

Development of Double-Neck Yoke and Harness for Animal Traction

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Abstract

The design and construction of the double-neck yoke and harness for animal traction was based on findings from series of discussions held with staff of the National Animal Production and Research Institute (NAPRI), staff of Agricultural Engineering Department at I. A. R., Ahmadu Bello University, Zaria, villagers involved with the use of animal draught technology in Kaduna State as well as literature and published articles on animal traction. Some disadvantages which reduce the performance of draught animals are heavy weight of yoke which results to bending of the animals' neck, wounds inflicted on the animal's neck due to persistent rubbing of the yoke on the neck, difficulty to fit and remove the yoke on the animal thereby causing delay in the time lag for work among others. Field observations and measurements of body size, bulls' weight, neck size and hoof size were carried out on thirty-seven bulls used for animal traction at Salanke, Madubi, Karfe, Nasarawa and Fulani villages in Kaduna State. The developed yoke eliminated the short comings of the existing yokes. It has a three-point linkage system which effectively distributes the load on a pairs of working bulls. It eliminates the use of nose ropes for controlling the animals during work and has allowance for adjustment thereby making it easy for the same yoke to be effectively used for different sizes of bulls. Also, excessive yoke weight and obstruction to movement of the bulls is minimized. The weight of the yoke is 20kg as compared to 25 and 30kg for existing yokes. The strength of the yoke is 78N/mm^2 while the length, width and thickness are 300mm, 100mm and 70mm respectively. Cost of construction is N=4,710.00.

Keywords: design, construction, yoke, harness, animal traction, bull

INTRODUCTION

In modern usage, technology or mechanization has come to mean the use of engines especially tractors for farm operations, but it should include any other source of power that helps the farmer from using his muscles for better advantage on the growth and efficiency of the mixed farming techniques in many African countries (Odigboh, 1991). Oxen in Nigeria and most of the West African countries are the common animals used for pulling tillage and other soil cultivation implements such as ploughs and ridgers, while donkeys are used to transport agricultural products. In a study of animal power utilization in Nigeria for increased agricultural production it was reported that animal traction apart from assisting man from drudgery (especially tillage work), economic analysis of animal (oxen) power utilization and management indicates and increase in yield to the farmers (Musa, 1989). It is reported that in the hypothetical advantages and disadvantages of tractorization, "the agricultural production, and employment situation in Bangladesh", there was no clear cut advantage of tractor over draft in terms of timeliness of operation and although a tractor enables faster cultivation, it must justify higher capital investment by cultivating higher total area than bullocks. The author further wrote that cropping intensity at plot level has no correlation to the method of cultivation, and statistical analysis of yields indicates that tractor cultivated area or plot did not

produce significantly higher yields than animal cultivated plots (Gill, 1981). Strong argument for animal traction technology in Nigeria has been advanced using the socio-economic and biological issues involved in the draught animal system (DAS) in four contexts of energy problems, farming system, appropriate technology, and self-sufficiency. The researchers highlighted the impacts of present versus future energy consumption, sustainability, scale, farming operations, capital versus labour intensity and self reliance import-dependence options and concluded that necessary modalities should be set up for promoting the use of animal traction for agricultural development in Nigeria (Ayoola and Ayoade, 1990). It has been reported that farming in Northern Nigeria is largely practiced by small scale farmers where about 86% still use hand hoe. Tractor use as of now has considerable limitations at the subsistence level. Such limitations are the economics of tractor use and its spares for repairs are hard to come by. The potential of animal traction as a means of increasing the efficiency of peasant farmers in the savannah ecological zones of Nigeria through timely agricultural operations were thus recommended (Phillip, 1988; Goe, 1983; Umogbai and Maigari, 2009). Despite the great progress of motorized power in agriculture, manual workers and draught animals will still continue to provide the main source of power for the farmers in many regions where the

use of tractors and tractor equipment does not yet pay for itself (Hopten, 1981). The use of motorized equipment and machinery is not advantageous when the size of the farm is small and the layout of the fields is irregular and where there is abundance of underemployed labour as obtains in Nigeria. In Nigeria, after the failure of many tractor schemes, the oil crises, and studies showing that the majority of the farmers were still using hand-hoe cultivation, animal traction began to be re-emphasized (Ayoola and Ayode, 1990). Considering the present cost of farm machinery in Nigeria, the use of animal on the farm as a source of power may likely assume a central role. Apart from environmental constraints which include short growing season, severe dry season and animal diseases, lack of appropriate equipment especially yokes that would limit injuries on the animals during work are essential for result oriented animal traction in Nigeria (Umogbai, 2009).

Factors considered in this study are that the yoke should allow efficient and speedy work with minimum fatigue, not injurious to man or animal, should be of simple design so that they can be made locally, light in weight for easy transportation, ready for immediate use without loss of time for preparatory adjustments, and made of easily available materials.

Appraisal of Yokes

Yokes and harnesses are methods of attaching the animals to the implements. There are many types of yokes and harnesses depending on the tradition of the farmers, the type of animal used, the number of animals used and the type of work to be done. The attachment consists of a yoke or an harness (which receives the power directly from the animal) and the linkage which receives the power from the yoke or harness and transfer it to the implement.

Horn/Head Yokes

The horn yokes are tied to the animal horns, while the head yokes are those tied behind the horns. The horn/head yokes are usually mainly on humpless muturu and Ndama cattles. There are the single and double fore-head or horn yokes in use in Africa, Latin America and Europe. A controlled study in Bolivia indicates that horn yokes were found to allow greater maximal force and greater overall power over a six hour period than the head yokes (Alkali, 1969). The horn yokes require more careful fitting and padding than other forms of head yokes and there may be greater risk of injury to the head if they are not correctly fitted. Head yokes tied behind the horns are also commonly used in West Africa, Latin America and Southern Europe. Single uncarved wooden poles can be used as head yokes, but these tend to rotate and slip. It is therefore usual to carve the yoke in such a way that it fits the head or heads and also have grooves and protrusions to allow easy and firm attachment of the ropes or straps. A head or horn

yoke must be strong and light for maximum comfort. They are suitable for cattle with relatively short and strong necks (NAPRI, 1989).

Shoulder (Wither) Yokes

Shoulder yokes are those placed immediately in front of the hump. They are mainly used with humped (white Fulani, Sokoto Gudali and Zebu) Cattle. They are most commonly used in Asia, Ethiopia, Western and Southern Africa, Europe and America. They are mostly made of wood, although a few designs in Africa and Asia have been made from steel pipe. The yoke simplest structure consists of a wooden pole with small descending pegs (staves or skeins) on each side of the animal to restrict lateral movement of the pole. These pegs may be joined by a loosed rope, chain or strip of hide, but this has no draft function and does not (or should not) pull against the windpipe of oxen. Shoulder yokes can be lightly padded with sheep skin or cloth covered with cowhide. The yokes that fully surround the neck with a frame (with U or double J-rods) provides a greater sense of security for the operator, but are more difficult to remove quickly should one animal or the pair fall (Starkey, 1990).

DATA COLLECTION AND DESIGN CALCULATIONS

Sources of Information

Data and information used in the design of the yoke were collected from staff of National Animal Production and Research Institute (NAPRI), Staff of Agricultural Engineering Department at the Institute of Agricultural Research (I.A.R.), Ahmadu Bello University, Zaria, and Villagers at Salanke, Madubi, Karfe, Nasarawa and Fulani villages.

Measurement of Animals

Body size, Neck size, size of hoofs, length of horns, spread of horns, span of hump, and sizes of 37 working bulls were measured using a tape and meter rule. To measure the area of coverage or spread of the hooves, the bulls' legs were firmly placed on a page of graph paper with the hoof outline marked out. The area of coverage is then determined by counting the squares covered (fig.1). The hoof area used is the sum of the contact area of all four hooves of each bull.

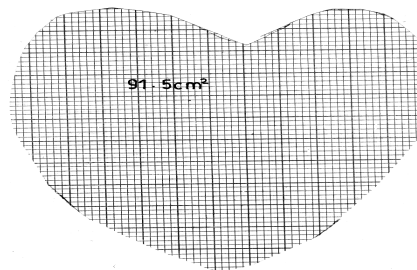


Fig. 1: Measurement of foot print of bull

Weight of Animals

The figures obtained from measurement of the bulls' body and the scapula-isocheimal lengths were used in obtaining the live weight of the animals by applying Ross equation for estimation of live weight of Nigerian cattle from linear body measurement (Jerry, 1958).

$$W = \frac{G^2 L}{208} \times 2.2 \text{ kg} \quad (1)$$

Where: W = Weight of bull in pounds
G = Girth of the bulls' body in inches

L = Scapulo-ischial length of the bull in inches.

2.2 kg = conversion factor from pounds units to kilogram units (Jerry, 1958).

Expected Draft force per bull

The expected draft force per bull was deduced using the standard values of bulls live weight and the corresponding draft forces. The angle of pull was determined using Inn's formula, which states (Starkey and Fadel, 1988).

$$\text{Angle of pull} = \frac{\text{Height of bull} - \text{Height of implement attachment}}{\text{Distance from neck to point of attachment of the implement to ground level}} \quad (2)$$

Forces Acting on Implement

Forces acting on the implement were determined using the closed polygon as shown in fig. 2 and fig. 3.

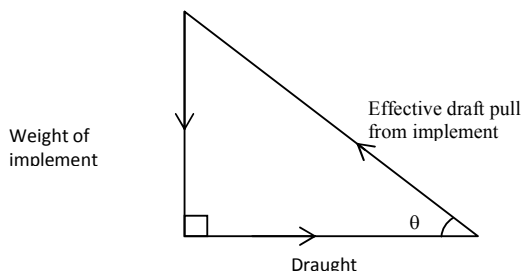


Fig. 2: Forces acting on the implement

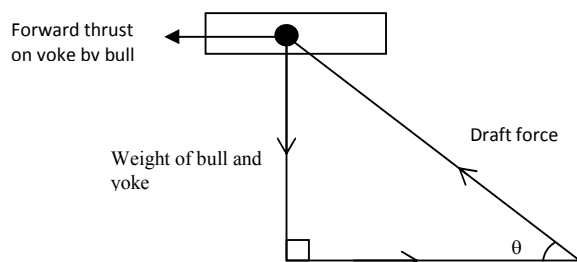


Fig. 3: Forward thrust of bull on yoke

Power of the Bull (Expected draft-force per bull)

Standard value relation between the bulls live weight and the corresponding draft force is adopted. According to Goe and McDowell (1980) a light weight cow (bull) would provide a total of 20kgf at low speed and 15kgf at high speed. However a heavy cow of about 575kg will supply a draft force of

58kgf and 48kgf at low and high speeds respectively. This implies a draft force to weight ratio of 1:10 at low speed (Goe and McDowell, 1980). Also Phillip (1988) presented a data showing that for bulls of 200kg weight in a team of 2, each would supply powers of 23.1kgf, totaling 46.2kgf instead of the expected 50kgf which would be supplied by 2 bulls working separately (Phillip, 1988).

CONSTRUCTION MATERIALS

Materials for constructing the yoke are wood, leather, metal chains, bolts and nuts attached to steel rings. Mahogany wood is considered suitable and is readily available. Its high bending stress of about 78N/mm² and resistance to rot and knot defects are added advantages (Illston, 1979). Raw hide and skin is cheap and locally available. Its toughness makes it ideal for the harness attachment. Steel rings, chain and N17 nuts and bolts which are locally available in the market are used for fastening. Vitafoam which is relatively durable and elastic was used for padding.

TESTING

The emcotl plough was used to test the performance of the yoke. The test which was observed by a group of over twenty local farmers was carried out in farms around Nasarawa and Fulani villages.

RESULTS AND DISCUSSIONS

From the collected data on 37 bulls, mean height of bull = 1470mm; height of implement from tillage level = 410mm; suitable distance (horizontal) to plough hitch point on the implement = 270mm; mean weight of bull = 351kg; mean length of neck of bull = 450mm; mean weight of plough (emcotl plough) = 47kg. Others are mean girth of stomach 172.53cm; scapula ischial length, 57.45cm; height of bull, 123.1cm; area of hoof, 91.5cm²; 36.19cm and girth of neck, 86.78 cm.

Determination of the Angle of Pull of the Plough

Assuming the plough is ploughing at a depth of 250mm, the angle pull is as shown in fig 4.

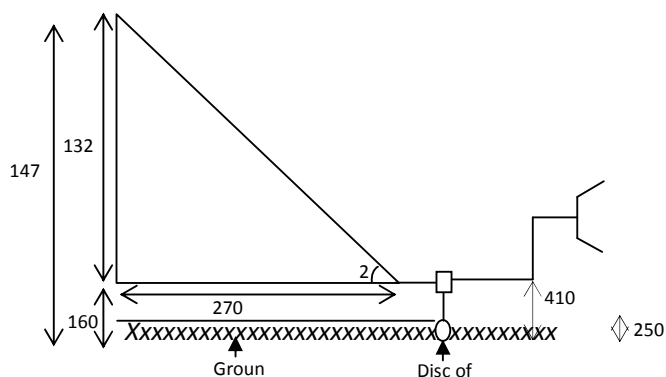


Fig 4. Angle of pull of the plough

$$\tan \theta = \frac{\text{Height of bull} - \text{Height of point of implement}}{\text{Hitch horizontal distance from yoke hitch point to implement hitch point}}$$

$$\tan \theta = \frac{1470 - 160}{2700} = 0.4852$$

$$= \tan^{-1}(0.4852) = 25.88^\circ$$

26° is the angel of pull of the implement.

Force Acting on the Plough

The weight of the plough of 47kg is equivalent to 461.07N. It is safer to design for a higher plough weight of 500N which would result in a shift to the safety of yoke and implement during operation fig 5 (a) and (b)

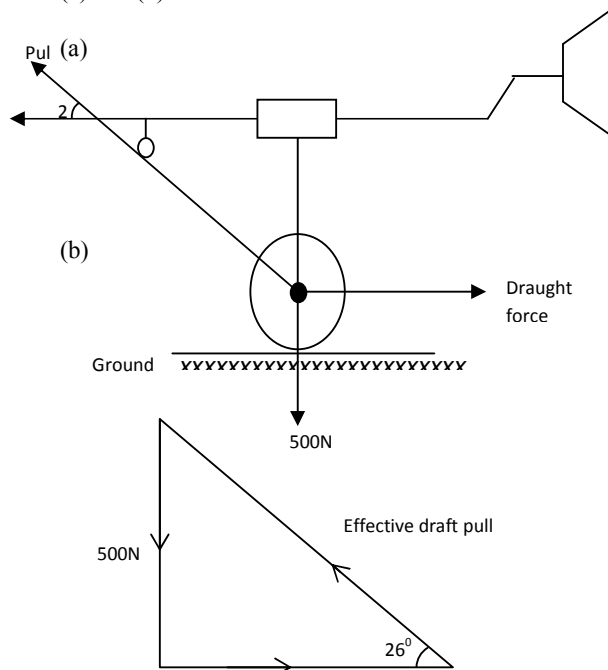


Fig 5: (a) and (b). Forces acting on the plough

$$\text{Effective draught pull} = \frac{\text{Weight of plough}}{\sin 26^\circ}$$

$$\frac{500N}{\sin 26^\circ} = 1140N = 1.14 \text{ KNss}$$

$$\text{Draught of plough} = \frac{500N}{\tan 26^\circ}$$

$$= 1025.5N = 1.025 \text{ KN} = 1.03 \text{ KN}$$

Forces Acting on the Yoke

A light wooden mahogany (beam) of approximately 5kg was used fig. 6 (a) and (b)

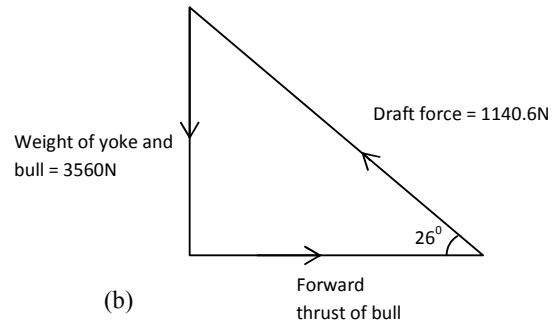
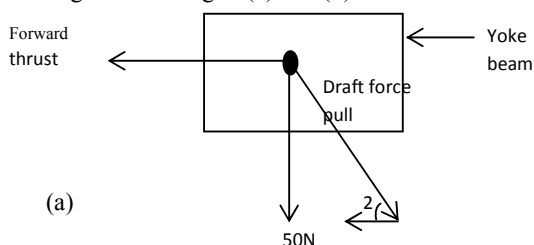


Fig. 6: (a) and (b) forces acting on yoke toward thrust of bull on yoke

$$\text{Forward thrust of bull on yoke} = \frac{3560N}{\sin 26^\circ} = 8120.97N = 8.12 \text{ KN}$$

$$\text{Net forward thrust} = \text{forward thrust} - \text{draught on plough}$$

$$= (8.12 - 1.025) \text{ KN} = 7.096 \text{ KN}$$

This implies that a forward thrust of 7.09 will cause a draft on the plough of draft

$$= \frac{7.096 \text{ KN}}{\cos 26^\circ} = 7.895 \text{ KN}$$

i.e the draft force of 7.895KN on the plough is supported by the yoke.

Dimensions of the Yoke

A yoke that is capable of supporting the expected draft force of 7895N should have dimensions determined by using the ultimate bending strength of the wooden material. The mahogany yoke beam which has the ultimate bending strength of 78N/mm² and a density of 497kg/m³ will thus be treated as;

$$78\text{N/mm}^2 = \frac{3PL}{2bd^2} \quad (5)$$

Where P Load or draft force in New tons

L = Span (length) of yoke beam in mm

b = Width of yoke beam in mm

d = thickness of yoke beam in mm (Illston, 1979).

Considering the bull's working allowance, size of bulls and existing yoke dimensions, the designed length is placed at 3000mm and with a thickness of 70 mm. These two dimensional parameters are the most critical to the designed yoke.

Since P = 7895N, b = ?

Substituting the values in (5)

$$78\text{N/mm}^2 = \frac{3 \times 7895N \times 3000mm}{2 \times b \times 70^2mm}$$

$$\frac{3 \times 7895N \times 3000mm}{2 \times 49000mm^2 \times 78N} = 92.95mm$$

$$b = 100mm$$

A summary of the parameters of the designed yoke are given on table 1, and the detailed drawings are shown in fig. 7(a), 7 (b) and 7(c)

Table 1: Parameters of the Designed Yoke

Strength	Length	Width	Thickness	Weight	Density
N/mm ²	mm	Mm	Mm	kg	kg/m ³
78	3000	100	70	10.64	497

Parameters of the Observed Local Yoke during Data Collection

A diagram of the fabricated typical yoke by blacksmiths for use in the study areas by the farmers is shown in fig 8. Samples of the yoke were observed during data collection.

Yoke circumference = 27cm, Weight of yoke = 25kg – 30 kg, Length of fastening rod (Stave in Hausa) = 56cm

Circumference of rod or stave = 3cm – 4cm

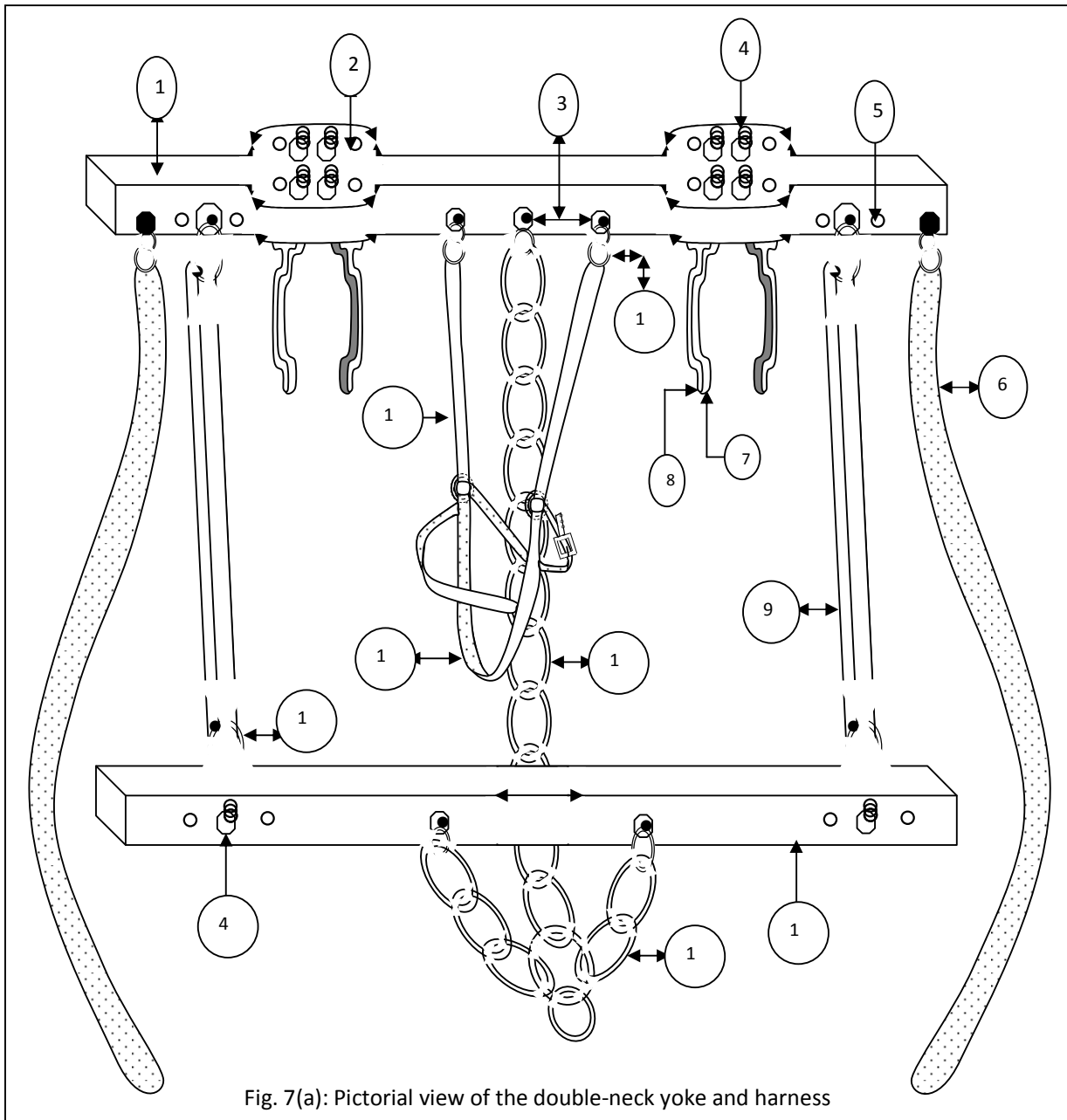


Fig. 7(a): Pictorial view of the double-neck yoke and harness

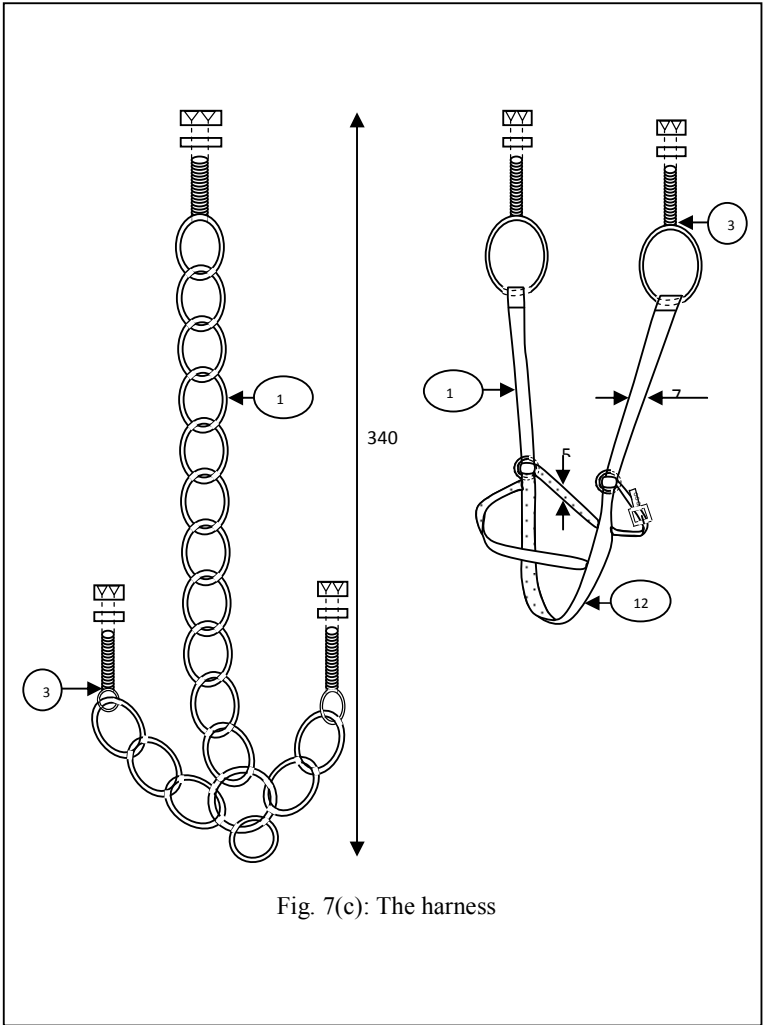
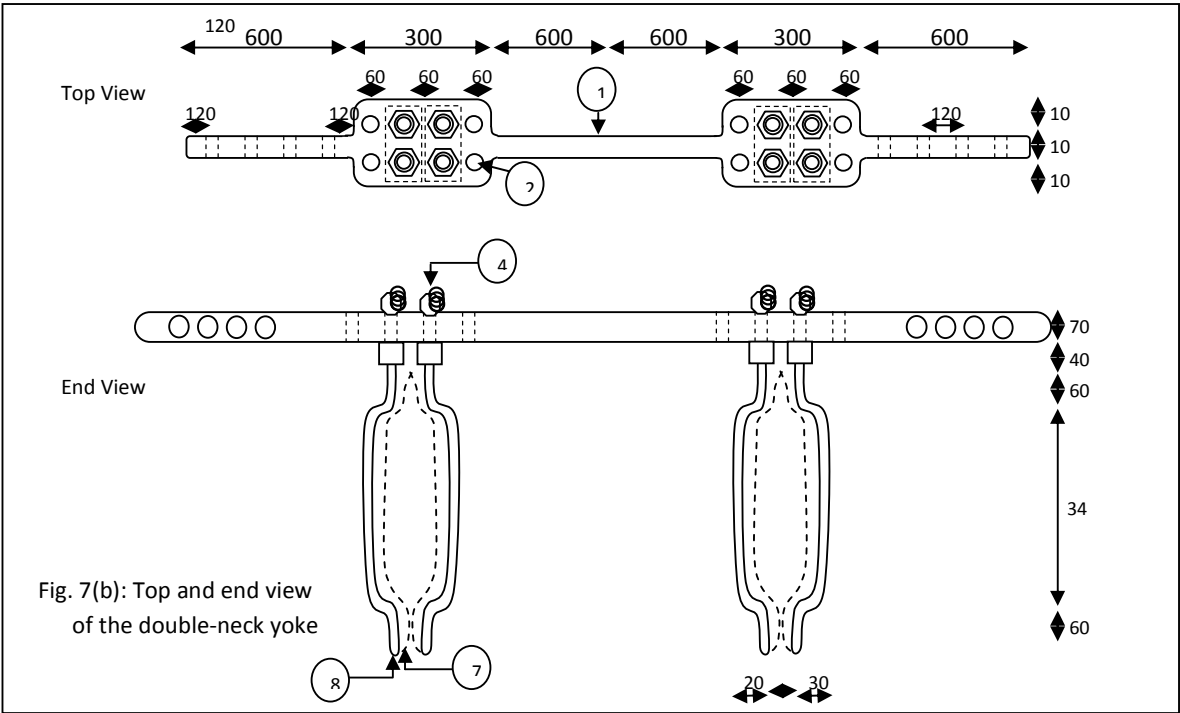
Cost of Production

The cost of production include material cost (wood, chain, leather, foam, bolts and nuts, and steel rings) and labour cost (carpentry, leather work, and blacksmith)

Material cost + labour cost

₦ 2,310.00 + ₦ 2,400.00 = ₦ 4,710.00

Total cost of production was ₦ 4,710.00



S/N	Item	Qty	Materials
1	Yoke Beam	1	Wood
2	Stave Adjust Hole	16	
3	Bolt Base	11	M/Stl
4	Bolt & Nut	19	M/Stl
5	Side Link Adjustment Hole	6	
6	Leather Trace	2	Leather
7	Leather		Leather
8	Stave	4	Wood
9	Side Link	2	Wood
10	Pulling Chain	1	M/Stl
11	Leather Trace	2	Leather
12	Breaching Trap	1	Leather
13	Metal Ring	8	M/Stl
14	Swinging Tree	1	Wood

All dimensions are in mm

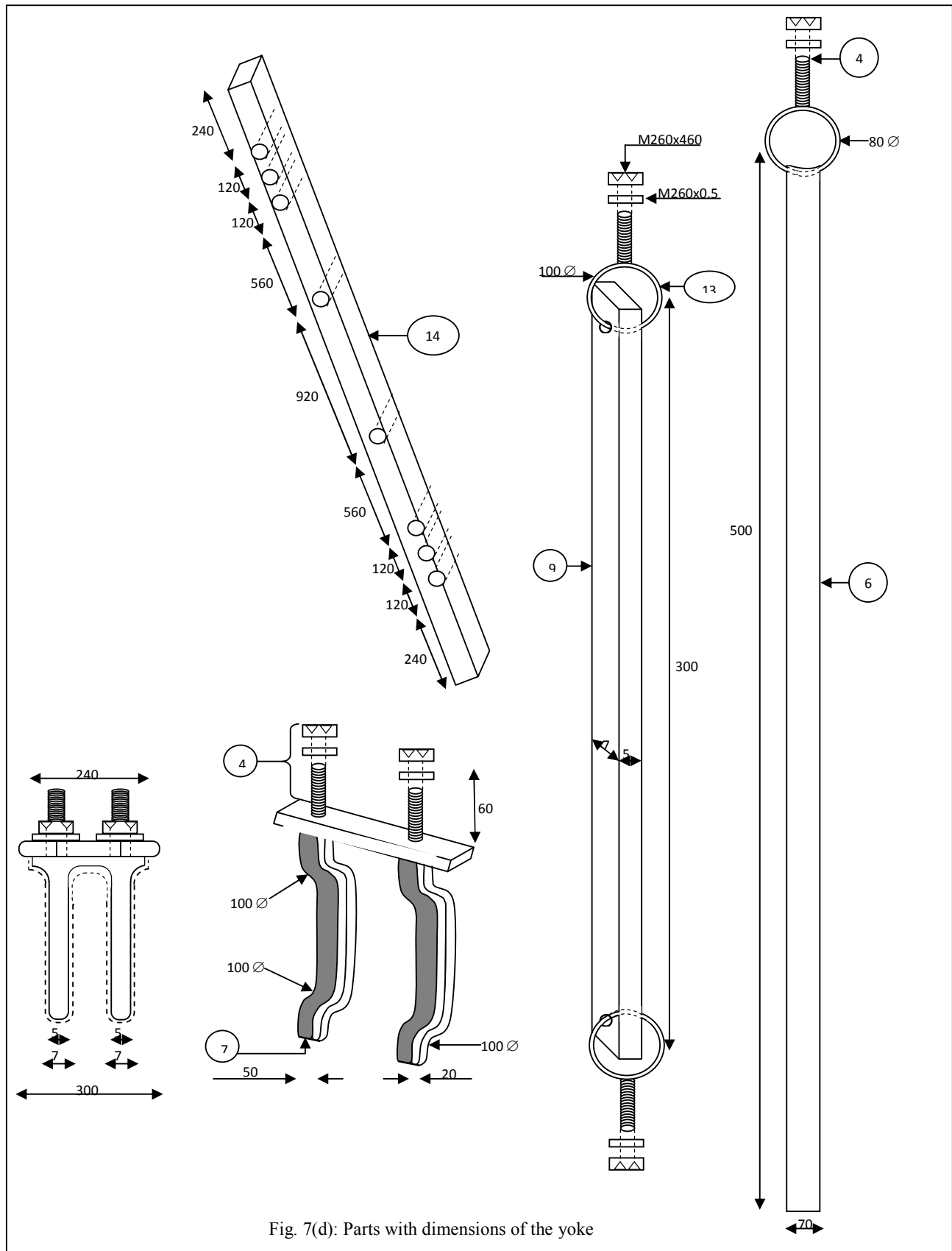
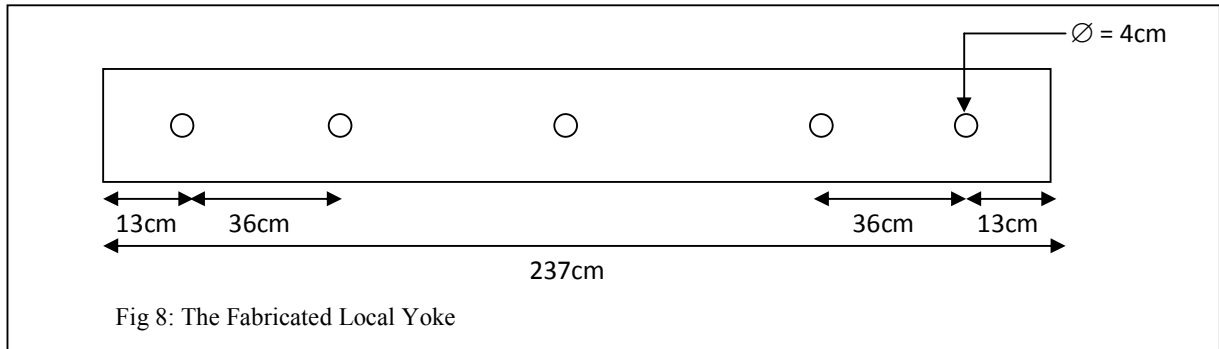


Fig. 7(d): Parts with dimensions of the yoke



Advantages of the Designed Yoke over the Locally Fabricated Yokes

When a pair of bull is used the load is evenly distributed about the individual working bulls which leads to stability and reduction in loss of energy. There is an increase in the working convenience, overall performance, efficiency and out-put of the bulls, as observed by the local farmers during test operations.

Only one operator is needed to control a pair of working bulls instead of two operators for the straight – bar yokes.

The use of nose ropes for controlling the animals during work is eliminated. Allowances and clearance for adjustments are provided which makes it easy for the different sizes of bulls.

Excessive yoke weight and obstruction to movement of animals during work is reduced.

Bruises and injuries at the contact area of the yoke with the animals are eliminated by the provision of 20mm foam – padding around such contact area.

CONCLUSION

The double – neck yoke has been designed, constructed and observed during tillage operation. Its objectives to minimize the arduous human labour expended in land cultivation as well as the use of an intermediate, less expensive, easy to acquire, and easy to adopt technology have been achieved.

The use of the yoke for animal traction for farm operations is not likely to pose management and service problems for the following reasons:

- The animals are in abundance and survive well in most parts of the country.
- Materials for construction/repairs are locally available.
- Local blacksmiths have long acquired the technical know-how of fabricating animal drawn implements such as ploughs, ridgers, planters, etc

- The technology is simple and does not require sophisticated advanced training.

The above advantages notwithstanding it is strongly recommended that proper training must be given to the animals to be used in farming operations. Also proper housing, good healthcare and adequate feeding must be made available to the animals.

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