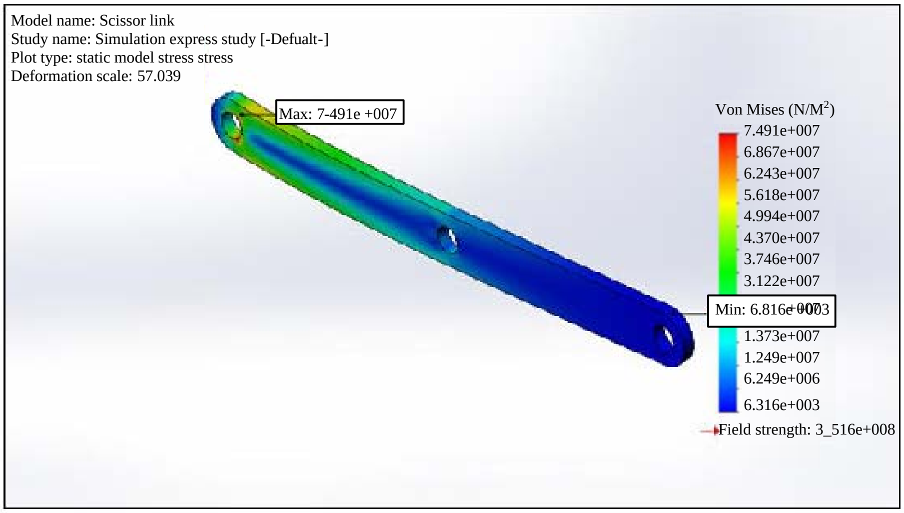

Fig. 4: Stress analysis study for 5 mm thickness of scissor bar

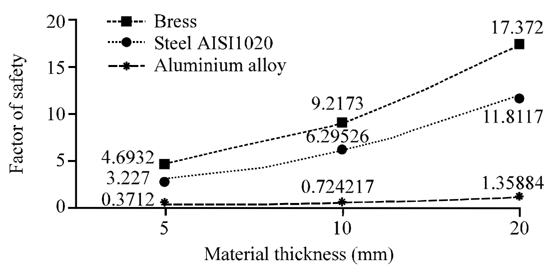

Fig. 5: Changes in factor of safety with the variation of material thickness with constant load

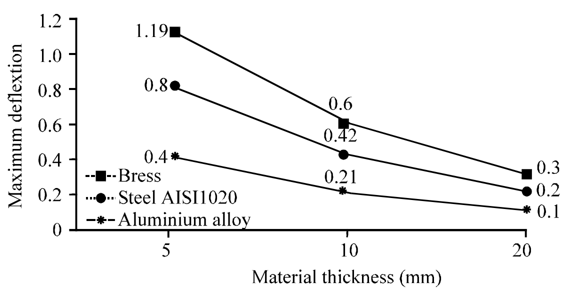

Fig. 6: Changes in maximum deflection of three different materials compared by the variation of material thickness with constant load

graph line based on the stress-strain analysis. The analysis was done in term of safety factor and deflection level.

The factor of safety is defined as the maximum strength of the system in compared to its steady load applied in daily application. In Fig. 5 and 6, the line graph pattern shows that as the link bar thickness increases, the factor of safety of the design also increases. The link bar with 20 mm thickness provides maximum value of the safety factor compared to the others bar with thickness of 10 and 5 mm This means that, the bar thickness influenced the strength of the design to support a certain value of load. As for the materials, the steel AISI 1020 gave the higher value of the safety factor compared to brass and aluminium 1060 alloy. This results shows that, the steel is more reliable materials in producing the best design of the lifting mechanism. Hence, the bar link with thickness of 20 mm and steel AISI 1020 was chosen to develop the lifting mechanism for an additional track system.

The graph of the maximum deflection against material thickness shown in Fig. 6 gives different pattern of outcomes. Based on the line graph, the deflection of the link bar decreases as the bar thickness increases for all materials. Followed the results from the safety factor, the bar with materials of steels AISI 1020 gives the lowest value of 0.1 mm for the deflection when a certain value of load was applied on it. While the aluminium alloy provided the highest value of deflection with 1.19 at 5 mm link bar thickness. Brass remains as the second option as the value is ranged between the steel AISI 1020 and the aluminium alloy. From both results, it can be concluded that the link bar with 20 mm thickness and material of steel AISI 1020 would provide the highest safety factor and lowest deflection for the lifting mechanism design.

CONCLUSION

The design concept was developed to improve the lifting mechanism of an additional track system for a tracked vehicle. Several features with different function were introduced accordingly in acquiring the best lifting mechanism design. The design process went through with concept generation and selection with evaluation. Three winning concepts were chosen from morphological table. Then, these design concepts are screened through the Pugh matrix to obtain the best design. 3D Model of the best design was presented using solid works. From this study, conceptual design 2 was chosen with scissor lifting mechanism concept using hydraulics power as the drive force. The stability of the lifting mechanism was evaluated using stress-strain analysis and justified in term of safety factor and maximum deflection. The scissor lifting mechanism using 20 mm bar thickness and steel AISI 1020 as the materials give the best design of the lifting mechanism. Last but not least, the objectives of this study have been successfully achieved.

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