DESIGN AND MANUFACTURE OF MANUAL ELECTRODE COATING MACHINE FOR SMALL – SCALE ARC WELDING ELECTRODE MANUFACTURE

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ABSTRACT

Local production of electrodes in Nigeria has always been by major manufacturers. The technical partners have maintained that there are no suitable substitutes for the raw materials locally in an attempt to continue to import from their home countries. Our effort at local sourcing required experimentation, which could not be carried out without a means of applying the coating to the wire. This was effected through a direct extruder, which was fabricated to coat electrodes under manual pressure built up through a plunger in an extrusion chamber. Once a wire was coated, the plunger was withdrawn to remove the pressure. The electrode-coating machine is expected to find application in research laboratories of tertiary institutions and small scale manufacturing outfits.

Keywords. Extruder, Plunger, Electrode Coating, Flux

1.0 INTRODUCTION

No success has been recorded in the project of locally sourcing wire, flux and binders for the manufacture of electrodes in Nigeria in spite of the pressure mounted on the Raw Materials Research and Development Council to expedite action on the project. All electrode manufacturers in Nigeria operate under some technical agreement with some foreign counties. To this extent, the foreign technical partners have maintained a strangle hold on local companies to ensure continued importation of processed raw materials from their parent companies. As a result, all the raw materials for electrode manufacture in Nigeria were being imported. Since 1998, welding electrodes manufacturers have been subjected to unfavourable tariffs on imported components to encourage local sourcing. This has led to serious decline in capacity utilization in the industry (see Table 1) and consequent "dumping" of inferior imported electrodes on the Nigerian market (Oyawale 2000). Some local retailers repacked some of these electrodes and sold them to unsuspecting buyers under local Trade Names that had been forced to shut down.

Most of the electrodes produced in Nigeria are through the extrusion process (see Fig. 1). Extrusion has been widely used in polymer processing of plain and coated sheets and metal forming. It has also been widely applied in the production of concrete and clay profiles and in cable insulation. Because of its suitability in providing a uniform coating around a core, it has also been applied in electrode production. By exchanging dies, the extruder may be used to produce various gauges of electrodes. The production method discussed therefore is the extrusion method. Fig. 1 shows the flow line for commercial manufacture of welding electrodes.

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Table 1: State of Electrode Manufacture in Nigeria as at 1998

Name of Manufacturer	Brand of Electrode	Installed Capacity (Metric Tonnes) Single shift	Capacity Utilized in 1998 (Metric Tonnes)	Percentage Utilization
1. Induweld (Nig) Ltd., Ijora	BOC formerly IGL	1000	Out of production	0
2. Electrodes Nigeria Limited ENL, Benin-City	OERLIKON	5000	250	5.0
3. Major Electrode, Aba	MAJOR	2400	120	5.0
4. Alliman Industries, Owerri	BEST	1250	70	5.1
5. G.M.O. Company, Onitsha	GMO	3000	150	5.0
6. United Nigerian Wire Ind. Kaduna	Not known	1200	Out of production	0
7. F. C. Anekwe Industries, Onitsha	Not known	1800	250	14
8. Blue Straps Limited, Ibadan	BLUARC	1200	50	4.1
9. Kuchen Industries Ltd., Enugu	KIL	1000	100	10
10. Dover Industries, Asaba	No records	-	-	0
11. Western Electrodes, Lagos	HOBAT	1200	Out of production	0
TOTAL		19050	990	5.2

Nevertheless, this commercial method is not available to researchers and small quantity producers due to the large quantity of flux required and the sophistication of the equipment. In addition, access to existing facilities in the country is highly restricted, hence the need for an alternative. The objective of this research therefore is to develop a coating machine that will satisfy the needs of small quantity producers such as higher institutions and those wishing to carry out experiments on flux formulation.

2.0 THE MANUAL ELECTRODE COATING MACHINE

The manual extrusion machine (Fig. 2) schematically shown in Fig. 3 was produced in the Production Engineering laboratories of the University of Benin (Oyawale, 2000). The ram extruder was used for the laboratory design because of its adaptability for use with small quantities.

2.1 Extruder Specification

The extruder was intended to meter a stiff flux paste of approximately 0.10m^3 into an extrusion chamber in which the core wire is placed such that as the paste is extruded, the wire will be coated as it is pulled through the extrusion chamber. It will be a screw press manually operated with a maximum human effort of approximately 0.1kN.

2.2 Kinematic Scheme

Fig. 3 shows the plan view of the manual electrode-coating machine. It comprises essentially, a couple of plates held together by four tie rods. One plate carries a power screw assembly 1,2,3 which is connected to a ram 8 by a coupling assembly 6,7. The ram moves the piston in an airtight extruder cylinder 9 located by a floating guide plate 10. In operation, the extruder nozzle is connected to the extruder block 12 which is held against a spring loaded support by pressure. The spring assembly activates a dial gauge which indicates the extrusion pressure. The extruder block carries the core wire and the coated electrode centering / withdrawal device assembly 13,14,15.

To produce a coated electrode, the coating flux is thoroughly mixed to the required consistency and loaded into the extruder cylinder. A previously cut and straightened wire is passed through the chamber and the end is clamped to the withdrawal holder 17. The holder is withdrawn gradually as the power screw activates the extruder plunger whose pressure discharges the flux thereby coating the electrode wire. The pressure of the nozzle on the extrusion chamber is self-adjusting thus ensuring a positive engagement. Concentricity of the core-wire in the coating is assured by the bushings in the extrusion chamber block 12 and the electrode guide head 15.

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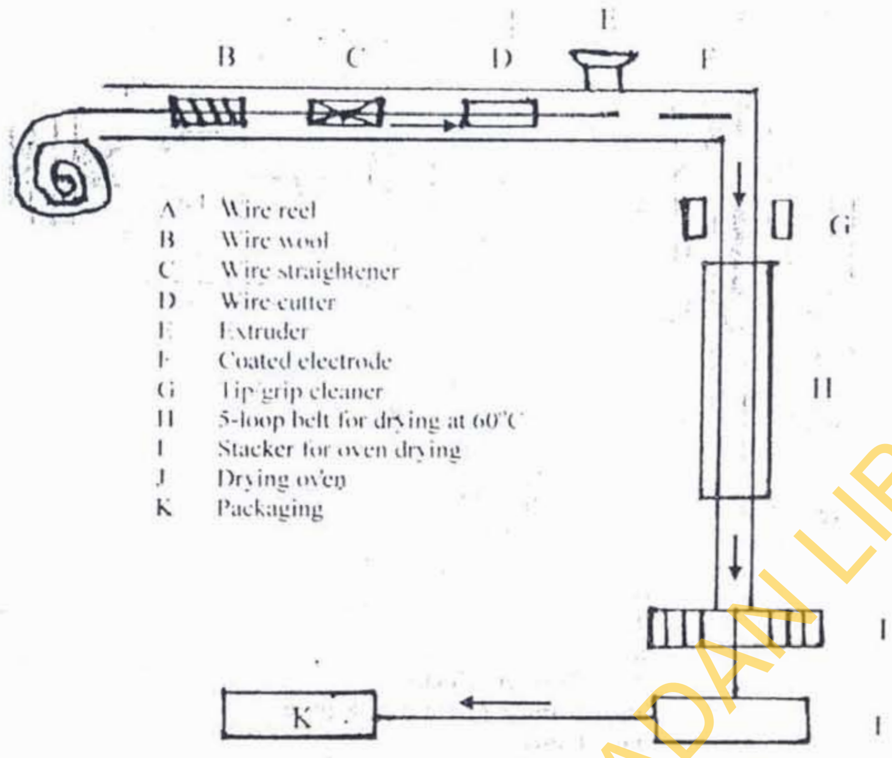

FIG. 1 Schematic representation of a typical flow line for the manufacture of coated electrodes.

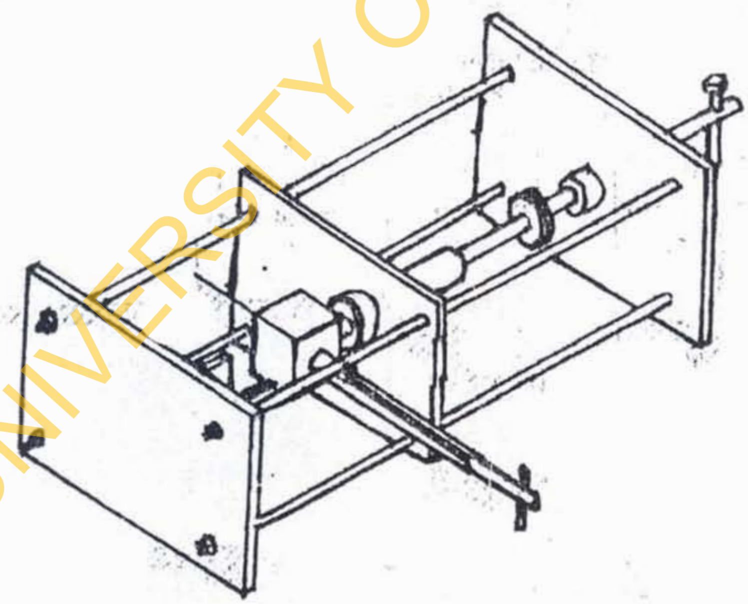

Fig. 2 Manual Electrode Coating Machine

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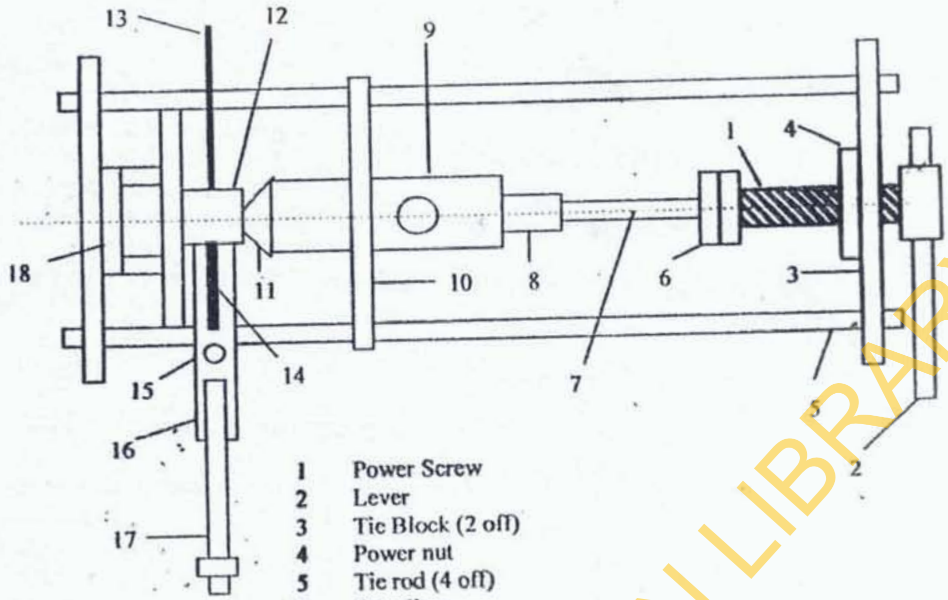
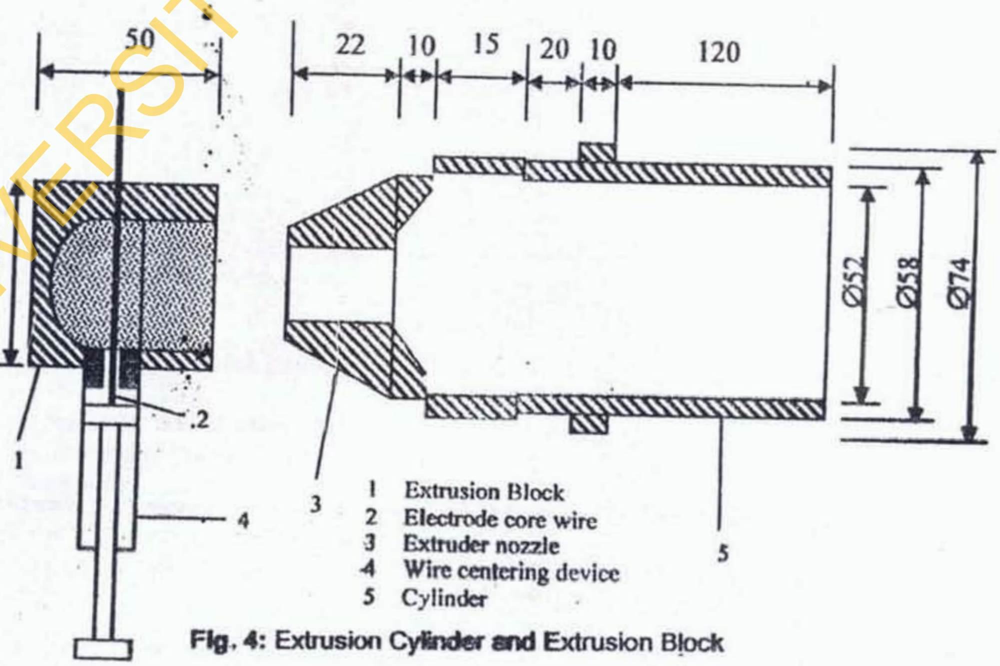


1 Power Screw
2 Lever
3 Tie Block (2 off)
4 Power nut
5 Tie rod (4 off)
6 Coupling
7 Plunger shaft
8 Extruder plunger
9 Extruder cylinder
10 Extruder cylinder guide plate
11 Extruder nozzle
12 90° extrusion chamber block
13 Uncoated electrode wire 2.7mm
14 Coated electrode wire 4.5 mm
15 Electrode guide head
16 Electrode withdrawal cylinder
17 Electrode holder/withdrawal plunger
18 Support

Fig. 3: Schematic of the Manual Electrode Coating machine



1 Extrusion Block
2 Electrode core wire
3 Extruder nozzle
4 Wire centering device
5 Cylinder

Fig. 4: Extrusion Cylinder and Extrusion Block

2.3 Extrusion Force

The pressure required to make a plastic solid bar of diameter 4.5mm and a total length of 350mm (equivalent to the dimensions of electrodes to be made) on the plastic injection-moulding machine was used as the design force. This was found to be about 2kN. With a factor of safety of 2, a design force of 4kN was used.

2.4 Component Design

The following critical components were designed:

i. Extruder pressure cylinder
ii. Power screw
iii. Tie rods
iv. Tie blocks

2.4.1 Extruder Pressure Cylinder

Fig 4 shows the extruder pressure cylinder. The inner diameter d_1 = 52mm and the outer diameter d_2 = 58mm. The thickness t, fo inner diameter ratio is $t/d_1 = 0.058$.

A cylinder with $t/d_1 < 0.05$ is generally regarded as a thin walled cylinder (Ryder 1977). Thus, this extruder pressure cylinder is a thick-walled cylinder. Using the thick walled cylinder theory, the radial stress σ_r, the hoop stress σ_h and the axial stress σ_z at a diameter d in the body of the cylinder are given as:

$$\sigma_r = \left(\frac{d_2^2 - d^2}{d_2^2 - d_1^2}\right)\frac{d_1^2}{d^2} \cdot p_1 \qquad \text{...(1)}$$

$$\sigma_h = \left(\frac{d_2^2 + d_1^2}{d_2^2 - d_1^2}\right)\frac{d_1^2}{d^2} \cdot p_1 \qquad \text{...(2)}$$

and

$$\sigma_z = 0 \qquad \text{...(3)}$$

for open ends of cylinder when an internal pressure P_1 is applied only.
The minimum stresses occur at the cylinder bore, that is, at $d = d_1$. The internal pressure which is equal to the extrusion pressure is:

P_1 = (Design extrusion force)/(Bore area)
= $(4000N)/(\pi x 52^2/4)$ = $1.9N/mm^2$

Thus, from equations 1, 2, and 3, the radial stress at the bore is $\sigma_r = P_1 = 1.9N/mm^2$ and the hoop stress at the bore is $\sigma_h = 17.3N/mm^2$.

The maximum octahedral shearing stress criterion of failure is used for the design (Ryder, 1977).

This criterion is given as:

$$\tau_{oct} = \frac{1}{3}\sqrt{\left\{(\sigma_h - \sigma_r)^2 + (\sigma_r - \sigma_z)^2 + (\sigma_z - \sigma_h)^2\right\}} = \frac{2}{3}Y \qquad \text{...(4)}$$

where Y is the yield stress of the material. Thus, substituting $\sigma_r = 1.9N/mm^2$, $\sigma_h = 17.3N/mm^2$ and σ_z = 0 into equation 4, we have $Y = 16.4N/mm^2$ which is less than the yield stress of mild steel ($Y = 280N/mm^2$) (Ryder 1977)

2.4.2 Power Screw

The power screw specified had a pitch diameter, D_p = 42mm, and thread pitch P_t = 12mm. In designing for thread wear the following formula is used (Dobrovolsky et al. 1977)

$$D_p = \sqrt{\frac{2P}{\pi \varnothing perm}} \qquad \text{...(5)}$$

where:
P = force acting along the screw
Perm = permissible mean unit pressure
$\varnothing = \frac{H}{dp} = 1.2$ to 2.5 for unsplit nuts and

H = nut thickness
We select $\varnothing$ = 2 and Perm = $0.80kN/cm^2$ (for steel screw, cast iron nut)

For P = 4kN, from eq. (5).
D_p = 12.6mm

which is less than the specified pitch diameter of 42mm.

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2.4.3 TIE RODS

The tie rods are designed for buckling for each of the four tie rods. The design load on each is 1kN. The inner and outer diameters of the tie rod specified were d_i = 19mm and d_o = 21mm respectively.

The slenderness ratio of the tie rod is L/K

Where $K = \sqrt{\frac{I}{A}}$ = radius of gyration

I = moment of inertia

L = Length of rod

A = area of transverse section

For a hollow circular section,

$$I = \frac{\pi(d_o^4 - d_i^4)}{64}$$

$$= 3149 mm^4$$

$$A = \frac{\pi(d_o^2 - d_i^2)}{4}$$

$$= 62.8 mm^2$$

$$\text{Therefore}, \quad K = \sqrt{\frac{3149}{62.8}} = 7.08\ mm$$

$$\text{and} \quad \frac{L}{K} = \frac{710}{7.08} = 100.3$$

To determine whether the Euler equation or the J.B. Johnson buckling equation is to be used, we evaluate (Hall et al. 1980)

$$\frac{L}{K} = \sqrt{\frac{2C\pi^2 E}{S_y}} \quad ...(6)$$

Where C = constant depending upon the end conditions of the column.

E = modulus of elasticity

S_y = yield point

For both ends of tie rod fixed, C = 4 and E = 21,000kN/cm^2,

S_y = 35kN/cm^2

From equ. (6), L/K = 218

Since actual L/K (=100) is less than eq. (6) then the J.B. Johnson equation is used, given as (Boressi et al.):

$$F_{cr} = S_y A\left(1 - \frac{S_y \frac{L}{K^2}}{4C\pi^2 E}\right)$$

Where F_{cr} = critical load to cause buckling

Thus for S_y = 35kN/cm^2

A = 0.62cm^2 L/K = 100.3, C = 4

E = 21,000kN/cm^2

Fcr = 19.64kN which is greater than the design load on tie rod of 1kN. Therefore, the design is within limits.

2.4.4 TIE BLOCKS

The two rectangular tie blocks had dimensions a = 380mm, b = 260mm and thickness t = 20mm. As an approximation, theory of small elastic deflections of rectangular plates with point load is applied to the design of the tie blocks. From design curves, for x = b/a = 0.68, the maximum bending moment at the centre of each tie block per unit distance is M = 0.044p = 176 N.mm/mm where P = 4000N (Boresi et al, Ryder 1977). Hence from the flexure formula the thickness, t, of the tie block is given as

$$t = \sqrt{\frac{6M}{w}} \quad ...(7)$$

where w = working stress assumed to be 124N/mm^2

Thus, t = 2.92mm from eg (3.6) for M = 176 Nmm/mm.

Since calculated plate thickness (=2.92mm) is less than the specified plate thickness (=20mm), the 20mm plate was used for the design.

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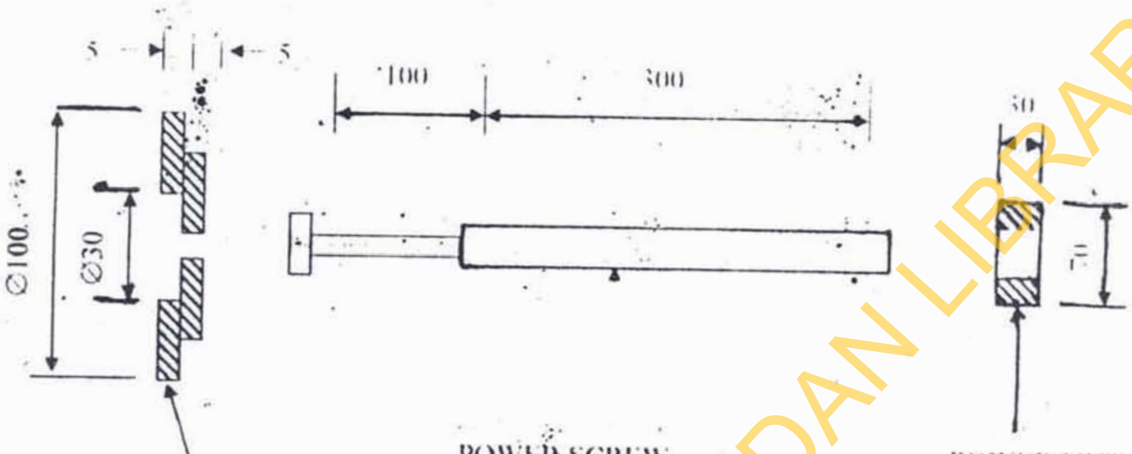

FIG. 5 POWER SCREW/COUPLER ASSEMBLY

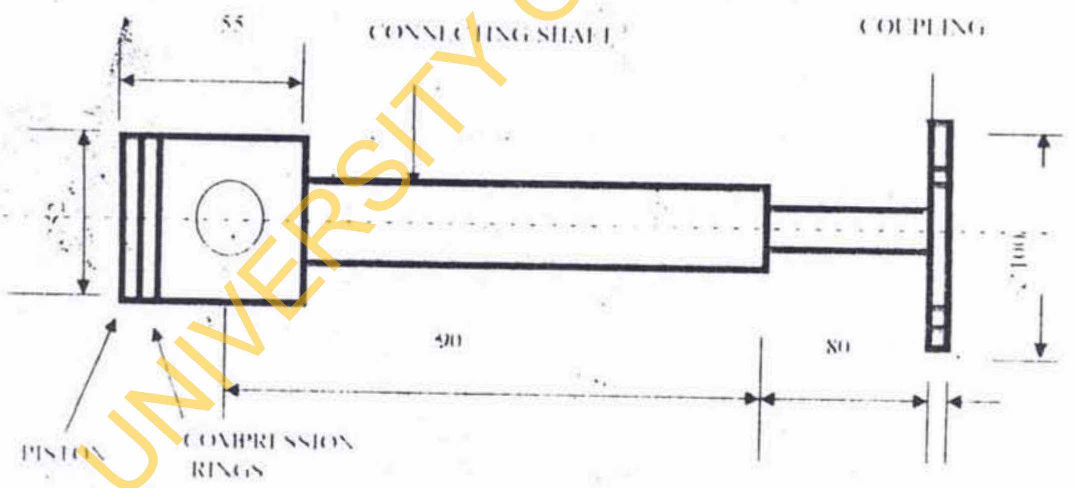

FIG. 6 EXTRUDER RAM ASSEMBLY

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3.0 MANUFACTURE

Four tie rods each of diameter 2cm were blinded at the ends with M10 screw studs. They were mounted on two main plates at the ends. Two plates were made to slide on the pipes. The first plate carried the extruder cylinder while the other acted as a coupler for the ram and the power screw which screwed through the main plate. The cylinder was hollowed out of a cylinder block. A cap P93 fitted with a nozzle was screwed to one end and a piston, which carried compression springs, was fitted from the other end. Figs. 5 and 6 show the power screw and ram assemblies. A hole drilled in the cylinder served as an alternative feed for the mixed flux.

The extruding block made of a mild steel cubical block side 50mm was the coating chamber. The main extruding chamber was a hole designed to force fit onto the nozzle of the ram block. Perpendicular to this a hole was drilled to carry the electrode wire. This hole was a loose fit of 2.5mm to carry the wire to be coated. On the other side of the block, another hole was drilled to act as a die for the coating thickness. To this end was also mounted a stud for carrying the extractor and the centring device. To avoid arc blow, the electrode wire must be properly centred in the coating. To ensure proper centring during manual extrusion, a hollow pipe was fitted onto the stud on the extrusion chamber. This pipe was fitted with an extractor. The extractor was a cylindrical block mounted centrally on a stiff rod and carrying a grip. A well-centred hole designed to grip a 2.5mm wire was drilled at the end. This blind hole was provided with a screw to ensure a proper grip (Fig. 2). The wire to be coated was gripped in this extractor prior to the application of pressure on the extruder. As the coating progressed, the extractor was carefully withdrawn through the guiding centring pipe.

4.0 PERFORMANCE TESTING

Tests were conducted in the laboratory condition. It was later used to produce electrodes from locally formulated flux for weld tests. The production rate was found to be thirteen electrodes per minute and the machine produced ninety electrodes from a loading of the flux paste. The performance indices of the electrodes compare well with ISO 2560 E432R11 for mild steel electrodes (Oyawale and Ibhadode, 2004). The total cost of the prototype is ₦14,960.

5.0 CONCLUSIONS

An electrode-coating machine has been produced from local raw materials. It does not require electric power to operate. It is expected to ease the problems of research in the area of coated electrodes and consequently expedite local production of flux for local manufacture which will definitely reduce the cost of locally produced electrodes to competitive level.

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