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# ASSESSMENT OF THE PROBLEMS OF MANUAL AUTOMOBILE TYRE BEAD BREAKING EQUIPMENT IN NIGERIA

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**Abstract**
***The tyre-rim bead bond must be broken to carry out repairs on a failed automobile tyre. The use of the locally fabricated manual bead breaking equipment as it is being practiced today by commercial tyre repair artisans in Nigeria is characterized by drudgery. This article reports a study of the local manual bead breaking technology with a view to identifying where engineering design effort could be directed to remove the drudgery involved. The results show that majority (62.5%) of the tyre repair artisans never went beyond elementary primary school education level. Majority (40.82%) of them are of the opinion that the redesign effort should be focused on the bead breaking edge to remove the characteristic drudgery. Furthermore, the bead breaking difficulty and time generally increased with increase in rim size. Specific recommendations were made for the redesign of the local tool to eliminate the drudgery of the bead breaking process.***

## 1. Introduction

The auto industry in most economies acted as an engine of growth in national industrial development scheme, especially with regard to the catalytic role of the sector, the diverse nature of its inputs and the unlimited value of its end products [1]. It generates employment for very many because of the numerous trades that spring up around it. The failed tyre repair trade, otherwise called vulcanizing, is one of them.

The tyre-rim combination is one of the most important of the thousands of parts that make up an automobile. It is as important as the engine of the vehicle because without it, power produced by the engine will not be transformed into the motion of the vehicle. It provides the only point of contact between the automobile and the road.

Before rubber was invented, the first versions of tyres were simply bands of iron placed on the wooden wheels of carts and wagons in order to prevent wear and tear of the wheels. The first tyre made of rubber came into existence in the 1800's [2]. Tyre companies were first started in the early 20th century, and grew in tandem with the Auto industry. Today, over 1 billion tyres are produced annually worldwide, with the three top tyre makers (Bridgestone, Goodyear and Michelin) commanding a 60% global market share [3]. The modern tyre consists of a tread, a body (made up of the side wall and shoulder) and the bead. Refer to Figure 1. A vast majority are pneumatic, comprising a doughnut-shaped body of cords and wires encased in rubber and generally filled with compressed air to form an inflatable cushion; the body ensures support. The tread is the part of the tyre which comes in contact with the road surface. It is a thick rubber, or rubber/composite compound that does not wear away too quickly and is formulated to provide an appropriate level of traction.

The bead is that part of the tyre which contacts the rim on the wheel. It is typically reinforced with steel wire and compounded of high strength and low flexibility rubber. The rim (also known as wheel), on which the tyre is mounted, is a circular device that is capable of rotating on an axle through its center. It may be a one or multiple piece (component) rim; it differs from vehicle to vehicle, but in general, the cross- section is such that there is a deep area called the drop-well or tyre-well at the centre. Figure 2 shows a typical one piece rim. The bead seats tightly against the rims on the wheel to ensure that the tyre does not shift circumferentially as the wheel rotates and, for tubeless tyres, to provide a seal against loss of air. Thus, the rim diameter is equal to the inner diameter of the tyre. Furthermore, the axial width of the rim in relationship to the tyre is a factor in the handling characteristics of an automobile, because the rim supports the tyre's profile. The bead-rim connection must be strong enough to withstand all acceleration and braking forces without slippage between the bead and the rim so that these forces are effectively transferred to the axle of the vehicle.

Failure of pneumatic tyres is one of the obvious hazards of road adventure. When it occurs, a repair has to be carried out. The process of loosening the firm bead bond between the tyre and the rim in order to effect a tyre repair is called bead breaking; the process is carried out with a bead breaking equipment or bead breaker. This process, as it is being done in the developing world today, is tedious, characterized by drudgery and prone to injuries for the tyre servicing personnel. Out of the injuries that occur while servicing tyres, 40% occurs during the bead breaking process while the remaining 60% occurs during the inflation process [4].

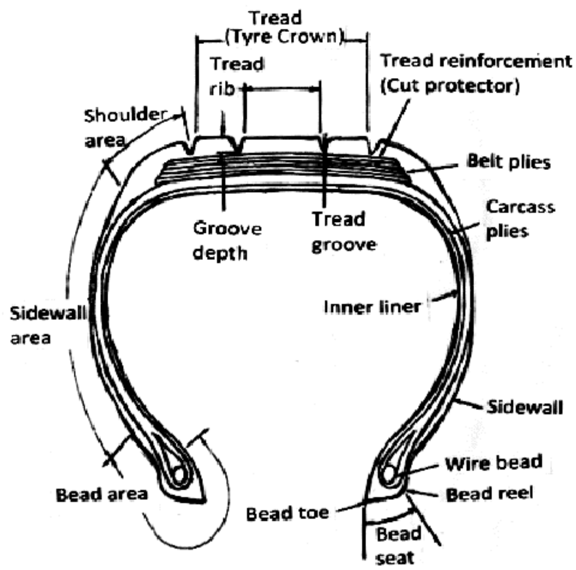


*Figure 1: A cross-section of the typical tyre [5]*

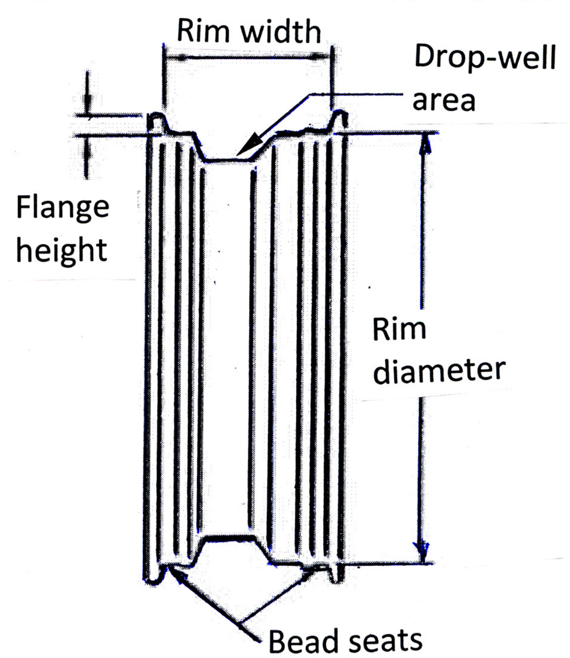


*Fig. 2: The typical one-piece rim (Adapted f*

There are various bead-breaking techniques, with a number of bead-breaking tools and machines (also called tyre changers) commercially available. The rubber mallet technique is the simplest and least expensive, but the most labour-intensive. It involves the use of a rubber mallet to repeatedly hit the edge of the tyre until it comes off the rim. This method is completely out of date (except in situations where there is no alternative tool) as it takes time and it requires back-breaking effort.

There is the drive–over technique in which 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 deflated tyre such that it does not climb onto the rim. It will thus force the tyre bead off the rim. Obviously, this is a crude and dangerous method that should be used only in a situation where other de-beading tools are not readily available. If the vehicle tyre that runs over the deflated one is a little too far from its rim, the deflated tyre will stand upright and smack the side of the vehicle, then pop out from under the driven wheel, fly a short distance, and possibly land on someone nearby.

In another de-beading method, the high-lift jack technique, the deflated tyre is placed under the bumper of the vehicle, and the high-lift jack is positioned between the tyre and the bumper in such a way that the base plate of the jack is as close as possible to, but does not touch, the edge of the rim. The jack is then activated. In this method, extra care must be taken because the tyre can lift up on the side opposite the jack. Also, the base plate has been known to damage the sidewall of tyres where the bead is strongly attached due to rust that has formed between the bead and the rim [7].

The locally made, manually operated bead-breaking tool that is available in commercial tyre repair workshops in Nigeria (and most other parts of the developing world) is illustrated in Figure 3 and that re-designed by Adetan *et al.* [7] is shown in Figure 4. Both tools work on the third-class lever principle in which the load to be overcome (the deflated tyre's bead breaking force) is between the effort and the fulcrum. The major parts of the manual bead breaker, as shown in Figure 3, are: the effort arm, the fulcrum, the pole, the bead breaker edge support, the bow-shaped bead-breaking edge and the rigid base.

The effort arm is typically made from an iron pipe, and the bead breaker edge support from a solid steel rod. The bead breaker edge support hangs from a pin joint around which it can swing on the effort arm. The bow-shaped bead-breaking edge, which is usually made from a flat steel bar, is welded to the lower end of the support. The rigid base is made from a very strong steel bar. To de-bead a tyre with this manual bead breaker, the deflated tyre is placed flat on the rigid base such that the outer side of the rim is on top. The bead-breaking edge is placed on the tyre against the edge of the rim, and force is applied downward on the free end of the effort arm to break the bead on this side of the tyre. Then, still working on the outer side of the rim, the tyre is turned $180^0$ such that the bead- breaking edge of the tool can engage the other side of the tyre. The effort arm is again actuated to complete the process of breaking the bead on this outer side of the tyre-rim assembly. The tyre is now upturned such that the inner side of the rim is on top and the bead-rim bond on that side of the tyre is also similarly broken albeit with a much lower effort than that required for the outer side of the rim. This tool is simple and cheap, and it can be produced by any welder in a typical African village. However, its major shortcoming is that even with the smallest tyre, considerable back-breaking effort is required to break the bead from the rim on the side of the tyre that is first engaged. The re-designed manually operated bead breaker developed by Adetan *et al*. [7] on the other hand, requires less bead breaking effort than the existing traditional tool because of the introduction of additional links (levers). Another setback of the local bead breaking process is that because the operation is performed on the bare ground, sand and other solid particles often enter the tyre during the process. This may later cause damage to the tyre if not properly removed [8]. Meanwhile, the more sophisticated electrically powered bead breaker is beyond the reach of the typical tyre servicing personnel in a developing country like Nigeria.

There are heavy-duty pneumatic and hydraulic tyre bead breakers also known as tyre changers that are electrically operated and designed to take on the widest wheels. These machines are ideal for the high-volume shop where large tyres are part of the business. They are sophisticated in design, construction and operation, as well as in their repair and maintenance. The machine is however out of the reach of the common tyre repair artisan in Nigeria because of its high cost which varies with its complexity; the least price of a brand new one is about ₦800,000.00 [9]. Also, it cannot be recommended for use in Nigeria because of the epileptic problem of electricity.

An earlier study reported that hitherto date, tyre repair artisans in Nigeria have only been interested in the pay that comes from their job without bothering to properly understand the rudiments of the job [10], the technical details of their equipment and the reasons for the drudgery involved. This article reports an assessment of the current status of local tyre bead breaking technology in Nigeria with a view to identifying its main setbacks and recommending ways to improve on the technology towards eliminating these setbacks.

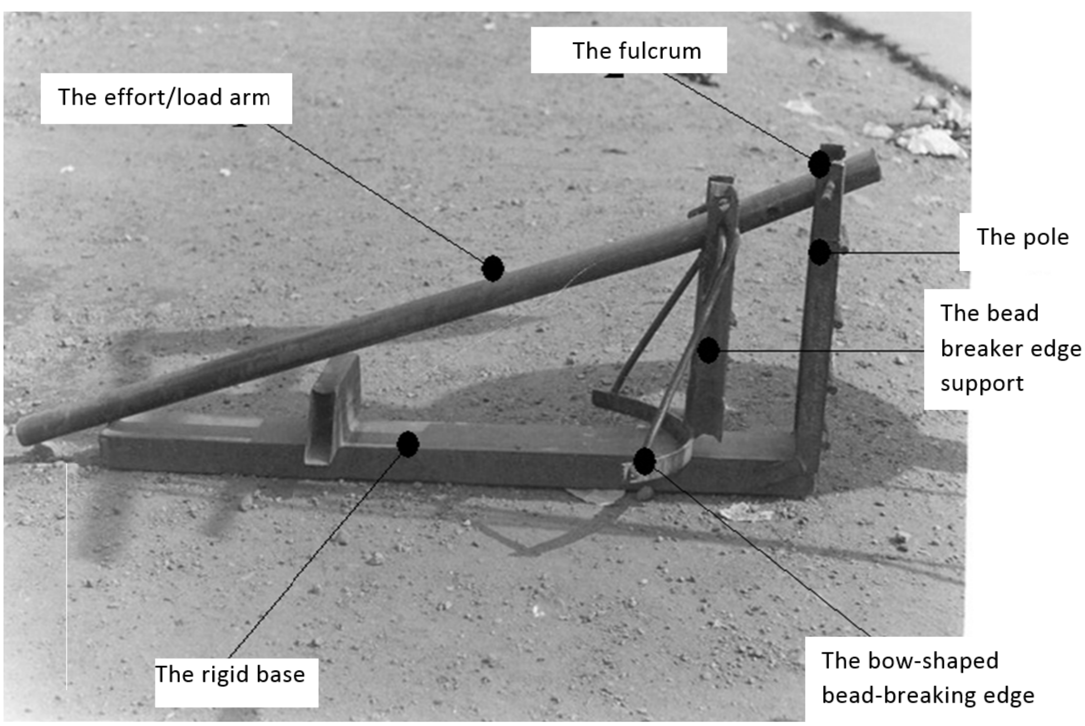


*Figure 3: Manually operated bead breaker [7]*

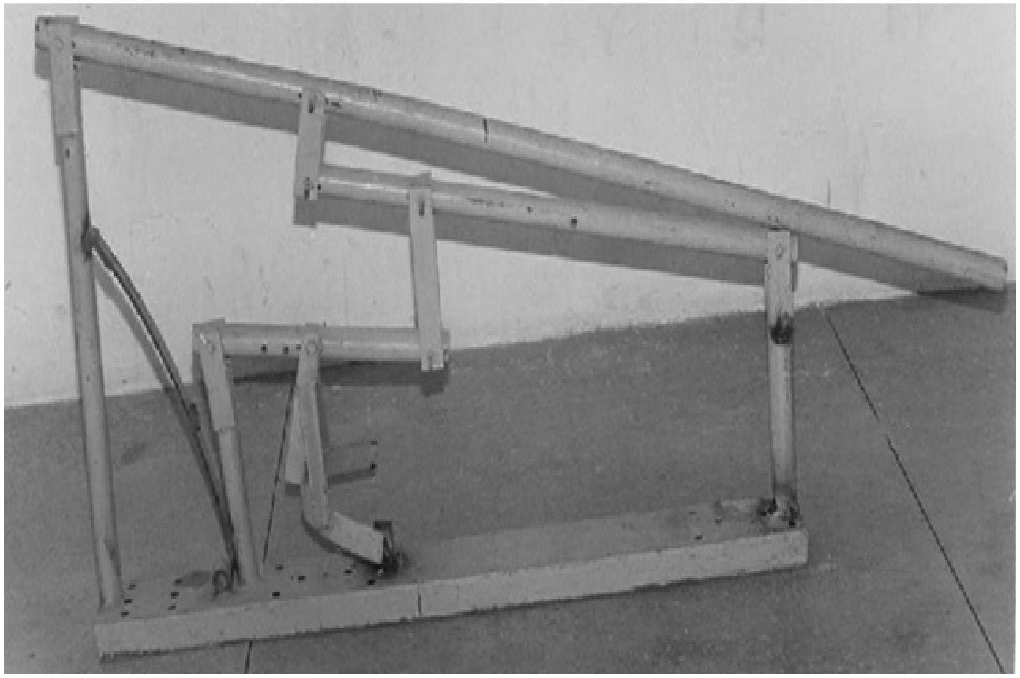

*Figure 4: The Re-designed Manually Bead Breaker [7]*

## 2. Methodology

Questionnaires were administered to 120 tyre repair artisans (otherwise called vulcanizers) within Lagos state and Ile-Ife in Osun state of Nigeria. This was with a view to obtaining qualitative information from these current users of the existing conventional manually operated bead breaker for a comprehensive assessment of the problems encountered in using it. In order to capture a wide range of artisans in these locations, the questionnaires were administered on the day of the vulcanizers' general meeting. On the questionnaire, respondents were asked, among other things, to indicate their level of education, the difficulties they face using the conventional bead breaker and the part of the tool they think would need an improvement or re-design. Out of the 120 copies of the questionnaire administered, 112 were retrieved. Six tyre service workshops in Osogbo, Osun State, Nigeria were randomly chosen for quantitative evaluation tests. Each workshop was visited for two (2) days. The evaluation was based mainly on the ease with which the tools could be used as measured by time (t) required to successfully carry out the bead breaking process and the Velocity Ratio (VR) of the tool.

The time taken to break the bead of a tyre of given rim size was taken as the opportunity arose (i.e., as motorists came with tyres to be repaired) in each of six workshops chosen for this study. In a normal operation, after completing the first bead-breaking action on one side of a tyre–rim assembly, the remaining portion of the bead comes off the rim easily. Therefore, the time measured was the time needed to successfully carry out the first bead breaking action on one side of the tyre. The time was measured using a stopwatch that could be read to the nearest 0.5 s. The rim diameter of each tyre being de-beaded was also noted. In this manner, a total of 49 data points was taken during the 12 days spent on the experiment. Each tyre service artisan had his own locally made manually operated bead breaker, so six different bead breakers were used for the evaluation process. The data collected spanned tyre rim sizes 13, 14, 15, and 16 inches.

The average time spent by each tyre repair artisan to break the bead for a given rim size was computed and noted as t; thus, for the six tyre repair artisans and four rim sizes, there were 24 values of t. Analysis of variance (ANOVA) was carried out on the bead breaking time data to establish whether there are significant differences between the artisans or between varying tyre rim sizes with respect to bead breaking time.

The velocity ratio may be referred to as the tool's theoretical mechanical advantage (TMA) which is the MA for a frictionless tool. It is the ratio of the length of the effort arm to the length of the load arm. These lengths were measured using a meter rule. The length of the effort arm is the total length of the effort/load arm while the length of the load arm is the length measured from the point of suspension of the bead breaker edge support from the effort/load arm to the fulcrum (see Figure 2). VR was measured for the bead breaking tool used in each of the six workshops visited and the average was computed.

## 3. Results and Discussions

### 3.1 Level of education of tyre repair artisans

Table 1 shows the levels of education of respondents, the tyre vulcanizers to whom the evaluation questionnaires were administered. The result shows that 30 (26.8%) of the 112 respondents never attended any formal institution, 40 (35.7%) started working as tyre servicing personnel after their primary school education, 25 (22.3% ) had secondary school certificate and 17 (15.2%) attended post-secondary schools. Obviously, the level of education of these tyre repair men is generally low; a total of 62.5% of the respondent tyre repair artisans never went beyond the elementary primary school education level. It is thus expected that the level of intelligence brought to bear on the job by them will be generally low. It is not surprising therefore that this work remains a drudgery in Nigeria and, indeed, in other parts of the developing world.

*Table 1: Level of education of tyre repair artisans*

| Level of Education | Frequency | Percentage (%) |
|---|---|---|
| None | 30 | 26.8 |
| Primary | 40 | 35.7 |
| Secondary | 25 | 22.3 |
| Post-secondary | 17 | 15.2 |

### 3.2 Difficulties in using the equipment

The result shows that 98 (87.5%) of the 112 respondents from whom questionnaires were retrieved agreed that using the conventional local bead breaker is bedeviled with a lot of difficulties. The remaining 14 (12.5%) of the respondents are of the view that it is not difficult using the existing conventional bead breaker; they believe they can cope with it. This information is illustrated in a pie chart in Figure 5. This suggests that efforts towards improving the current manual bead breaker with a view to eliminating the difficulties will be quite beneficial to, and highly appreciated by, the local tyre repair artisan.

### 3.3 Part of the equipment that needs re-design

Ninety eight (98) of the 112 respondent tyre repair artisans offered suggestions on the part of the conventional manual bead breaker that requires greatest re-design attention in order to remove the drudgery of the bead breaking process using the tool. Majority (40) of the 98 respondents (or 40.82%) are of the opinion that it is the bead breaking edge that must be redesigned. It is their belief that if this part is properly redesigned such it can easily and quickly engage the bead firmly and divide effectively between it and the rim, it will greatly assist in reducing the energy and time expended on the bead breaking process. Some other respondents believe that the redesign engineer's attention should be focused on parts of the tool other than the bead breaking edge as shown in Table 2.

*Table 2: Parts of the conventional manual bead breaker that need re-design*

| Part requiring redesign | Frequency (no. of respondents) | Percentage (%) |
|---|---|---|
| Effort/Load arm | 15 | 15.31 |
| Fulcrum | 3 | 3.06 |
| Pole | 7 | 7.14 |
| Bead breaker | 9 | 9.18 |
| Bead breaker edges | 40 | 40.82 |
| Rigid base | 7 | 7.14 |
| All the parts | 17 | 17.53 |

### 3.4 De-beading Time

Table 3 summarizes the results of average times required to break the bead with the convectional bead breaking tool. Across all four rim sizes, the overall average time spent breaking the bead was 19.04s. Analysis of variance (ANOVA) was carried out on the bead breaking time data shown in Table 3 and the resulting ANOVA Table is shown in Table 4. At more than 10% significance level, there is no statistically significant difference between the artisans with respect to bead breaking time. Generally however, it was observed that the bead-breaking time increases as rim size increases. This is expected because the larger the rim size, the bigger is the thickness of the tyre bead and the firmer is the bead bond between the tyre and the rim; therefore, as the rim size increases, it naturally becomes more difficult to break the tyre-rim bead bond. Further analysis however shows that the difference in bead breaking time between tyres of rim sizes 13 and 14 inches was not statistically significant at 5% significance level.

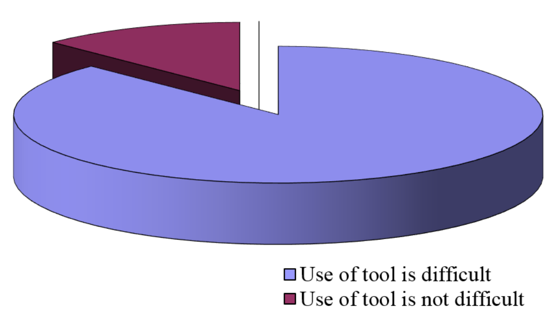


*Figure 5: Assessment of difficulty in using the tool*

*Table 3: Average bead-breaking times, t, for four rim sizes and six sample artisans*

| Tyre repair artisan | Rim size (in) | | | | Average bead breaking times for each repair artisan (s) |
|---|---|---|---|---|---|
| | 13 | 14 | 15 | 16 | |
| 1 | 2.33 | 3.90 | 24.00 | 56.00 | 21.55 |
| 2 | 2.90 | 4.00 | 14.00 | 42.00 | 15.75 |
| 3 | 2.50 | 3.50 | 16.00 | 48.00 | 17.50 |
| 4 | 2.33 | 3.25 | 23.00 | 52.00 | 20.15 |
| 5 | 2.75 | 3.25 | 34.00 | 42.00 | 20.50 |
| 6 | 2.80 | 3.50 | 23.00 | 46.00 | 18.75 |
| Average bead breaking time for each rim size (s) | 2.60 | 3.57 | 22.33 | 47.67 | |

Grand average bead breaking time =19.04 s

*Table 4: ANOVA Table for bead breaking times*

| Source of variation | Sum of squares | Degree of Freedom | Mean squares | F ratios |
|---|---|---|---|---|
| Tyre repair artisan | 92.34 | 5 | 18.47 | 0.89 |
| Rim size | 8040.57 | 3 | 2680.19 | 128.42 |
| Residuals | 313.09 | 15 | 20.87 | |

### *3.5 Velocity Ratio*

The average velocity ratio (the theoretical mechanical advantage) computed for the local bead breaking tool is 5.1. This appears quite low for a tool used to do so strenuous a job as was observed in the manual pneumatic tyre bead breaking process. An effort towards improving the VR of the local tool could therefore yield impressive result in reducing the drudgery involved in the manual bead breaking process.

## 4. Conclusions and recommendations

The current status of the tyre bead breaking process in Nigerian tyre repair shops was assessed. From the study, the following conclusions could be drawn:

(a) The bead breaking process is yet characterized by drudgery.

(b) Majority of the tyre repair artisans in Nigeria never went beyond the elementary primary school education level.

(c) The time spent to break the bead of a tyre increases as the rim size increases. This is because the thickness of the tyre bead and the binding force between the bead and the tyre increase with rim size.

It is recognized that the average Nigerian tyre repair artisan cannot afford the electrically operated bead breaker. Essentially therefore, attention should be directed towards addressing the shortcomings of the local equipment assessed in this study. To improve on this tool and therefore eliminate the drudgery involved in its use, it is recommended as follows.

(a) The manual effort applied to break tyre beads using the equipment could be drastically reduced by redesigning it to increase the velocity ratio. This could be done by scientifically relocating the fulcrum and/or integrating a number of load/effort arms into a single equipment. The commonly available manual automobile screw or hydraulic jack could also be used to apply the required effort.

(b) Designers should focus on how to make the bead breaking edge of the local bead breaker able to divide quickly and effectively between the tyre bead and the rim. Instead of the one bow-shaped bead breaking edge that the local equipment currently has, it could be made to have two such bead breaking edges that would be oppositely located and could be actuated to break the tyre bead on two opposite sides of the rim simultaneously. This will eliminate the time and effort expended on turning the tyre around to complete the bead breaking process after the first bead breaking action on a side of the rim.

(c) A wider rigid base for holding tyres off the floor during the debeading process should be provided for the equipment to ensure that the tyre does not contact the ground to pick up sand and other potential tyre damaging particles during the debeading process.

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