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Case study of recurrent failure of worm screws in locally fabricated palm kernel oil extractors

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Worm Screws in palm kernel oil screw press have been found to fail often and usually require constant replacement. The failure rate is also more with locally fabricated worm screws which usually need to be replaced after about 4 – 5 batches of inlet capacity of palm kernels have been processed. This causes downtime in the machine's operations and the wear of the worm screw deposits metal particles in the extracted oil which should be avoided at all costs as palm kernel oil is usually refined for food and cosmetic use amongst others. The method currently used for the local fabrication has been discussed and recommendations have been made that could result in better useful life of the locally fabricated worm screw. The limitation preventing Nigerian Engineers from fabricating the worm screws with best engineering practices are also discussed.

Keywords: Worm screw, Palm Kernel Oil, Screw Press, Local Fabrication.

1. Introduction

Palm kernel oil (PKO) is obtained from the kernel of the oil palm fruits [1]. One of the oldest industries in the world is seed crushing industry. It is believed that as far back as 300 B.C, the Chinese extracted oil from raw materials. The Egyptians also were reported to use presses to extract oil. In the early 1900s, the modern mechanical screw press was developed and invented [2].

There are various methods of extracting oil from palm kernel seeds. They include the traditional, chemical/solvent, supercritical fluid extraction and mechanical. The traditional method is tiresome and has a lower oil efficiency than the other methods. In this method, cooked palm kernel seeds are pounded, crushed and /or boiled in water, the oil is skimmed off the top for further treatment. Another traditional method is to roast the palm kernel seeds over a fire. Chemical or solvent extraction uses enzymes or solvent in recovering oil from crushed palm kernel seeds. An oil efficiency of 99% can be achieved using this method. Supercritical fluid extraction uses supercritical or high pressure solvent for oil extraction, such as carbon dioxide (CO_2). The Mechanical method yields about 90-95% oil efficiency. It is safer and cheaper than the solvent extraction method as well as more efficient than the traditional method. The mechanical methods of oil extraction are the hydraulic pressing and the screw pressing method [3], [4], [5].

A common method of extracting oil from palm kernels in Nigeria is with the use of a screw press. The screw press consists of a series of continuous worms built on a steel shaft that rotate within a perforated housing and operates against a restricted opening. The worm flights provide the means of conveyance for the kernels being processed. The conditioned kernels are fed through a hopper into the housing and are forced along as the screw rotates, compressing and heating up the mass. The heating and the crushing facilitate oil extraction. [3]. Palm kernel oil extractor can be designed for a range of small to large scale production capacity. With proper management, maintenance problems are minimal [3] However, during pressing operation moderate metal wear occurs. The rate at which this happens depends on nut-to-fibre, moisture content, friction, type of press, pressing method, etc [5].

This study examines the recurrent failure of the worm screw in locally fabricated palm kernel oil extractors and makes recommendations for an improved worm screw. Three Palm kernel Oil factories in Benin City were visited for this study. Figure 1 shows a picture of a screw press in one of the factories

Figure 1: Locally Fabricated Palm Kernel Screw Press.

2. The Worm Screw

The worm shaft is essentially a tapered screw conveyor with the volumetric displacement being decreased from the feed end of the barrel to the discharge end. In this way, the seeds are subjected to pressure which expels oil from them as they are propelled forward by the screwing process [6]. The forces acting on the shaft include weight of material to be processed, pulley and thread [6]. Aung, et al. [7] describes the worm screw as the "heart of the screw press" because it creates the pressure needed to extract the oil from the raw materials. Its failure is undesired as it accrues to extra cost. Figure 2 shows a locally fabricated worm screw.

Figure 2: Locally Fabricated Worm Screw

The worm screw (and cage casing/barrel) creates the compression effect, friction and continuous pressure needed to extract oil. The worm screw has the function of conveying, crushing, grinding and pressing the oilseed inside the barrel. The rotating worm screw crushes the palm kernel seeds against perforated barrel and continuously transports the palm kernel cake towards the exit causing an increase in pressure. It is this increased pressure and friction (compression) that generates heat which reduces the palm kernel oil viscosity and improves the oil flow rate. [7], [8]

2.1. Local Fabrication of the Worm Screw

Three PKO factories in Benin City were used as case study. The fabrication of the worm screw followed the following sequence.

1. Acquisition of material from commonly available materials in the locality. The material used is the leaf spring of a heavy-duty vehicle, Mild steel rods are used as the main shaft
2. The leaf spring is cut to size
3. This cut out piece of metal is heated and a hammer is used to hit and bend it to shape.
4. The bent metal piece is immediately welded to the shaft

The worm screw is composite. The screw thread is welded to the rod after which surface finishing is carried out on it. A similar approach is seen in the "Design and Fabrication of a Palm Kernel Oil Expeller Machine" by Amiolemhen and Eseigbe [9]. The material for the screw thread commonly comes from bars or rods of low to medium carbon steel composition. Figure 3 shows the process of local fabrication of worm screws

Figure 3: Local Fabrication of a worm Screw

2.2. Observed Failure Mode of the Locally Fabricated Worm Screw

The continuous crushing of the palm kernel seeds leads to constant friction between the worm screw and the palm kernel seeds as well foreign particles. It is therefore necessary to improve the hardness, strength, wear resistance of the worm screw.

Summarily, the worm screw fails by

1 Wear of worm screw surface
2 Fracture of the worm

These failure modes are osbserved under constant work and in the presence of foreign particles e.g pieces of metal, palm kernel shells. Figure 4 shows a failed worn screw.

Figure 4: Failed Worm Screw

At the palm kernel oil factories used for this study, it was estimated that the worm requires servicing/refabrication after a period where about 4-5 toaster/cooker capacity of kernel had been processed to PKO. The capacity of the toaster/cooker was estimated as 3050 Litres.

2.3. Limitations of the Locally Fabricated Worm Screw.

The crude fabrication method has the following limitations resulting in quick wear of the worm screw

1. The heated and hammered leaf spring metal would become brittle due to the stresses induced by the process. As this material comes in contact with hard kernels, metallic particles would easily break off from the surface. The oil and mashed kernels assist in moving the particles from the metal surface thereby revealing fresh surfaces for further wear, till the worm can no longer work effectively.
2. Welding the leaf spring to the shaft results in a non-composite material, no quality checks are done to ascertain a good weld and the point of weld joint for a weak point for material removal.
3. Heat treatment is not carried out on it to improve, strength and toughness. Surface hardening is not done to improve the wear resistance.
4. The locally fabricated worm screw is not designed properly, no proper sizing or load calculations are used as basis for the fabrication. These can lead to failure due to excessive loading.

2.4. Limitations leading to the Use of Better Engineering Practices.

The method for the fabrication of worm screws described in 2.2 is not a good engineering practice, A better method would be Machining, Machines that are used include Lathe, Milling machine, Precision Threading Machine. In machining, the rod is selected with diameter larger than the required base shaft diameter. By using a lathe machine, the rod is machined to the required base shaft diameter with the screw thread machined at a decreasing depth of screw to create a taper. An example of such a worm screw is described in the “Design, Development and Testing of a Screw Press Expeller for Palm Kernel and Soybean Oil Extraction” by Olaniyan, et al. [6]

A proper design to aid fabrication is also necessary. Proper Design of the worm screw would account for the number of worms, the length of each worm, pitch of worm, screw hub diameter, spacers, compression ratio, mass flowrate of material flowing across each worm [10].

Also, the use of alloy steel would be better as most refined palm kernel oil are processed for human consumption. Some of the challenges resulting in the crude method used are:

1. Unavailability of Furnaces to carry out heat treatment on alloy steel
2. Unavailability of alloy steels in the local market
3. Unavailability of modern machine tools
4. Unavailabilty of Competent Technicians

3. Recommendations

The following recommendations can improve the useful life of worm screws

1. Machining method should be adopted in fabricating the worms screw. This would help achieve correct profile for the worm screws.
2. Heat treatment processes like annealing and normalizing should be used to achieve a tough core and case hardening to achieve a hardened surface for the worm screw.
3. Proper Material Selection may also help achieve better strength and surface hardening. Also better material selection would help to avoid corrosion and metal wear thereby making the PKO oil more suitable for human consumption.

Proper engineering design calculations should be carried out to enable proper fabrication.

4. Conclusion

Locally fabricated Machines represent most of the machine needs of the populace and designing them to better standards would be a great contribution of the engineer to the society. The work of local craftmen can therfore be examined and improved by the engineer. The locally fabricated worm screw for the screw press was examined to check the reasons for the recurrent failure and the main reasons are poor material selection, wrong fabrication methods, improper design and the ommision of heat treatment. Using some or all the recommendations given, fabricating a worm screw with better useful life would be achieved.

Conflict of Interest

The author declares that there is no conflict of interest.

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