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DESIGN AND PRODUCTION OF A MECHANIZED COATING MACHINE FOR ARC WELDING ELECTRODE

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ABSTRACT

This paper presents the design and local manufacture of a mechanized extruder for electrode coating. The extruder uses a worm screw injector for propelling the flux paste through the extruder die area. The worm screw injector is driven by a separate electric motor unit. A hopper which is able to hold a large quantity of flux paste at a time feeds this worm screw injector and consists of a feed wire mechanism coupled to the extruder block assembly. This wire feed mechanism is responsible for driving the inlet roller and consequently feeding the extruder die block with straightened bare wire. The extruder is suitable for small scale electrode manufacture.

***Key words:* worm screw, extruder die, flux paste, wire feed mechanism**

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INTRODUCTION

Bare wire can be used for arc welding, but it is more usual to use a flux-coated electrode. When steels are welded using bare wire electrodes, oxides and nitrides can form and remain in the weld with a consequent loss of strength and toughness. Flux-coated electrodes are therefore widely used. The composition of the coating is complex and a variety of different coatings are used to cater for different types of welding applications. However in all cases the coating is formulated to form fusible slag, to stabilize the arc and to produce an inert gas shield during welding (Davies, 1990; Oyawale et al, 2004). The production method selected for the manufacture of coated welding electrodes is the extrusion process (Oyawale, 2000). Hitherto it has been impossible to produce electrodes in small quantities. In a pioneering effort, Oyawale and Ibhadode produced a manual electrode coating machine. Though this served in the production of electrodes, it did not meet the needs of small scale producers because of the speed of production. The objective of this research is therefore to produce a mechanized electrode coating machine capable of producing electrodes more rapidly than the manual version. The mechanized coating machine uses a worm screw for propelling the flux through the nozzle orifice. This worm screw is fed by a hopper which is able to hold a large quantity of flux-coating at a time, and is easily maintainable to withstand operating conditions.

THEORETICAL BACKGROUND

An electric arc is formed when an electric current passes between two electrodes separated by a short distance from each other. It is easier with the direct current because once the gap is ionized the direct current keeps the flow. When alternating current is used and bare wire is the electrode, the arc is difficult to control. The globules are exposed to the atmosphere in their travel from the rod to the pool and absorption of oxygen and nitrogen takes place resulting in welds that are porous and brittle (Kou, 1987). SMMAW is the commonest arc welding process used because of its flexibility, simplicity and accessibility to difficult locations. Whereas the current range is dependent on the size and type of electrode used, the thickness of material and the burn off rate, the quality of the welded joint generally depends on the operator skills. Electrodes used in manual arc welding are usually covered with a flux coating that vapourizes in the heat of the arc to form a protective gas (CO_2). This gas excludes nitrogen and oxygen from the molten metal thus preventing the formation of undesirable oxides and promoting a smooth flow of molten metal (Kou, 1987). The theory of extrusion is well known but for this purpose is based on flux paste flow. The basic principle governing the forward drive of the material is drag flow. Drag flow is equivalent to the volumetric discharge from an extruder under zero head pressure (i.e. open discharge). Since the pressure builds from zero at the feed throat inlet to several thousand Pascal at the die, there must be a reverse component of flow (from the high pressure at the die to the low pressure at the feed throat) and this is called pressure flow (Amsted, 1985) Pressure flow is dependent upon screw diameter, the cube

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of the flight depth, pressure differential, specific gravity and viscosity of material and the length of the channel. It is difficult to calculate pressure flow accurately without an involved analysis of the process on an inch-by-inch basis, since viscosity varies through the extruder, and is affected by shear rate and temperature. The features considered in the design of the extrusion machine include extruder size, length to diameter ratio, drive horsepower, gear reducer size, thrust bearing capacity, feed system and screw design The combination of drag flow and pressure flow in reality results in a circulation of material within the screw channel, which contributes to good mixing. The net output is approximately equivalent to drag flow minus pressure flow. For practical purposes, the flow through a single screw extruder is determined by the following relationship:

$$Q = (1.04305)D^2Nhw \times 0.8 \quad \dots\dots (1)$$

Where Q = flow (kg/hr), D = screw diameter (in), N = screw rpm, flight depth (in) and w = specific gravity of material. The factor 0.8 compensates for pressure flow. An important consideration in the selection of extrusion equipment is the shear rate, which is the rate of application of energy to material by the differential velocity between the rotating screw and the stationary cylinder. Shear rate is expressed as follows:

$$S = \frac{\pi DN}{60h} \quad \dots\dots (2)$$

Where S – shear rate, $\min^{-1}$; D, N and h are as above.
Solving equations 1 and 2 simultaneously and assuming values for Q, S, N and w will yield the required diameter and flight depth (Amsted, 1985).

EXTRUDER SPECIFICATION

The extruder was intended to meter a stiff flux paste of approximately $0.001\,m^3$ in an extrusion chamber in which the core wire is placed such that as the paste is extruded, the core wire will be coated as it is pulled through the extrusion chamber. The extruder will be a worm screw injector which is chain driven by a separate electric motor unit. The design force of 4kN, which was developed for the manual extruder developed by Oyawale (Oyawale, 2000) was used for this design.

MATERIALS AND METHODS

The extruder consists of the following main components: the worm screw which forces the flux into the extrusion chamber, the extruder pressure cylinder, the gear reducer, the thrust bearing, the feed wire mechanism and the flux box.

DESIGN THEORY AND CALCULATIONS

Screw design is at the heart of the extrusion process, which suffers if the screw is not well suited to the application. The worm is the member having a screw-like thread worm teeth frequently referred to as thread. If we develop one turn of the worm thread, it forms the hypotenuse of a right angle whose base is equal to the pitch circumference of the worm and whose altitude is equal to the lead of the worm.

EXTRUDER PRESSURE CYLINDER

The inner diameter d_1 = 51mm and the outer diameter d_2 = 57mm. The thickness t to inner diameter ratio t/d_1 – 0.12. A cylinder with $t/d_1 < 0.05$ in general is regarded as a thin walled cylinder. Using the thick-walled cylinder theory (Hall et al, 1980), the radial stress σr, the hoop stress and the axial stress at a diameter d in the body were calculated (Oyawale et al. 2004)

$$\sigma_r = \left(\frac{d_2^2 - d^2}{d_2^2 - d_1^2}\right)\frac{d_1^2}{d^2}\cdot p_1 \quad \dots\dots (3)$$

$$\sigma_h = \left(\frac{d_2^2 + d_1^2}{d_2^2 - d_1^2}\right)\frac{d_1^2}{d^2}\cdot p_1 \quad \dots\dots (4)$$

and

$$\sigma_z - 0 \quad \dots\dots (5)$$

for open ends of cylinder when an internal pressure P_1 is applied only.

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$$P_1 = \frac{\text{Design extrusion force}}{\text{Bore area}} = \frac{4000}{\left(\frac{50^2 \pi}{4}\right)} \quad \text{.......................} (6)$$

$$= 2.04 \text{N/mm}^2$$

Thus from equations 4, the radial stress at the bore is $\sigma_r = 2.04\text{N/mm}^2$ and the hoop stress at the bore is $\sigma_h = 19.15\text{N/mm}^2$. The maximum octahedral shearing stress criterion of failure is used for the design (Hall et al., 1980). This criterion is given as

$$\tau_{oct} = {}^1/_3 \sqrt{\{(\sigma_h-\sigma_r)^2 + (\sigma_r-\sigma_z)^2 + (\sigma_z-\sigma_h)^2\}} = {}^2/_3 Y \quad \text{.......................} (7)$$

where Y is the yield stress of the material. Thus, substituting $\sigma_r = 2.04\text{N/mm}^2$, $\sigma_h = 19.15\text{N/mm}^2$ and $\sigma_z = 0$ into equation 3.2, we have $Y = 25.8\text{N/mm}^2$ which is less than the yield stress of mild steel ($Y = 280\text{N/mm}^2$) Dobrovolsky et al, 1977).

GEAR REDUCER

The drive is connected to a gear reduction system, which decreases the drive output and increases the torque to a satisfactory level. Applying laws of physics and rearranging elements to establish necessary power and energy relationships,

$$\text{Power} = \frac{P\pi DN}{60} \quad \text{.......................} (8)$$

Where P = design force

THRUST BEARING

Since the extruder screw is pumping against a die pressure of several thousand Pascals, there is a reactive thrust of the screw against the driving mechanism. The bearing must withstand this thrust and keep the extruder screw in place. This is called the thrust bearing (Hall et al, 1980)

FEED WIRE MECHANISM

The feed wire mechanism is the assembly of inlet rollers for feeding the die block area with electrode bare wire. It comprises the shaft roller assembly and sprocket drive for driving the roller. The lower roller was grooved and welded to the shaft that was connected to the sprocket drive while the upper roller was allowed to rotate freely on the shaft.

FLUX BOX

The flux box is a cylinder welded at the base to an inverted frustum of a cone.

MANUFACTURE

The electric motor was mounted on a support on top of the flux box and this support was welded to the cylindrical surface of the flux box. The gear box comprising two bevel gears was connected to the sprocket drive through a drive shaft. The extruder drive assembly was connected to the extruder screw through a coupler. The flux box was welded to one end of the extruder cylinder and the other end welded to the extruder die barrel. The main extruder was aligned and welded to the extruder assembly. To ensure proper centering of the core wire, rollers were mounted at the inlet of the main extruding chamber (see Plate 1).

DISCUSSION

The machine operates semi-automatically. The core wire was fed by hand and was coated. It was able to coat an average of 20 electrodes per minute. With slight adjustment the core wire was centered by the feed mechanism. The coating was firm. During the coating operation, it was observed that there were few discontinuities of coating on the bare electrode at the initial stage of operation but these disappeared as the coating continued.

CONCLUSION

In this project, a mechanized electrode coating machine suitable for use in production laboratories and small scale manufacture has been produced from locally available raw materials. It fills the gap between the manual extruder and the industrial extruder.

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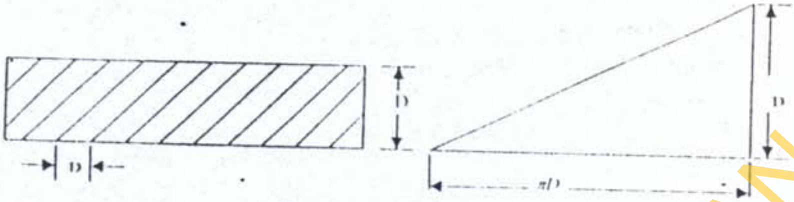

Fig. 1: Schematic representation of the worm screw dimensions

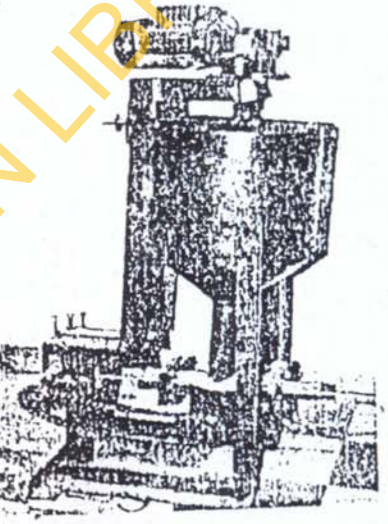

Plate 1 Extruder Machine

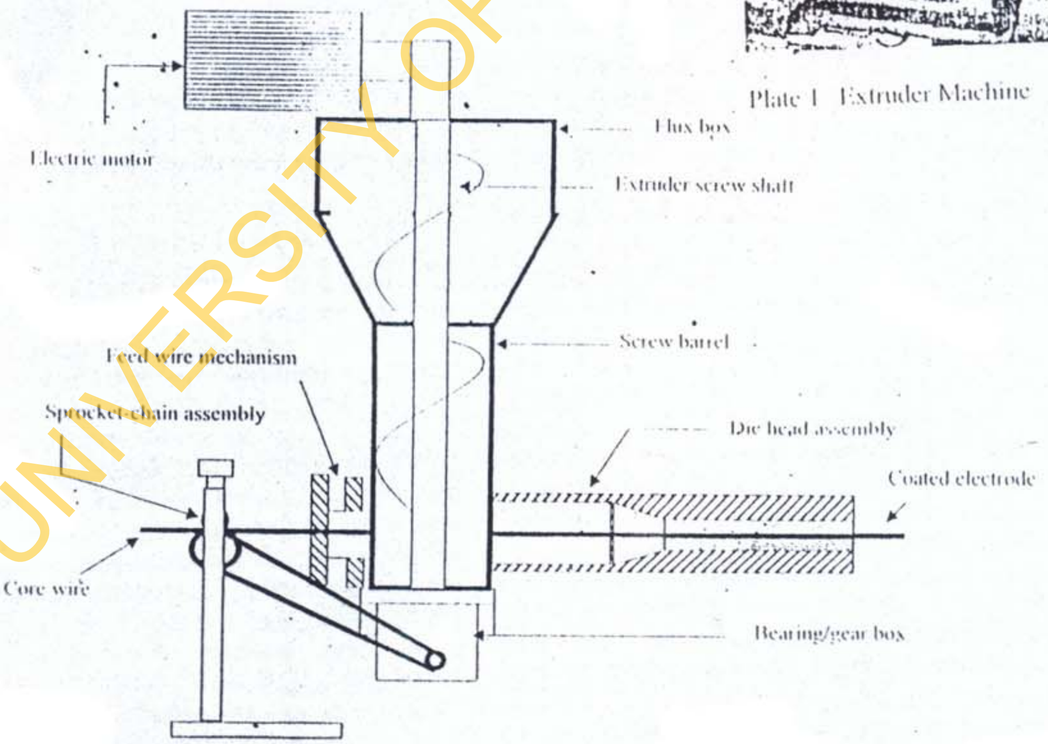

Fig 2: Extrusion Assembly

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