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Study, design and prototyping of an animal traction cam based press for biomass densification

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Abstract

An animal traction piston press was studied for applications in developing countries, aimed at producing biomass briquettes as alternative household fuel. Experiments were carried out with different biomasses for determining the minimum compaction pressure and the relationship between applied pressure and volume reduction. Two cams were designed for moving the machine mechanisms: their shape was determined with the aim of minimising the applied draft force, considering the experimentally determined biomass behaviour. The machine was prototyped and tested in Senegal, giving satisfactory results.

Keywords: Cams; Briquettes; Biomass; Compression

1. Introduction

Wood is the main energy source in many developing countries, used especially in household or handicraft activities [1,2]. In some places, the increasing energy need is enhancing deforestation, especially in sub-Sahara countries, with consequent economical, environmental and social harms [3,4]. For this reason, is more and more urgent to increase the use of alternative renewable fuels, providing their accessibility to everybody. A possible alternative energy source is the wasted biomass coming from agriculture, handicraft activity or industrial production: for instance, sawdust, fruit skins or husks, straw, and other similar biomasses can be recovered.

However, for an efficient exploitation of this kinds of biomass, densification techniques are necessary: in fact, they increase the volumetric calorific value of fuels, reduce the costs of transportation and storage, and improve their suitability to handling [5,6]. Moreover, fine raw biomass, such as sawdust, cannot burn in ordinary domestic burners because it inhibits the necessary ventilation. Different biomass densification techniques have been developed, producing solid fuels that can be roughly classified according to their shape and

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dimension. The most diffused are pellets (solids whose characteristic dimension is shorter than 25 mm), briquettes (solids whose characteristic dimension is larger than 25 mm) and globular agglomerations (spheres whose diameter is shorter than 50 mm). They are obtained by aggregating raw biomass particles through the application of pressure and/or addition of binding materials, both inorganic (clay [7]) and organic (cassava, molasses [8]).

In order to obtain a wide diffusion of wasted biomass use in poor countries, characterised by low economical resources, high energy cost, restricted energy availability and transportation difficulties, the densification technology to be chosen should be cheap and suitable to be managed by small rural communities.

Biomass briquetting seemed the most appropriate technology for this purpose, because briquettes are morphologically similar to the woody domestic fuels diffused in developing countries, and this implies that common burners presently available should not be changed. As binders are concerned, it was chosen to exclude them, although they allow a lower densification pressure: in fact, organic binders are not available everywhere, and inorganic binders decrease the briquettes calorific value.

In the world there are several kinds of briquette-making machine, among which two main groups can be recognised: piston presses and screw presses [5,6]. A piston press compacts the raw biomass in strokes by hydraulic cylinders, while in a screw press the biomass is extruded continuously by a screw through a heated taper die. The former is usually more efficient in terms of power consumption, but it needs a higher level of maintenance, and the briquettes quality is lower if compared to the screw presses product. Both kinds of machine, however, do not satisfy the exigencies of rural districts in several developing countries, because they are too expensive, too difficult to be managed by local communities and, often, they cannot be installed because electricity is not available.

Thus, a new more appropriate technology was studied, aimed at low briquettes production, just to fit the demand of small rural communities [9,10]. The piston press technology was chosen, because, although its product is of lower quality than the one of screw presses in terms of storability and combustibility, it seemed a simpler technology in terms of components fabrication. However, the electric and hydraulic systems usually present in commercial machines were substituted by mechanisms: this implies a further technological simplification, and allows animal traction, making it suitable also for rural regions, that often are not electrified. These features should make possible to replicate the machine in the destination countries, maximising the use of locally available technologies and materials, and minimising the number of imported components: thus, local management and maintenance, and cost reduction should be obtained.

As the available animal force for running is limited, the densification process has to be optimised, in order to obtain the maximum possible efficiency and a satisfactory productivity. For this reason, the biomass behaviour in densification was studied in detail, obtaining some general results that can be taken as a basis for briquette-making machines design. Starting from these results, a cam-based mechanism was studied for driving the piston motion; the choice of a cam system was motivated by the consideration that the freedom allowed in cams profile design is the most powerful tool for optimising the machine on the basis of biomasses behaviour. The cams were designed taking in to account, as primary controlled parameter, the draft force to be applied by the animal for applying the correct pressure on the biomass, and not the piston motion law, as is usually done in cams design [11–14]. Although in this paper a specific cam application is shown, the method followed in its design could be a general guideline for designers.

2. Experimental characterisation of raw biomass behaviour in compaction

As a preliminary step for an optimised briquette-making machine design, experimental tests were carried out for characterising the different biomasses mechanical behaviour in compaction; in particular, they were aimed at obtaining some important parameters such as the minimum pressure value for biomass particles agglomeration, the variation of biomass volume vs. applied pressure, the effect of biomass type and particles dimensions.

The testing apparatus is shown in Fig. 1: it is composed by a fixed part and a mobile one, separated by a system of springs. The mobile part is a flanged cylinder, that is biomass filled; the fixed part is a frame sustaining a piston through a nut–screw coupling. The piston is forced, by a torque applied to the screw, to advance compressing the biomass in the cylinder, and the compression force is transferred to the springs