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Agglomeration of natural fibrous materials in perpetual screw technique – a challenge for designer

Krzysztof Talaśka[a,*], Ireneusz Malujda[a], Dominik Wilczyński[a]

[a]*Chair of Basics of Machine Design, Poznań University of Technology, Street Piotrowo 3, 60-965 Poznań, Poland*

Abstract

The paper presents the characteristics of consolidation of natural fibrous materials for getting the renewable solid fuel. A special attention was focused on the perpetual screw technique. A detailed analysis of the consolidation process for this technique allowed to find its advantages and drawbacks. Economic reasons for this technique are also presented. Detailed characteristics of the process allowed to separate the stages when the designer can improve the construction and get the higher efficiency of the consolidation process of the material. Design algorithm for designers of such type of machines is presented.

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Keywords: compacting machine with perpetual screw; design; fragmented natural materials

1. Introduction

Energy strategy of the country is a symbol of its position in international area. Production of electrical and thermal energy has a decisive effect on the development of the industry, and the size and condition of the industry has a direct influence on the state of economy. Fossil fuels are widely applied for the production of the most of the energy. The main drawbacks of this solution are high emission of noxious chemical compounds and limitation of resources of this type of energy source. Therefore, the governments of many countries are looking for new, alternative and renewable energy sources. These types of energy sources are solar energy, wind energy, geothermal energy, wave power, water energy and renewable solid fuels.

* Corresponding author. Tel.: +48 61 224 4512; fax: +48 61 665 2245.
E-mail address: krzysztof.talaska@put.poznan.pl

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Renewable solid fuel is called as a biomass. The entire organic mass in the world can be called as biomass, but for the energy market the most important is wood and a wide group of natural fibrous materials such as straw, grass, special energetic plants etc. [1, 2].

Poland belongs to the group of the countries which uses mainly brown and hard coal for the production of the energy. It is estimated that over 70% of produced energy in Poland is obtained from coal burning and just about 10% is obtained from renewable sources of the energy. The rest i.e. 20% is obtained from gas burning. Energy politics of the European Union force the members to take the defined attitude. According to [3] the program 3x20 will be taken by all members of the European Union until 2020. This means that all members of the European Union will decrease the production of greenhouse gases about 20% until 2020. Besides, the energy consumption will be decreased about 20% and the application of renewable energy sources for energy production will be on the level of 20%. This value of 20% will be the average value for all member countries. The ambition of the Polish government is to get the level of 15% of renewable energy sources in the entire production of the energy.

To satisfy the requirements, it is necessary to find new renewable energy sources and apply the existing renewable energy sources in effective way. One of the most promising renewable energy sources is straw of cultivated corns in Poland. According to [1, 4, 5] the annual production of straw in Poland is on the level of 25 million tons where 40% of this value is the production surplus. These 10 million tons can be applied for energy production. The calorific value of the straw is in range 13 – 20 $MJ.kg^{-1}$ depending on the type and moisture of straw [6, 7]. The drawback of this material is a small concentration of energy and variable value of moisture which depends on weather conditions. Some special processes are needed to increase the energy concentration and provide the repeatable values of the moisture. To achieve these improvements, we need the machines which will satisfy the defined functions. We need the machines for agglomeration of such type of material, of course the preparation of straw demands also some machines for drying or breaking up. The straw consolidation is applied to increase the density of final product which is called briquette and its density is in range 300 – 450 $kg.m^{-3}$ [6, 8]. The straw with such form can be burnt in most of conventional furnaces, and the form of briquette allows for transportation and storage.

Consolidation techniques of fragmented natural fibrous materials such as straw have been known for many years. The most propagated technique is agglomeration in perpetual screw technique. Many types of machines have been designed for this technique [9, 10]. The development of these machines is running and it is caused by the increase of variety of materials which are applied for the energy production and pursuit of effectiveness improvement of consolidation process. It was found that the mechanism of the bonding process of fraction of loose material is still not recognized [11]. This process is complex and connected with variable thermo-mechanical properties of the condensed material. The aim of this work is the determination of the complexity of the design process of compacting machines for fragmented natural plant materials.

2. The characteristics of consolidation process

Fig. 1 presents the kinematic scheme of the compacting machine with perpetual screw. General idea of consolidation process with the application of this technique is based on supplying the fragmented material which will be agglomerated to container 4.

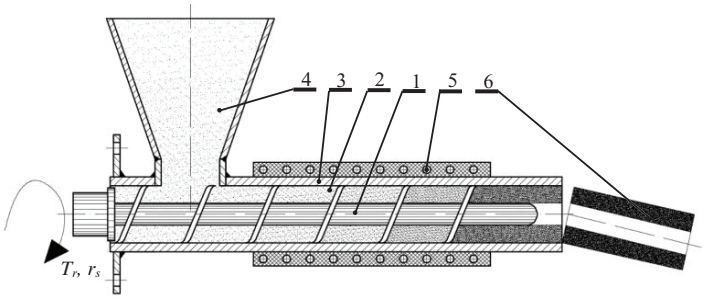

Fig. 1. Scheme of consolidation process of fragmented fibrous materials with the application of compacting machine with perpetual screw: 1 – perpetual screw, 2 – consolidated material in consolidating chamber, 3 – forming cylinder, 4 – container, 5 – heater, 6 – briquette.