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Characterization of oilseeds mechanical expression in an instrumented pilot screw press

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ABSTRACT

This work studies oil seeds mechanical expression in a screw press. For this purpose, a pilot-scale screw press (0–40 kg/h) was instrumented by installing sixteen pressure sensors and three temperature probes throughout the screw. Canola (*Brassica napus L*) and flax (*Linum usitatissimum*) seeds were used for investigation. The impact of the screw rotation speed on the press performances and the matter flow inside the press was investigated. The screw press capacity, passage time, extraction yield and specific energy consumption were studied is the range of 0–18.2 rpm. For each experiment the radial pressure, the internal residual oil content and the matter velocity evolution were measured all along the screw.

Results show that increasing the rotation speed enhances the press capacity and decreases the passage time, reduces the extraction yield and the specific energy consumption. The recorded data allowed the identification of different functional sections of the screw press (feed, compression and mixing/relaxation sections) in relation with the screw geometry. In the compression sections, high pressure leads to oil expression and the formation of hard cake. In the mixing sections, pressure falls to zero and press-cake becomes friable. The matter velocity in the mixing sections is quick as compared to that in compression sections. Furthermore, results show the existence of oil reflux phenomena inside the screw press cage.

Based on the obtained results, the continuous screw press behavior was schematized as a succession of several individual batch presses with intermediates steps of press-cake mixing and oil refluxes in order to facilitate process modeling.

1. Introduction

Solid–liquid expression (pressing) is a unit operation in which a liquid is separated from a solid–liquid mixture by mechanical compression. It is widely used in food and related industries, to express juice and vegetable oils from cellular materials. Hydraulic presses ensuring discontinuous and unidirectional compression are often used on laboratory and pilot scale. Screw presses are implemented at the industrial scale for continuous pressing of oilseeds (Beach, 1983; Hoffman, 1989; Homann et al., 1978; Laisney, 1983; Tindale and Hill-Haas, 1976; Ward, 1976).

Industrially, seed oil recovery is achieved by a sequential process of mechanical expression and hexane extraction. Mechanical expression is generally considered as the most efficient technique to recover virgin oil of high quality, but it only allows a partial defatting of the seeds. Therefore, the resulting press cake is usually defatted by means of percolation with hexane. Screw presses are the most prevalent equipment used for oil seeds expression. A screw press consists of an horizontal or vertical screw fitting closely inside a perforated cage (frame) where liquid (oil) is expelled. Both screw and cage are tapered toward the discharge to increase the pressure on the material. The screw press performances mainly depend on the applied/developed pressure. Contrarily to a hydraulic press where the applied pressure can be set to the desired level, the pressure developed in a screw press is rather difficult to control and predict.

Batch pressing has been intensively studied and referred in the literature, as a first approach for understanding the expression mechanism (Daun et al., 1993; De Ginestel, 1998; Hickox, 1953; Lanoisellé, 1996; Savoire, 2008; Willems et al., 2008). The impacts of seeds pretreatments (moisture conditioning, dehulling, flaking and cooking) and pressing parameters (pressure, temperature and time) have been studied for different oil seeds (sunflower, flax seed, rapeseed, etc.). Experimental data were analyzed and different phenomena were identified (air expulsion, primary and secondary consolidation, creep).

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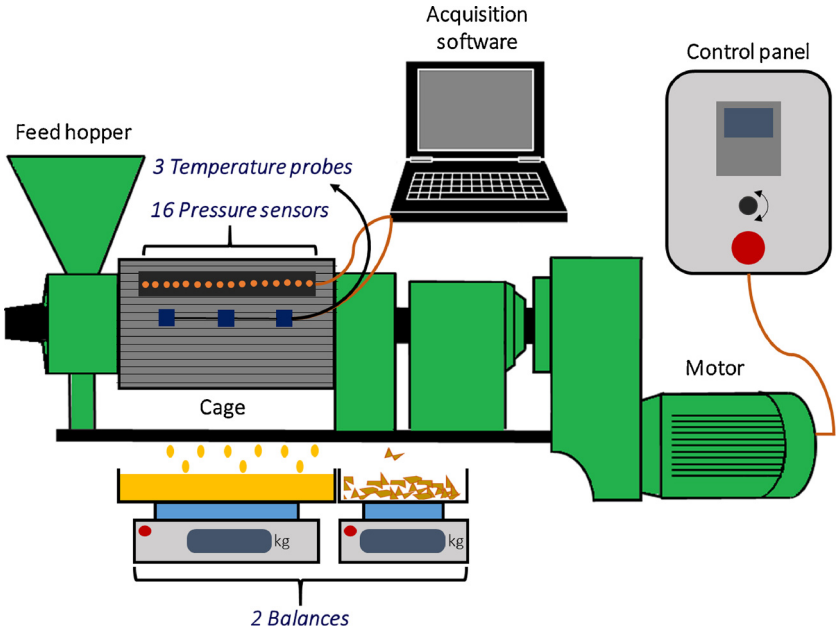

Fig. 1. Schema of the experimental set-up.

Different models were also developed and used (Abduh et al., 2016; Koo, 1942; Lanoisellé, 1996; Mhemdi et al., 2014; Mrema and McNulty, 1985; Schwartzberg, 1983; Shirato et al., 1987; Shirato et al., 1982; Shirato et al., 1970; Singh et al., 1984). Otherwise, the continuous pressing of oilseeds has also been studied (Chapuis et al., 2014; Karaj and Müller, 2011; Kartika et al., 2005; Rombaut et al., 2015; Romuli et al., 2017; Subroto et al., 2015). Savoire et al. (2013) reviewed the data currently available on these equipment. The studies available in the literature are particularly focused on the impact of raw material (species and seeds pretreatment) and operating conditions (temperature, screw rotation speed, opening choke adjustment) on continuous presses performances. However, none of them provide an accurate description or a comprehensive approach of the physical phenomena occurring inside the cage. Experiments conducted on various species showed that the optimum parameters depend on the seeds properties and must be studied and optimized for each specie independently. For rapeseeds, literature mentions optimal performances for flaked and cooked seeds, with optimal moisture content around 5%. A decrease of screw rotation speed leads to a pressure increase in the cage associated to a better oil extraction yield (Vadke and Sosulski, 1988). Generally the studies available are focused on the impact of the operating parameters.

Due to the diversity and complexity of the mechanisms involved in this dynamic process (transport, shear forces, compression, filtration…), literature sorely suffers from a lack of data concerning the constraints development and the oil expression along the screw. Despite significant recent advances in the field of press design and automation, it remains difficult to predict the continuous expression performance based on a theoretical approach. In fact the physical phenomena governing continuous pressing are not fully known (Bredeson, 1983; Shirato et al., 1982; Vadke and Sosulski, 1988), screw presses are still considered as black boxes (Shirato et al., 1985; Shirato et al., 1978) and their design mainly result from manufacturers conception standards. Nowadays, screw presses operation is still difficult to control and an important variability can be observed on their yield, capacity and energy consumption (Sivakumaran and Goodrum, 1988; Wiesenborn et al., 2001; Zheng et al., 2005) according to the processed seeds properties (maturity, variety, moisture content, pretreatments) (Olayanju, 2003; Olayanju et al., 2006; Ward, 1984; Zheng et al., 2003). In this context, manufacturing and crushing industries are continually seeking to better understand the phenomena occurring inside the press, in order to improve and predict equipment's performances. Nevertheless, few studies describing evolution of internal expression parameters (pressure, oil content, porosity) inside the screw press are available in the literature. More investigations are required to better understand and characterize the oilseeds flow and expression in a screw press (Zanetti et al., 2013).

The aim of this work was to investigate the evolution of continuous pressing parameters (internal pressure, temperature, oil content) inside of the screw press. For this purpose, a pilot (0–40 kg/h) screw press was instrumented by installing sixteen pressure sensors and three temperature probes throughout the screw. Canola seeds were used for investigation. For each rotation speed, the pressure, the temperature and the oil flow rate were measured and recorded. Additionally, samples of press cake were taken inside the cage and their oil content was determined. The cake and oil flow rates and the matter velocity profile were also experimentally determined and analyzed to characterize the matter flow in the press.

2. Materials and methods

2.1. Plant materials

Canola seeds and flax seeds were provided by the technical center for oilseeds "Terres Inovia" (Pessac, France). The oil content in seeds and press cake was measured by Nuclear Magnetic Resonance (NMR) in OLEAD laboratory (Pessac, France), according to the international standard ISO 10565. Seeds and press cake porosity was estimated using a helium pycnometer.

2.2. Experimental set-up

The Reinartz AP08 screw press (length 1800 mm, width 500 mm and height 800 mm) was used for this study (Fig. 1). This pilot screw press is a ready-made press for cold-pressing of oilseeds. The motor rotation speed can be adjusted between 0 and 1500 rpm on the control panel. It is linearly correlated with the screw rotation speed, which vary in the range 0–18.2 rpm. The press is equipped with a single rotating screw with a mean median diameter of 61 mm and a length of 62 cm surrounded by a perforated cage for oil outflow.

The screw geometry, schematically presented in Fig. 2. shows that the screw arrangement is composed of a succession of 4 sections with