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Development of Manually Operated Tyre Debeading and Insertion Device

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Abstract: The process of tyre removal as it is being done in developing economies before repair and replacement after repair requires so much human effort and is prone to accident. This article reports the development and testing of an improved technology which is a modification on the existing technology for bead breaking, tyre removal and insertion which overcomes a significant percentage of the drawbacks of the technology currently in use. The development considered the ease of operation, direction of application of force and the amplification of input effort. Performance evaluation was carried out for tyre of rim sizes 14 and 15 inches and the results show that the overall time taken for the entire bead breaking and tyre insertion process is shorter than that required for conventional bead breaking device.

Keywords: Tyre, bead, removal, insertion, performance evaluation

I. Introduction

The automobile industries in most economies are major drivers of economic growth due to its catalytic role and the diverse nature of its input and unlimited nature of its end products which has led to the development of many people acquiring skills to match the requirements of the industry [1]. One of such skill involves the repair of damaged vehicle tyres. The repair of damaged vehicle tyres is also known as vulcanizing is done by vulcanizers.

The earliest tyres were bands of leather, and then iron (later steel) placed on wooden wheels used on carts and wagons to prevent wear and tear of the wheels [2]. The first set of rubber tyres were in the 1800s. Tyre companies were first established in the early 20th century and grew in conjunction with the automobile industry [3].

The materials of modern pneumatic tyres are synthetic rubber, natural rubber, fabric and wire, along with carbon black and other chemical compounds. They consist of a tread and a body. The tread is the part of the tyre that comes in contact with the road and hence, provides traction while the body provides containment for a quantity of compressed air.

Damage to the pneumatic tyres of a vehicle is a very common occurrence. The process of fixing a damaged vehicle tyre involves the addition of new raw rubber to a damaged area of a tyre to create a repair suitable for the rest of the tyres road life. Before the tyre of a vehicle can be repaired, the tyre needs to be separated from the rim, a process known as bead breaking or de-beading, followed by the removal of the tyre from the rim and finally the insertion of the repaired tyre back on the wheel.

In the repair of damaged vehicle tyres, a very important stage is the bead breaking which involves the breaking of the bond between the bead and the rim, this process is known as bead breaking and the equipment used in breaking the bead is known as a bead breaker. The tyre bead breaker produces a force, which acts downward on the bead area of the tyre usually placed on a solid structure.

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The combination of the tyre and rim is one of the most important parts that make up an automobile [3]. The part of the tyre that is in direct contact with the rim is known as the bead. When the tyre is inflated, the bead is securely fixed against the rim and it helps in ensuring that the tyre is not shifting circumferentially as it rotates. It also serves the function of sealing against loss of air in tubeless tyres.

The bead can easily be argued as one of the most important components that make up a tyre [4]. Without the tread, a vehicle can still travel on an inflated tyre, but without a tyre bead that is functioning well, a tyre could not stay securely on the rim and as a result, the tyre is rendered useless. The tyre bead is the inner circle of the tyre; the part of the tyre that connects the tyre to the rim and holds the entire wheel together.

The use of power tyre removal and insertion device is limited in developing countries due to the high cost resulting in the use of traditional tyre changer which is very tedious with the operators being susceptible to varying degrees of musculoskeletal injuries to the shoulder, lower back, wrists and arms [5,6]. Traditionally, the process involves bending, twisting, hard pressing and twisting making it time-consuming and tiring. Also, the hand tools employed for tyre removal sometimes damage the tyre and rim if not properly handled necessitating the service of very skilled and experienced operators [5].

Locally fabricated bead breaker commercially available in Nigeria and most developing countries operate on the principle of the third-class lever. Here, the force required to break the bead of a deflated tyre (load) is situated between the effort and fulcrum. The major parts of this tyre changer which is manually operated are the effort arm, the fulcrum, the pole, the bead breaker edge support, the bead breaking edge (bow-shaped), and a rigid base [3]. The effort arm is fabricated using a steel pipe and is attached to the bead breaker edge support using a pin joint thereby allow for a swinging motion of the bead breaker edge support while the bead breaking edge is welded to the rigid base. This equipment is very simple to construct and very affordable, however, it requires a very great effort to operate the equipment. Apart from the effort required to break bead in existing bead breaker, more effort is also required to rotate the tyre on the base of the device since it may be necessary to break the bead in more than one point before the tyre can be removed sometimes. The device also makes the operator bend in an awkward position to achieve the required bending effort due to the height of the bead breaker above the ground. The process of bead breaking using the locally fabricated device also result in damage to the tyre and rim since the base of the tyre changer is very close to the ground leading to sand and other particles adhering to the surface of the particle. Authors [7] redesigned manually operated tyre changer by incorporating additional levers to it. This modification reduced the effort required for breaking the bead.

Most artisans involved in the repair of tyre in Nigeria are focused only on the money obtained from the process without any consideration for the technicalities involved and energy required for the process which has an overall impact on their health and well-being. Due to the limitations inherent in conventional bead breaking device, this study fabricated an improved manually operated tyre de-beading device to reduce the drudgery involved in the process and improve the overall efficiency of the process.

II. Literature Review

The simplest and least expensive method of tyre removal is known as the rubber mallet technique although it is the most labour intensive. It involves hitting the edge of the tyre severally with the aid of a rubber mallet until the tyre falls off the rim [3]. This method is no longer in use except in situations where there is no alternative. Another crude and dangerous method is the drive over technique, the deflated tyre requiring repairs is placed in a position in-line with a fully inflated good tyre on a vehicle, the vehicle is then driven over the edge of the tyre in such a way that it does not climb the rim thereby forcing the tyre bead off the rim [3]. This method„ has the disadvantage of causing injury to the car or people nearby since the tyre has the tendency of hitting the car or flying off during the process.

The high-lift jack technique also described by [3] is similar to the drive over technique but less dangerous. Here, the deflated tyre is placed under the bumper of the vehicle with the jack placed between the tyre and the bumper in such a way that the base plate of the jack is very close to but not touching the edge of the rim. The activation of the jack thereafter separates the tyre from the rim. However, extreme care must be taken because there could be an uplift of the tyre on the side opposite the jack and the base plate may damage the sidewall of tyres.

Several bead-breaking improved technologies are in existence such as the screw-operated, electrically powered and heavy-duty pneumatic and hydraulic bead breakers. [5] reported on various machines for tyre removal and fitting on the rim of a wheel. They gave the basic idea about the effort required for pressing the tyre by manual operations and they also gave an idea on the construction for the model, various machine parts and new mechanism that can be employed. [8] discussed the screw theory-based approach for the analysis of flexible joints using wire and sheet flexure, their focus was on the design of a flexure system having a simple geometry.

An entirely mechanical lightweight economical tyre bead breaker which can be conveniently operated with a single hand wrench was developed by [9]. A wide variety of tyre sizes can be serviced by the tool. A clamping screw and cooperating clamp bar unit forces three wedges between the tyre bead and rim. The recentre wedge is then driven away from the rim flange to dislodge the tyre bead through the operation of a breaker screw.

[10] developed an automated tyre changing equipment utilizing a positive contact force generated between the rims of the wheel and bead breaking device to break the tyre bead seals. The equipment provides for more effective tyre bead breaking by reducing the time and effort expended by the operators than the conventional machines.

A pneumatic bead breaker designed for agricultural, all-terrain, small off-the-road truck tyres was developed by Pneumatic bead breaker [11]. It requires a minimum pressure of 85 psi for operation. It is used by connecting the device to an airline and adjusting the collar to the desired width based on the thickness of the wheel. It is very fast and saves time compared with other conventional bead breakers. Electriforce bead breaker [12] developed a patented system which provides the most powerful, speedy and universal bead breaking system, its electric operation being controlled by 2 'in' and 'out' thumb-operated buttons situated conveniently on the handle.

III. Materials and Methods

This paper developed a device for breaking the bead between the tyre and the rim, removal of tyre and insertion of the tyre after repair thereby reducing the human effort and time required in repairing of car tyres.

A Principle of Operation

The designed tyre removal and insertion device is shown in Figure 1 below. The breaking process begins with the setting up of the base structure on which the tyre rests into the slot provided on the floor of the frame (3). After the base structure has been fitted, the tyre is positioned suitably so the bolts go into the required holes on the rim and then a nut is used to keep the bolts in place. The base structure is then moved in the slot to the position where the press bar falls in the bead area of the tyre. The control lever (1) welded to the gudgeon pin is then brought down so the protruding part on it rests on the top of the plunger (2). At the rear end of the control lever is where the effort is applied, one that pushes the breaker (plunger and press bar) down to break the bond between the tyre and the rim. The control lever is helped back up automatically by the tension spring (6) around the plunger which pushes the breaker and control lever back in place each time effort is applied at the rear end on the control lever. After the bead has been broken at a side, the tyre is rotated so the edge of the press bar falls on another area. This is repeated until all bonds round the tyre have been broken. The tyre is then flipped over to the other side and the same processes are repeated.

After the beads on both sides of the tyre have been broken, the removal of the tyre starts by moving the base structure with the tyre on it through the slot to the free side of the frame. Insertion of the flat end of the picker rod (4) into the space between the tyre and the rim ensuring it's tilted upwards then takes place. After a firm position has been attained with the flat end of the picker into the tyre, the tyre gets rotated so the picker goes round it to ensure removal of the tyre. After that has been done at the top side of the tyre, the flat end of the picker, following the earlier process, gets inserted all the way through to the bottom surface of the tyre and then rotation of the tyre takes place again, holding the picker rod firmly in position. The geometry at the other end of the picker is used to fit in a new tyre into the rim.

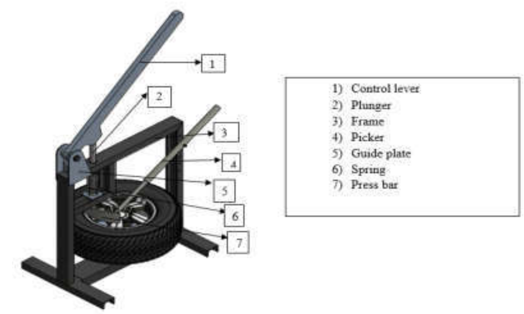

Figure 1: Tyre Bead Breaking, Removal and Insertion Device

B. Design Procedure

The operations taken in achieving the fabrication of the vehicle tyre bead breaker are discussed below. Workshop operations including marking out, cutting, welding, etc. relating to how the tyre bead breaker was achieved are discussed.

i. Marking Out

This is the process of transferring the design to the workpiece. The marking out operation was done on the c-channels, circular plates, rods, and pipes. The marking out tools used to transfer the designs to the workpiece includes; scriber, metre rule, measuring tape, callipers, ruler, etc.

ii. Cutting and Drilling

After the marking out operation has been completed, the workpieces on which the marking out was done are then cut and drilled according to the dimensions marked out on them. The plasma cutter was used to provide the slot in which the base shaft slides in. The workpieces are clamped in a stable position before the cutting and drilling took place. Holes were also drilled onto the base shaft to allow for the bolts that go through it for keeping the tyre stable on the base. The cutting and drilling tools used includes; angle grinder, electric hand drill, plasma cutter.

iii. Welding

The welding process began after the workpieces have been cut and drilled into the respective shapes and sizes. The frame or the structure of the tyre bead breaker was welded together using the arc welding machine with steel electrodes. The press bar, consisting of two 4mm plates welded together to give a strong bar was welded to the base of a plunger that goes through a hole provided on the frame with bracings provided to ensure a more rigid connection between both components. An 8mm square rod was welded to the plunger at a certain distance, as a means to keep the plunger in place. The guide plates, which hold the gudgeon pin to which the control lever was welded to were also welded onto the top of the frame. The base plate, made of two 4mm plates on opposites of a circular bracing provided was welded to the base shaft. The base plate and base shaft are the assemblies on which the vehicle tyre is supported on. The base shaft was provided with a bushing underneath. The bushing below the base shaft was attached to it using a bolt that goes into a hole treaded by employing tap and die in the base shaft. Welded to the floor of the frame are doubled 4mm plates, to a height which leaves little clearance between it and the base plate when fitted into the slot, to prevent racking of the base plate when press bar acts on the tyre. The picker, used for the removal and insertion of the tyre, with two different geometries were welded on opposite sides of a one-metre pipe.

IV. Results and Discussion

The fabricated tyre bead breaking, removal and insertion device is shown in Figure 2 below. The tyres used for the performance evaluation was collected from a tyre repair artisan who was also present at the performance test of the developed device. The device was tested for two tyre sizes (14 and 15 inches).

Performance Evaluation of the Tyre Bead Breaking, Removal and Insertion device: Four key stages were identified in the process as tyre setting, bead breaking, tyre removal and tyre insertion. The time required for each of these stages was compared using the developed device and conventional method. The procedure was replicated three times and the result is presented in Table 1. From Table 1, the average time required for setting of a tyre using the conventional method was 6s for the two tyre rim sizes considered while the average time required for tyre setting in the developed device was 5s for the two rim sizes considered. The average time required for bead breaking using the conventional method was 17s for rim size of 14 inches and 18s for rim size of 15 inches while the average time required for bead breaking using the developed device was 14s for both rim sizes.

Figure 2: Fabricated Tyre Bead Breaking, Removal and Insertion Device

Table 1: Total Time Required for Tyre Replacement

SECTION	CONVENTIONAL BEAD BREAKER		VEHICLE TYRE BEAD BREAKER	
	SIZE 14 T(s)	SIZE 15 T(s)	SIZE 14 T(s)	SIZE 15 T(s)
Tyre setting	6	6	5	5
De-beading	17	18	14	14
Tyre removal	25	35	20	25
Tyre insertion	35	35	25	25
Total Time (s)	83	94	62	68

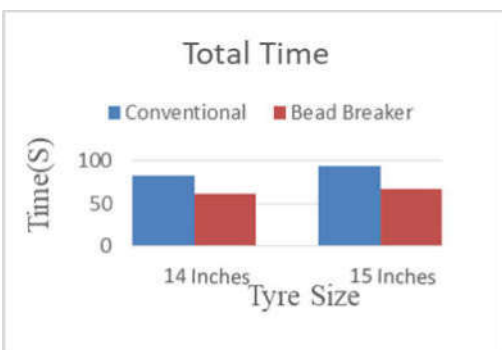

Figure 2: Total Time Required Using Conventional Method and Developed Device

In the removal of the tyre from the rim using the conventional method the average time taken for rim size of 14 inches was 25s and for rim size of 15 inches, the average time taken was 35s while for the developed device the average time taken for tyre removal was 20s for rim size of 14 inches and 25s for rim size of 15 inches. For tyre insertion using a conventional method, the average time taken was 35s for both rim size while the time taken using the developed device was 25s for both rim sizes.

The average total time required (Figure 2) for the entire bead breaking operation using the conventional bead breaker was 83s (14 inches) and 94s (15 inches). On the other hand, using the developed device, the average total time spent was 62 (14 inches) and 68s (15 inches). Operators of the conventional bead breakers also reported lesser effort being expended while using the improved bead breaking device.

V. Conclusion

The fabricated bead breaker and insertion device is more flexible and the performance of the device was found to be very satisfactory for tyres with rim sizes of 14 and 15 inches when compared with conventional bead breakers.

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