Production of Unitary Moulded Pulp Products Using Rapid-Köthen Apparatus

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This study shows that it is possible to manufacture moulded products from fibrous pulp at the laboratory scale using the Rapid-Köthen apparatus (found in almost every paper laboratory) and a special sieve form set. This process includes the design of elements of the mould forming sets by special software, production of these elements using a numerically controlled tool machine, the assembly of the sieve form, its installation in the Rapid-Köthen apparatus, and the forming and drying of the pulp product.

Keywords: Form moulding technique; Laboratory scale; Sieve form set; Rapid-Köthen apparatus

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INTRODUCTION

Moulded (or molded) pulp products (MPPs) produced by felting of plant fibres on a sieve form can replace some types of plastic products. Before introducing MPP's into serial production, it is necessary to perform tests on their properties influenced by the shape of the product, the type of fibrous pulp, its degree of beating, the drying conditions and the method of finishing (Eagleton and Marcondes 1994; Hoffmann 2000; Gurav *et al*. 2003; Wang *et al*. 2012). For these kinds of tests, a limited number of samples is needed. Making such a number of products using an industrial forming machine is difficult due to the need to produce an expensive and large sieve mould that fits the slot of the machine.

There is relatively little information in the papermaking literature concerning the detailed method of production of unitary MPPs. For example, Onilude *et al*. (2013) presented the construction of a laboratory mould for making egg pulp trays and a machine to make such MPP's. This study examines the possibility of producing of these products using the Rapid-Köthen apparatus.

EXPERIMENTAL

Design and Manufacture of Laboratory Moulding Set

The SolidWorks 3D CAD program (Dassault Systemes, Paris, France) was used to design the elements of the laboratory moulding set. These elements were made of blocks of polypropylene or aluminium and a steel mesh. Elements from the former two materials were made using a tool machine from Haas Automation, Inc (Oxnard, USA). These works were made possible thanks to the courtesy of the company Dinopol (Ostrów Wielkopolski, Poland) (Sikora 2017).

Fibrous Pulps, Moulding and Drying of MPPs

MPPs were made from unbeaten bleached pine, spruce thermomechanical pulp, or waste paper pulp. The standard Rapid-Köthen apparatus was used for manufacturing of the MPPs. The vacuum pressure during forming was -0.9 MPa. After forming, the MPPs were dried in a standard laboratory drier at 70 °C to a dryness of around 6%. It is believed that with minor constructional changes in the MPP's forming set (a screw connection between the metal plate and counterform), these products could be dried together with the sieve form in the dryer, which would have a positive effect on their dimensional stability.

RESULTS AND DISCUSSION

In the first stage of the study, a Rapid-Köthen apparatus was examined. The examination showed, that in the upper part of the sieve cylinder of this apparatus, there is a place where the mould set could be installed, as illustrated in Fig. 1 (Sikora 2017).

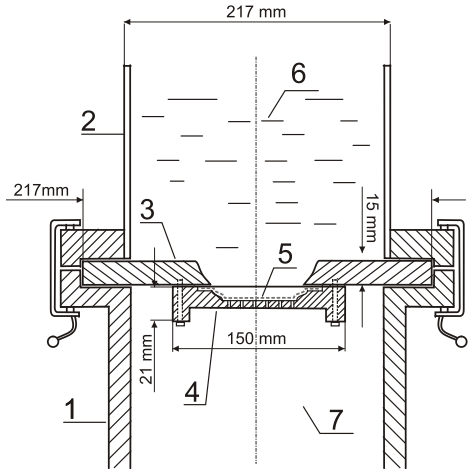
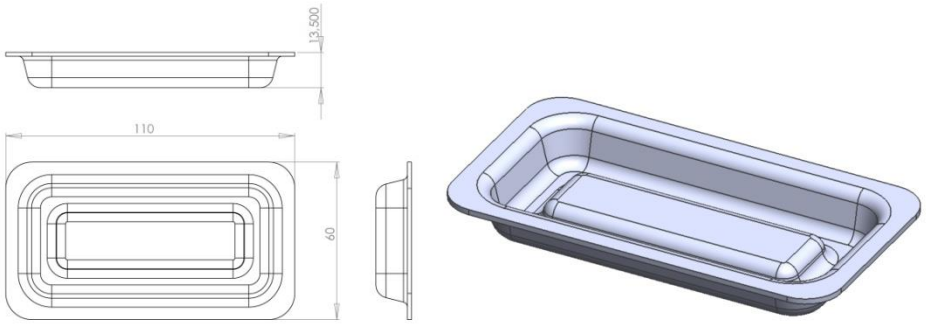


Fig. 1. Location in Rapid-Köthen apparatus where the moulding set can be installed. (1) Metal sieve cylinder; (2) glass cylinder for collecting pulp; (3) metal plate for mounting of moulding sieve form; (4) sieve support; (5) metal net; (6) fibrous suspension; and (7) inner part of Rapid-Köthen sieve cylinder

Further work consisted of designing and making the moulding set. It was decided to try to make an MPP for protecting a small cellular phone in a paperboard box. A technical drawing of the MPP and its 3D drawing are shown in Figs. 2A and B, respectively.



A **B**

Fig. 2. (A) Technical and (B) 3D drawings of MPP for protection of a small cell phone against damage in a paperboard box

A metal sieve having the shape of the product was created. The sieve was made from a metal net with openings of 0.3 mm by placing a piece of the metal net on the polypropylene sieve-shaped form (Fig. 3A) and shaping it by hitting it with a small hammer until the shape of the product was obtained. The polypropylene sieve-shaped form was designed in SolidWorks software and then produced from the rectangular piece of polypropylene using a digital tool machine. The sieve produced by this method is presented in Fig. 3B (Sikora 2017).

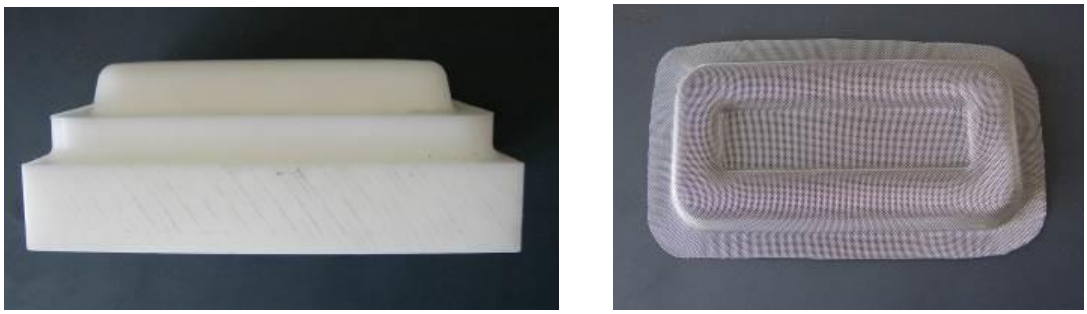


Fig. 3. (A) Polypropylene sieve-shaped form and (B) metal sieve

The other parts of the form set were a sieve support and a round metal plate needed to mount the set of elements of the sieve in the Rapid-Köthen apparatus. They were also designed in the SolidWorks software and made from a rectangular block of polypropylene and an aluminium plate, respectively, using the digital tool machine. At the bottom of the sieve support, several dozens of holes were drilled in order to enable the action of the vacuum on the pulp slurry through the sieve while forming the pulp product in the cylinder of the Rapid-Köthen apparatus. The sieve support, the metal plate, and the assembly are shown in Fig. 4 (Sikora 2017).

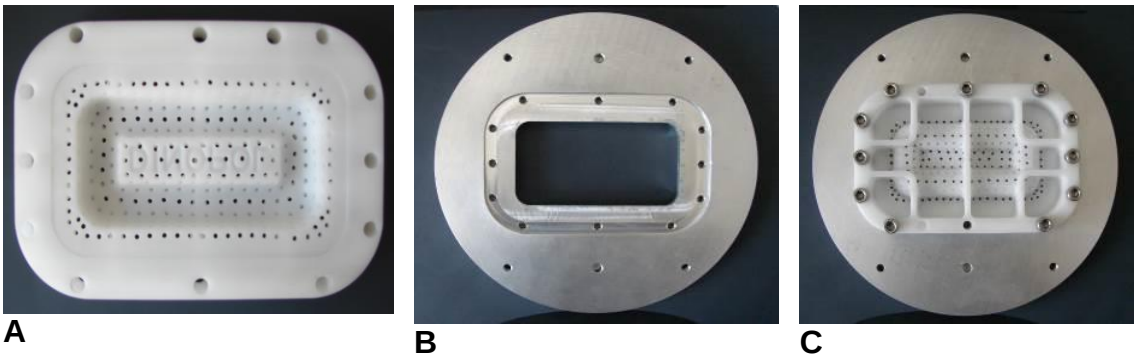


Fig. 4. Sieve support (A) (inner side), round metal plate (B), and the assembly of parts A and B (C). Note: The metal net was placed between the sieve support and the metal plate in Fig. 4C.

To remove the MPP from the sieve form, a counterform was used. The counterform was built of two parts: a polypropylene form having the shape of the MPP and a rectangular metal plate. The polypropylene form had many openings, while the metal plate had a valve on its upper surface to connect to the vacuum.

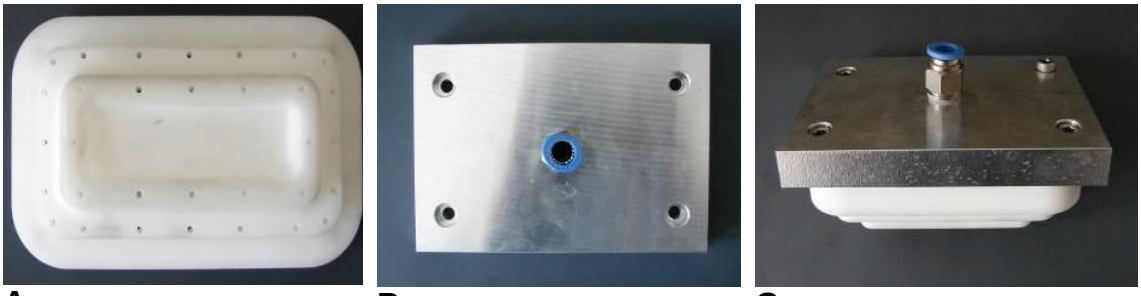


Fig. 5. Counterform (A), metal plate with the vacuum valve (B) and two of these parts assembled together (C)

The process of making the MPP using the moulding set and the Rapid-Köthen apparatus consisted of the following steps, as shown in Fig. 6: (A) placing the set in the forming cylinder of the Rapid-Köthen apparatus; (B) applying the cylinder for collection of fibrous slurry on the sieve cylinder, sealing of these two cylinders, and pouring 5 L of pulp slurry into the upper cylinder, which contained 5 g of oven-dried pulp; (C) activating the vacuum to remove the water from the fibre slurry and opening the upper cylinder; (D, E) putting the counterform on the sieve form and removing the formed pulp product from it using vacuum; and (F) drying the product in an air-convection oven set at 105 °C (Sikora 2017).

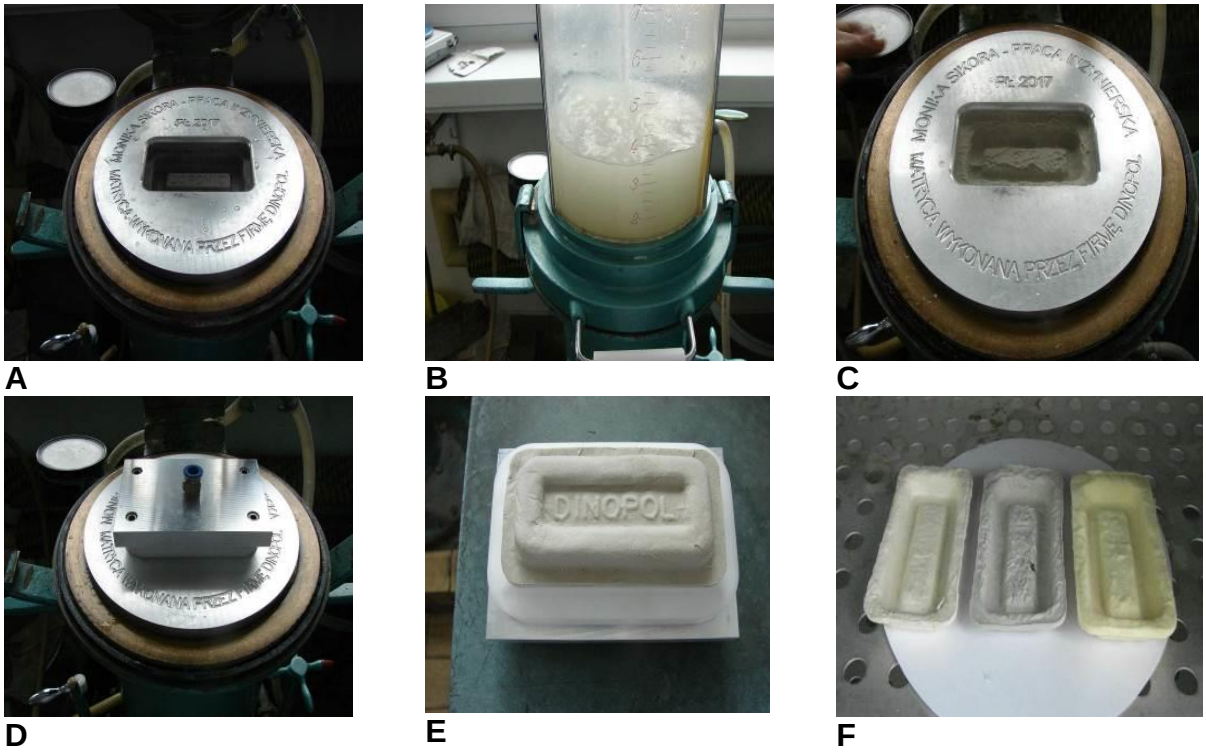


Fig. 6. Stages of manufacturing of MPP in Rapid-Köthen using the moulding technique. (A) Sieve-form in Rapid-Köthen apparatus; (B) forming of MPP; (C) MPP after finishing of forming; (D) removing MPP using the counterform; (E) MPP on the counterform; and (F) MPPs prepared from bleached pine pulp, waste paper pulp and CTMP pulp after drying

CONCLUSIONS

1. Some moulded pulp products (MPPs) or their elements may be produced at a laboratory scale using the Rapid-Köthen apparatus and a simple moulding set.
2. The proposed method of manufacturing such products can be used to produce them on a unitary scale, which is interesting from the point of view of the possibility of testing their properties without a need to build large production sieve forms.
3. The possibility of producing MPP's in many laboratories around the world can help to increase the number of works concerning these ecological packaging products. This can contribute to increase the scope of use of them and thus bring additional benefits to the pulp and paper industry, very well-ordered in the period of observed decreased consumption of printing papers and pulps used to manufacture them.
4. The possibility of using the proposed method of manufacturing of MPP's can also be interesting from educational point of view. For example, exercises for pupils and students, as well as demonstrations for ordinary people (not related to the pulp and paper industry) showing that there is the possibility of producing 3D products not only from plastics but also from pulps.

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