DEVELOPMENT OF LOCALLY MANUFACTURED HAMMER MILL KNIVES USING FINITE ELEMENT METHOD

By

HEBA SABRY ABED ALRHMAN SABET
B.Sc. Agric. Sci. (Agricultural Engineering), Fac. Agric., Cairo Univ., 2005

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APPROVAL SHEET

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APPROVAL COMMITTEE

Dr. AHMED TAHER IMBABI………………………………..
Professor of Agricultural Engineering, Fac. Agric., Fayoum Univ.

Dr. GAMAL EL- DEIN MOHAMED NASR…………………
Professor of Agricultural Engineering, Fac. Agric., Cairo Univ.

Dr. AHMED EL-RAIE EMAM SULIMAN……………………
Professor of Agricultural Engineering, Fac. Agric., Cairo Univ.

Date: / /2013

SUPERVISION SHEET

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SUPERVISION COMMITTEE

Dr. Ahmed EL-Raie Emam Suliman
Professor of Agricultural Engineering, Fac. Agric., Cairo Univ.

Dr. Wahba Mohammady Ibrahim
Assistant Prof. of Agricultural Engineering, Fac. Agric., Cairo Univ.

Dr. Youssef Farg Sharobeem
Head of Research, Agric. Eng. Res. Inst. Agricultural Research Center.

Name of Gandidate: Heba Sabry Abed Al-Rhman Sabet **Degree:** M. Sc.
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Supervisors: Dr. Ahmed EL-Raie Emam Suliman
Dr. Wahba Mohammady Ibrahim.
Dr.Youssef Farg Sharobeem.
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ABSTRACT

The research aimed to improve the performance of the hammer mill by studying some engineering factors affecting on the performance of the grinding knives. The experiments of this study were carried out during the agricultural seasons from 2008 to 2010 for milling grains and some crops residues in Sakha research Center, Sakha, Kafr El Sheikh Government. The hammer mill used in this study of concave hole diameters of 5, 8 and 10mm. The moisture content of grains and crops residues (rice straw, corn stover, cotton stalks, corn kernels and soya bean straw) were determined. The original and modified knives manufactured from local materials were tested for chemical analysis, hardness and tensile test. These tests were carried out at Central Metallurgical Research Development Institute (CMRDI), Helwan, Cairo. Also the finite element method was used to determine force on knife edge (serrated or smooth) and knife tip thickness. Finite element method suggested the modified knive design parameters. The chemical analysis proved a high content of carbon 0.78% and 0.26% of crom. The maximum stress was 15300×10^3 N.mm^{-2} with cotton stalks and the minimum stress was 47.291×10^3 N.mm^{-2} with corn grains. The modified knives which are made of spring steel materials with smooth edge with 0.55mm thickness, 20 mm knife thickness and 45° bevel angle because it achieved the highest efficiency for widely range of agricultural residuals and grains. These results lead to save in knives material (using suitable tip thickness, shape edge). Using new material leads to decrease the wear rate in modified knives by 65% compared with original knives. The machine productivity increased by using modified knives compared with the original knives. The percentages of increase ranged from 0.0114 to 0.0182, from 0.1592 to 0.2810, from 0.0153 to 0.0230, from 0.0126 to 0.0426, from 0.7720 to 1.5768 and from 0.0379 to 0.0480 Mgh-1, at concave hole diameter 5mm for rice straw, corn stover, cotton stalks, corn kernels, corn grains and soya bean straw, respectively.The results indicated that FEM can be used as a successful analysis technique in developing functional element of farm machine. The using finite element save time and money and the modified knife has more working life.

Key words: Hammer mill, crops residues, finite element method, wear rate for knives, particle size distribution.

DEDICATIN

I dedicate this work to my parents, brothers, spouse and my kids for all the support they lovely offered during my post-graduate studies.

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INTRODUCTION

The cutting tool in agricultural applications is an essential element in for harvesting, crushing or any other cutting processes of plants. Its effective knives are subjected different types and degrees of wear. The knife material properties of importance besides hardness are tensile strength, modulus of elasticity and coefficient of friction between knife and the material. Some measure of edge brittleness may be important.

Because field crops residues are considered to be one of the most critical problems facing the Egyptian farmers. Referred to Ministry of Agriculture and land Reclamation, Egypt (2012) recent statistics about 40 million tons of agricultural residues are generated each year,

Grinding is the most common, cheapest and simplest method of feed preparation. It is usually accomplished by means of hammer mill, which, by impact, reduces the particle size of the grain to pass through a screen of a certain size.

Hammer mill process feed with the aid of rotating metal bars (hammers) that blow the ground product through a metal screen. Medium-fine grinding, which can be distinguished by a gritty feeling as some of feed is rubbed between the fingers, is best. Very fine grinding makes feeds dusty and lowers palatability. However, fine grinding may be desirable when pelleting is to follow, Ensminger *et al.* (1990)

The goal of the finite element modeling is to understand the finer mechanical interactions between the growing crack and constituent material properties of turmeric. The mechanical modeling allows the determination of the effects of individual parameters such as morphology, orientation and properties of the fiber and the strength of the interfacial phase on the fracture processes. Knowledge gained from such studies can be used to predict fracture mechanism in a given food material and efficiently design and optimize processes of food size reduction systems.

The advantages of grinding crop residues by hammer mill can be summaried as follows:

It makes crop residues in small particle, so it becomes suitable for further steps of compost processing, due to increasing the surface area for microbial attack, easily controlling and easy handling of grinding materials, collection of grinding materials of crop residues in minimum storage area, so burning and pollution of the environment can be avoided.

But there are some disadvantages of hammer mill:

a. Low grinding efficiency for grinding crop residues compared with grains
b. Low productivity and quality of product.

The research aimed to improve the performance of the hammer mill by studying some engineering factors concerning the performance of the grinding knives.

Achieving the aim of the present study was planned to be realized through performing the following stages:

1. Study some physical and mechanical properties of rice straw, corn stover, cotton stalks, corn kernels, soya bean straw and corn grains.

2. Study the effects of hammer mill components on grinding.
3. Evaluate hammer mill performance before development.
4. Develop new knives by using the finite element method.
    a. Using the finite element method to determine the maximum and the distribution of stresses knives may face.
    b. Find out the best shape of the knife edge (serrated or smooth), which reduced the induced stresses in the knife.
    c Find out the best value of the knife tip thickness, which reduces the induces stresses in the knife.
5. Measure wear rate.
6. Evaluate hammer mill performance after development.

REVIEW OF LITERATURE

1. Definitions of hammer mill

Culpin (1986) defined a hammer mill as a machine whose purpose is to shred material into fine particles. Hammer mills have many sorts of applications in many industries, including:

1. Shredding paper.
2. Milling grain.
3. Shredding scrap automobiles.
4. Waste management

The mill consists of a number of steel hammers which rotate at high speed on a shaft or rotor set in a strong housing.

Koch (2008) stated that the hammer mill remains the most industry standard machine for size reduction. It is capable of reducing the particle size (grinding) of any friable material. Major points of emphasis include the number of hammers/kW of motor power, their arrangement on the rotor, and screen area 2/kW of motor power. Improper hammer numbers and arrangement can decrease production rate. Too little screen area can result in decreased production rate and the heating of the product when it does not immediately exit the grinding chamber.

Wikipedia (2008) defined a grinding mill as a unit operation designed to break a solid material into smaller pieces. In materials processing a grinder is a machine for producing fine particle size reduction through attrition and compressive forces at the grain size level.

2. Types of hammer mill

Smith (1976) divided the fastened of hammers on the cylinder to ridge type and swinging type. The free-swinging hammers are hinged, but the redied is fastened to a rotor shaft or cylinder by jam nuts. The shape of the hammer edge varies to the idea of the designers. The hammer should, however, be made of high grade hardness steel to prevent excessive wear. A screen, usually of one piece, encloses screens, in most machines, the lower all of the cylinder. It consists of holes punched through sheet steel. Various sized holes are used, depending upon the fineness of grinding desired. The size of the holes ranges from 5/64 inches (0.2mm). The smaller holes are used when grinding grains, while the larger sizes are used when grinding roughage, such as sorghum stalks, corn stalk.

Bell (1989) divided mills into:

(a) The hammer mill: It consists of a number of steel hammers which rotate at high speed on shaft or rotor set in a strong housing. As the material is fed from the feed hopper into the mill, the hammers strike it with great force and rapidly pulverize it. At a point close to the periphery of the hammers is a screen, and as the material is reduced in size it passes through this screen. It is then usually elevated by bagged off. The fineness of grinding is regulated by the use of screens of different mesh as shown in (Fig. 1).

(b) Roller crushers: Crushing mills consist essentially of two cylindrical rollers between which the grain is crushed. Grain is delivered to the crushing rollers by a small fluted feed roller, through a variable slide in the bottom of the hopper as shown in (Fig. 2) when the rollers are of unequal sizes the larger one is keyed to the main driving shaft and is carried in fixed anti-friction bearings. Effectiveness of a roller crusher depends on securing an even flow of