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Full Paper

Vehicle jack with wedge mechanism

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Abstract: In many developing countries, particularly Nigeria, the high cost of production of a vehicle jack and the prevailing economic situation has made the commercial production of vehicle jacks difficult. Thus, the development of an appropriate technology for a vehicle jack would be of vital utility to vehicle users. This paper presents the design and construction of a low-price, simple mechanical jack with wedge mechanism to provide a lift of about 160 mm with a self-locking capability for both small- and medium-sized vehicles. The design calculations involve the evaluation of applied force required, the screw shaft design, and the lift head design analysis. The fabricated jack was tested on some small and medium vehicles, which resulted in a good lift without any pre-manual lifting. The jack weighs about 4 kg and costs about ₦1000 per unit.

Keywords: vehicle jack, screw system, wedge mechanism, vehicle lifting

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Introduction

A very important repair tool in the automobile industry is the vehicle jack. Essentially the jack is used in raising a vehicle sufficiently above the ground to remove tyres when required. A vehicle owner without a jack will, at an unguarded moment, suffer loss in time, finance and energy. Although the vehicle jack does not contribute directly to the smooth running of a vehicle engine, yet its availability is crucial during tyre deflation.

There are two broad types of vehicle jack that can be obtained in practice, viz. the mechanical type and the hydraulic type [1, 2]. The mechanical jack can be of the scissors type or of a simple screw jack. When the scissors jack is placed in position under a vehicle, the rotation of the handle causes the frame to rise, thus producing a lift of the vehicle. When it is not in use (unload condition), the handle is given reverse rotation, which collapses the frame and makes it compact enough for packaging. For a simple screw jack in operation, two gearwheels are meshed so that their shafts are at an angle of 90^o to form a bevel gear. One gearwheel locates the handle while the other contains an internal thread in its bone that meshes with the load screw. By rotation of the handle, the driving gearwheel is rotated and this is transmitted to the driven gearwheel, which also induces a lift of the load arm and consequently a lift of the vehicle. The second type of the vehicle jack, the hydraulic type, has its lift provided by hydraulic fluid forced against the load head by a reciprocating motion of the handle. This jack has a higher mechanical advantage compared to mechanical jacks.

Three possible factors militate against the purchase and use of a jack. First the cost is a crucial factor that limits the purchase of a vehicle jack. It is known that in the present circumstances of many developing countries, the prices of imported vehicle jacks are high, thus limiting the number of potential buyers to the few. The second factor relates to the fact that failure encountered in some jacks is more frequent and effective repair difficult. For instance, in the scissors jack excessive load acting on the driving screw frequently causes wear on the screw. Repairs as locally done on this jack involve re-threading the screw and/or welding of the shaft when there is breakage, whereas a more effective approach is to reproduce the square threaded screw shaft or at least order for spares that are not easily disposable to the local metal shop. The third problem confronting the use of vehicle jacks relates to inadequate facilities and personnel. A commercial production fulfilling all design requirements of existing jacks requires special equipment which includes a thread-rolling machine, a gear hobbing machine and other facilities. All these are expensive and technical personnel required are scarce. It is important to note that while vehicle jacks exist in their varieties, a consideration of another option, a wedge jack, that may be used in a developing country is reasonable. The literature on this type of jack seems to be either nonexistent or poorly documented. This is the motivation for the current paper. In particular, this paper presents the design and construction of a low-priced, simple wedge jack to provide a lift of about 160mm with a self-locking capability for both small- and medium-sized vehicles.

Design and Development

By considering all the problems discussed in the previous section, a proposal is now made on the possibility of designing and developing a wedge jack that can be used for vehicles in developing countries. At this stage, it is important to describe the vehicle wedge jack designed and developed. The jack consists of five main parts, viz. the lift head, the sliding wedge, the driving screw, the handle, and the jack body (Figure 1). The lift head is constructed of a mild steel pipe capable of supporting compressive load from the vehicle. The contact surface is cylindrical and coated with high lubricating fluid. In constructing the sliding wedge, a flat steel bar is used with a black hole to locate the drive nut. The slope angle is kept at 45^o to minimise space. For the driving screw, the forward and backward movements of the sliding wedge are provided by a threaded shaft that is located via a bushing. The screw is made of hardened steel to withstand excessive wear and loading. At the slotted top of the screw is the handle. The handle transmits motion and energy from the user to the load. By constant clockwise rotation of the handle, the sliding wedge is driven forward and this induces a vertical motion

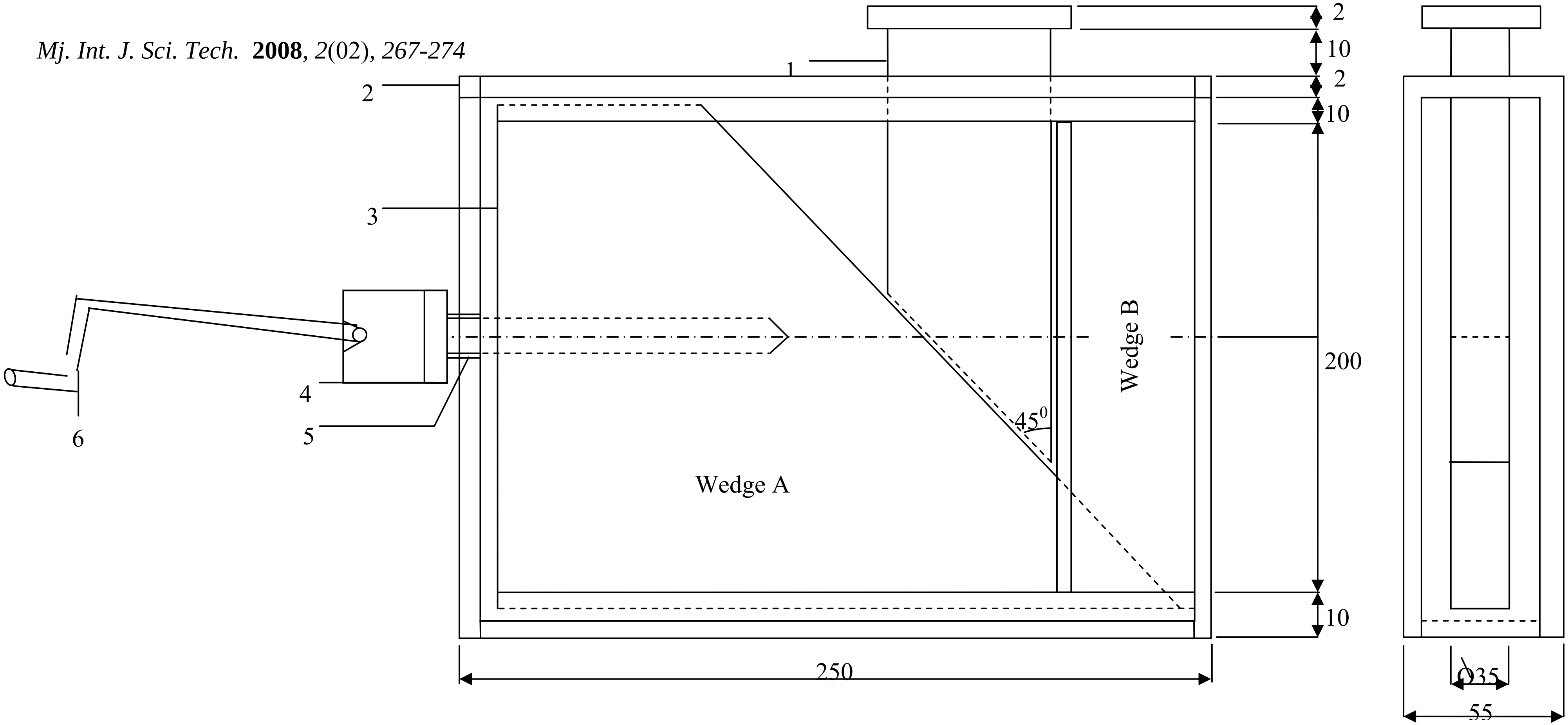

Figure 1. Wedge jack and components
All dimensions in millimeters. (For all other unspecified dimensions, use 5 mm.)

Part no.	Description	Quantity
1	Lift head body	1
2	Body	1
3	Sliding wedge	1
4	Slotted screw	1
5	Driving nut	1
6	Handle	1

on the load head giving the desired lift. The handle axis lies at different inclination to the horizontal resulting in the estimated mechanical advantage of about 120 based on ergonomic and other considerations. The handle is made of a steel rod with a welded pin at the end to locate the slot on the driving screw. The jack body is fabricated from a 2-mm flat bar. A back plate locates the bushing from which the screw rotates. The front portion is uncovered to allow the sliding wedge to traverse the whole length. The lift head guide is welded to the top cover of the body.

Consideration is given to the fact that a low technology product is desired for ease of use. It has to be cheap, light, potable, and operated with minimum effort. It is desired that the jack provides a lift of about 160mm. In order to obtain the design data, reference is made to Bosch Automobile Handbook [3]. Tables 1-3 were complied from Bosch Automobile Handbook 2 [3]. From Table 1, it is observed that the minimum ground clearance for common passenger cars is 120 mm.

Table 1. Ground clearance for common passenger cars in Nigeria [3]

Type of car	Ground clearance (mm)
Audi CC	120
BMW 318	125
BMW 524	140
Escort 1.4 cc	140
Sierra 1.8 GL	120
Peugeot 505 GR	120
Peugeot 305 GLD	120
Renault R4 GTL	175
Accord Ex	160
Mazda 323 Lx 1.3	150
Toyota Corolla 1.3 GL	160

Thus, in essence this implies that the maximum height of the jack cannot be more than 120mm, otherwise it will be physically impossible to place the jack directly under the chassis before providing a manual lift. Equally, from Table 2, the maximum inflated tyre thickness which constitutes the minimum lift for clear raising from ground is 130 mm.

Table 2. Inflated tyre thickness for some selected passenger cars [3]

Type of car	Inflated tyre thickness (= minimum lift) (mm)
Audi CC	116
BMW 524	123
Peugeot 505 GR	123
Sierra 1.8 GL	116
Accord Ex	130
Mazda	109
Toyota Corolla 1.3 GL	123

This also constitutes a useful guide in jack proportioning in the design data. The maximum weight from the range of vehicles tabulated in Table 3 is 1,660 kg. Since about 2/3 of the weight will be on the engine side, and this will equally be shared between the two tyres at the engine side, the maximum load on the jack (W) will be 610 kg.

Table 3. Curb weight and maximum weight for selected passenger cars in Nigeria [3]

Type of car	Curb weight (kg)	Max weight (kg)
Audi CC	950	1410
BMW 524	1310	1810
Peugeot 505 Sr	1215	1655
Sierra 1.8 GL	1065	1600
Accord Ex	1105	1660
Mazda	880	1450
Toyota Corolla	865	1385

At this stage, an evaluation of applied forces is done. The forces are evaluated from the standpoints of wedges A and B, which are indicated in Figure 1. The basic equations for the evaluation of applied forces, as presented by McGill and King [4] are as follows:

(Nomenclature: μ = coefficient of friction
F_1, F_2 = frictional forces
N_1, N_2 = normal forces
P = applied load
W = vehicle load
D = diameter of shaft
D_i = linear diameter of shaft
D_o = outer diameter of shaft
FS = factor of safety
θ, α = angle of inclination
E = modulus of elasticity
L = lift distance
π = 3.142
W_{cr} = critical load to cause bucking
P_{cr} = critical applied load)

For wedge A (see Figure 1), summing up forces along the x-axis yields

$$P - F_1 \cos\theta - N_1 \sin\theta - F_2 = 0 \quad (1)$$

$$F_1 \sin\theta + N_2 - N_1 \cos\theta = 0 \quad (2)$$

$$F_2 = N_2 \quad (3)$$

$$F_1 = \mu N_1 \quad (4)$$

For wedge B (see Figure 1):

$$N_1 \sin\alpha - F_3 - P = 0 \quad (5)$$

$$N_1 \cos\alpha - N_3 = 0 \quad (6)$$

$$F_3 - \mu N_3 = 0 \quad (7)$$

By substituting (3) and (4) into (1) and (2), also substituting equation (7) into (5), four basic equations are obtained as follows:

$$P - \mu N_1 \cos\theta - N_1 \sin\theta - N_2 = 0 \tag{8}$$

$$\mu N_1 \sin\theta + N_2 - N_1 \cos\theta = 0 \tag{9}$$

$$N_1 \sin\alpha - \mu N_3 - W = 0 \tag{10}$$

$$N_1 \cos\alpha - N_3 = 0 \tag{11}$$

These equations are solved for input values of θ, α, μ and W. The next stage is to utilise specific design values of $\theta = 45^0$ (for minimum traverse length), $\alpha = 45^0$ (lift head being vertical), μ = 0.20 (metal to metal contact), W = 7982N (actual load x FS) (vehicle load), where FS is the factor of safety given as 1.5. Now, by substituting these values in the set of equations (8) to (11), we obtain P = 5096N, which is the load on the screw required to advance the screw in the direction of loading. For the screw shaft design, the screw is treated as a column subjected to the point load P. The critical load to cause bucking, defined as W_{cr}, is expressed as

$$W_{cr} = \frac{\pi^3 E D^4}{256L} = P \tag{12}$$

Given that E is the modulus of elasticity of the material, and L = 160mm (minimum lift + 30 mm), then D is obtained as 15 mm. This is the required screw diameter to transmit the load applied. The lift head is another item to design. The lift load is treated as a column. Thus, the governing equation used, represented as P_{cr} or W, is defined as follows for the hollow section:

$$P_{cr} = W = \frac{\pi^3 E(D_o^4 - D_i^4)}{256L} \tag{13}$$

By substituting appropriate values and solving iteratively, this yields D_o = 35mm and D_i = 30mm.

Product Fabrication and Test

Based on the design proposed above, a model jack was fabricated and tested on some common passenger cars found in Nigeria, which have low and medium ground clearance. The material used for fabrication were mainly steel plates and iron rods. Test results show that the jack gave a good lift without any pre-manual lifting. Also, the jack weighs about 4 kg, which is an acceptable weight in comparison with other kinds of mechanical jacks (Table 4). The information provided in Table 4 also ascertains that a cost of ₦1,000 ($1 = ₦125) is within the range for other mechanical jacks. However, the large-scale production of this specimen is expected to considerably reduce its production cost to a very competitive price.

Table 4. Cost and weight comparison of some jacks [5]

Type of jack	Weights range (kg)	Cost range (₦)
Mechanical	2.5-4	1000-3000
Hydraulic	2.5-5	1000-2500
Designed wedge jack	4	1000

On a careful observation, the merits derivable from the production of the jack fall into three classifications: operation performance, manufacturing techniques, and self-locking capability. For its operational performance, it is noted that failure in the driving screw could not be rampant because the dead load is not directly acting on it, which in turn minimises wear. The basic manufacturing required offers benefits in terms of manufacturing. The techniques required are welding and machining, thus making it easier to produce in a machine shop and consequently reducing the level of skillful personnel required. In addition, on operation the jack is automatically self-locked by the wedge base and has near-zero danger level of unloading the system. This may be induced in some jacks by worm thread or gear teeth.

Conclusions

A vehicle-lifting technology has been developed, which is an option that might be easily adapted in developing countries. The wedge jack which has been designed, fabricated, and tested offers a comparatively good performance as well as a comparative price range and certain advantages. It is believed that the use of wedge jack will make a positive influence on the vehicle-lifting industry. Since the novelty of the work lies in the fact that this is the first time that the current design is reported in a systematic way, several directions of thoughts needs to be investigated in future studies to make the product mature.

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References

1. P. Gallina, "Vibration in screw jack mechanisms: experimental results", *J. Sound and Vibration*, **2005**, *282*, 1025-1041.
2. M. S. Garcia, M. Nouillant, and P. Viot, "Study and improvement of a high speed hydraulic jack", *J. Phys. IV France,* **2006**, *134,* 775-781.
3. BOSCH Group, "Automotive Handbook", 1st English Edn., Dept. of Technical Publications, Stuggart, **1976**.
4. D. J. McGill and W. W. King, "Engineering Mechanics-Statics", 2nd Edn., PWS-KENT, Boston, **1989**, p. 403-408.
5. O. E. Akingbemen, "Design and construction of mechanical jack using wedge mechanism", Unpublished Final Year Undergraduate Project, University of Ibadan, Nigeria, **1995**.

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