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Evaluation of automatic vacuum- assisted compaction solutions

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Abstract

Currently on the mould-making machines market the companies like: DiSA, KUENKEL WAGNER, HAFLINGER, HEINRICH WAGNER SINTO, HUNTER, SAVELLI AND TECHNICAL play significant role. These companies are the manufacturers of various solutions in machines and instalations applied in foundry engineering. Automatic foundry machines for compaction of green sand have the major role in mechanisation and automation processes of making the mould. The concept of operation of automatic machines is based on the static and dynamic methods of compacting the green sand. The method which gains the importance is the compacting method by using the energy of the air pressure. It's the initial stage or the supporting process of compacting the green sand. However in the automatic mould making machines using this method it's essential to use the additional compaction of the mass in order to receive the final parameters of the form. In the constructional solutions of the machines there is the additional division which concerns the method of putting the sand into the mould box . This division distinquishes the transport of the sand with simultaneous compaction or the putting of the sand without the pre-compaction. As the solutions of the major manufacturers are often the subject for application in various foundries, the authors of the paper would like/have the confidence to present their own evaluation process confirmed by their own researches and independent analysis of the producers' solutions.

Keywords: Foundry production; Moulding processes; Moulding machines; Vacuum moulding; Vacuum models

1. Introduction

Automatic mould-making machines have a major role in the context of mechanisation and automation of foundry processes. The operating principles of automatic forming machines are based on the methods of static and dynamic compaction processes. The method that is becoming increasingly popular involves the vacuum-assisted process at the pre-compaction stage or as the process improving the final compaction performance. In automatic formers operated in accordance with this method, the additional compaction process is required to achieve the required mould parameters [1].

As regards their constructional features, automatic moulding machines are classified depending on the way the sand is filled to the system. In certain solutions sand mix is filled and compacted at the same time, in others the pre-compaction stage is absent.

Since the manufacturers' specifications in commercial brochures are often used as the basis for selection of particular solutions to be adopted in foundries, the Authors of the present study undertook to evaluate those solutions; their evaluation being supported by testing and thorough scrutiny of the manufacturer's specifications.

Several major manufacturers of foundry machines are now present on the market, including: Disa, Kuenkel- Wagner, Haflinger, Heinrich Wagner Sinto, Hunter, Savelli and Technical. Although their solutions utilise basically the same technology, yet their machines differ in constructional parameters, particularly in sand filling and compaction units.

2. Principles of vacuum-assisted moulding

Vacuum-assisted compaction processes are now widely used in flask moulding and snap-flask moulding installations. In both cases the vacuum-assisted process involves some blowing action. In traditional moulding technologies, methods using automatic process lines allow for application of low-pressure action in the area where aerated moulding sand is stored, to achieve the satisfactory level of pre-compaction whilst the final compaction effect can be improved by pressing.

In vacuum-assisted methods the compaction effect is achieved by the pressure gradient induced by the opening of the valve between the vacuum tank and the working space. Incoming air comes against the resistance offered by the sand mix, making it compact. With the precisely controlled vacuum pressure and the amount of sand mix, the mould can be completed within one cycle. The process takes place in the full height of the mould, causing the sand mix to be evenly distributed in its entire volume. The hypothetical model assumes the layered arrangement of the sand mix. In this model, the upper layers will interact with bottom ones during the sand movement and in the final stage the lower layers will be best compacted. Upper layers experience the action of atmospheric pressure, which presses them down to the lower strata subjected to lower pressure. Thus displaced sand layers are decelerated in the direction towards the pattern plate, giving rise to vertical inertia forces directed downward. Stresses occurring in the lower layers will increase, too. As a result of such process, the sand density becomes most favourable in the bottom and middle parts of the mould [5, 6, 7].

The method has two options, differing in the way the under - pressure is applied:

- sand is filled to the mould during the compaction process;
- the mould volume is filled with sand prior to the compaction process;

On account of low levels of pressure gradient applied in the method, the compaction effects are just satisfactory, yet vastly improved in hard-to- access mould sections (in relation to the pressing method). Obviously this technology has its merits and it has a great potential for use in flask-moulding and snap-flask moulding installations.

3. Evaluation criteria

Though all solutions proposed by manufacturers are based on general principles of pneumatic processes, they still differ in constructional and operational parameters.

In order to be able to compare and evaluate the existing solutions it is required that their key features be summarised and converted into evaluation criteria to enable a reliable comparison and evaluation of major parameters determining the process performance and the compaction effects [2].

This evaluation is based on the following parameters :

a) **constructional parameters**: relative to solutions used in the pneumatic installation and in the mould layout. The main components of the pneumatic installation include:

- a vacuum pump of the specified capacity;
- a vacuum tank of the predetermined volume;
- piping installation ensuring the required flow rates;
- an impulse valve ensuring the dynamic behaviour when opening;

As regards the chamber where the sand is compacted, the main components are:

- a moulding flask (size, connection to the pattern plate)
- a pattern plate (layout of patterns and vents)
- valve chamber (volumetric size)

b) **operational parameters:** attenuation should be given to elements associated with the pneumatic process involving the pressure gradient, flow rate in the piping installation and sand flow intensity and pressure decrease along the pipe conduits. In the moulding section we consider the method of sand filling (with or without sand handling systems). Of particular importance is the number and layout of vents and sand properties as these are major determinants of the mould filling process.

c) **production capacities:** expressed as the number of moulds per hour

d) **energy-related parameters:** energy expended to manufacture one mould

4. Description of industrial solutions

Basing on available technical specifications and manufacturers' advertisements, automated vacuum-assisted moulding machines can be classified depending on:

- the method of sand filling (with or without sand handling systems)
- staging of the compaction process (pre-compaction followed by pressing, simultaneous air assisted compaction and vacuum pressing)
- construction of the squeeze head

Major manufacturers of vacuum-assisted solutions currently on the market are: Keunkel-Wagner, Disa, Karl Heinz Sailer, BMD. The solutions with sand handling systems are offered by Kuenkel-Wagner, Disa, Karl Heinz Sailer (Fig 1,2,3), whilst BMD company use the line without sand handling systems (Fig 4). Keunkel-Wagner, Karl Heinz Sailer and BMD installations include the vacuum-assisted pre-compaction and pressing, the DISAMATIC lines (Fig 3) use simultaneous air-assisted and vacuum pressing processes [4,8].

Of particular importance are differences in the squeeze head design, which are better highlighted in Fig 5. These constructions differ in the method of sand filling, connection of vacuum lines and airflow directioning through the venting channels.

The solutions whereby the sand is filled and pre-compacted simultaneously seem more favourable than others because the pre-compaction effects are better and the sand is uniformly compacted along the mould's height and in its critical regions as the sand becomes more liquid during the compaction process. Sand being displaced will better fill the niche. Advantages offered by the solutions without sand handling systems (BMD and that developed by the Authors) include lower costs of the mould-making machines and of maintaining the system tight-proof.

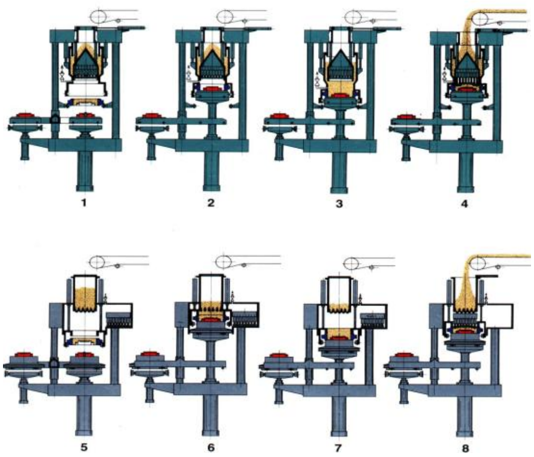

Fig. 1. Pressing machine Vacupress Kuenkel-Wagner [3]

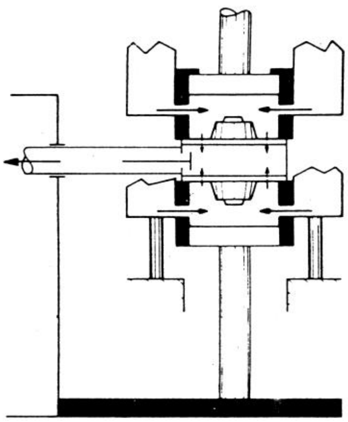

Fig. 2. Vacuum-assisted forming and pressing line (Haflinger) [3]

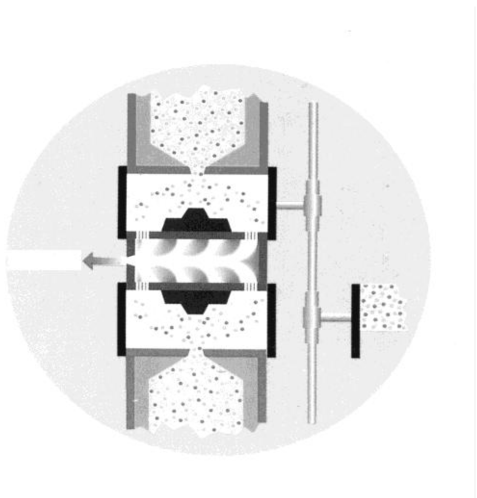

Fig. 3. Automatic forming machine Disamatic [3]

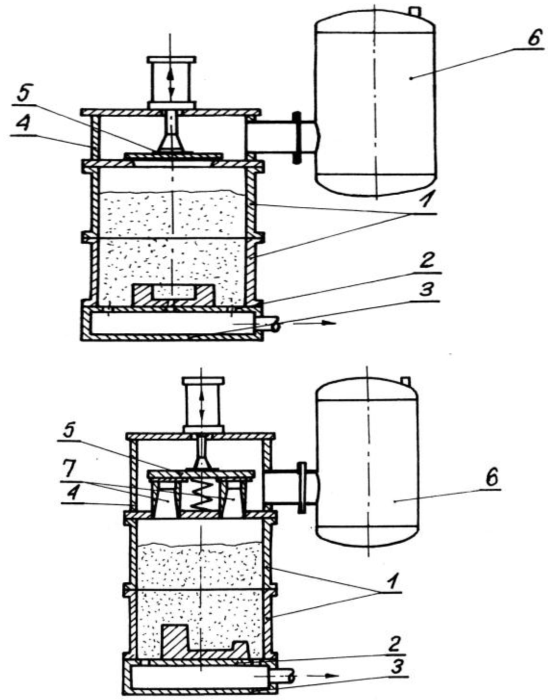

Fig. 4. Schematic diagram of forming lines patented by BMD [3], 1-moulding flasks, 2-vents, 3- vacuum chamber, 4- chamber, 5- valve, 6-pressure tank, 7- Lavel nozzle

5. Comparative evaluation of available solutions

The operating principles of automatic forming machines are based on the methods of static and dynamic compaction processes. The method that is becoming increasingly popular involves the vacuum-assisted process at the pre-compaction stage or as the process improving the final compaction performance. In automatic formers operated in accordance with this method, the additional compaction process is required to achieve the required mould parameters.

The analysis of available solutions reveals that they differ mostly in the construction of blowing heads. Underlying the evaluative study is the airflow model. At the same time, the comparison of performance of particular installations can be used to verify the model developed by the Authors.

The starting point in the model of airflow to the head units in vacuum-assisted moulding installations is the thorough analysis of constructional details. The following installations were analysed [5]:

a, d- Kuenkel-Wagner, Germany;
b- Disa Group;
c-Haflinger;
e- the Author's model

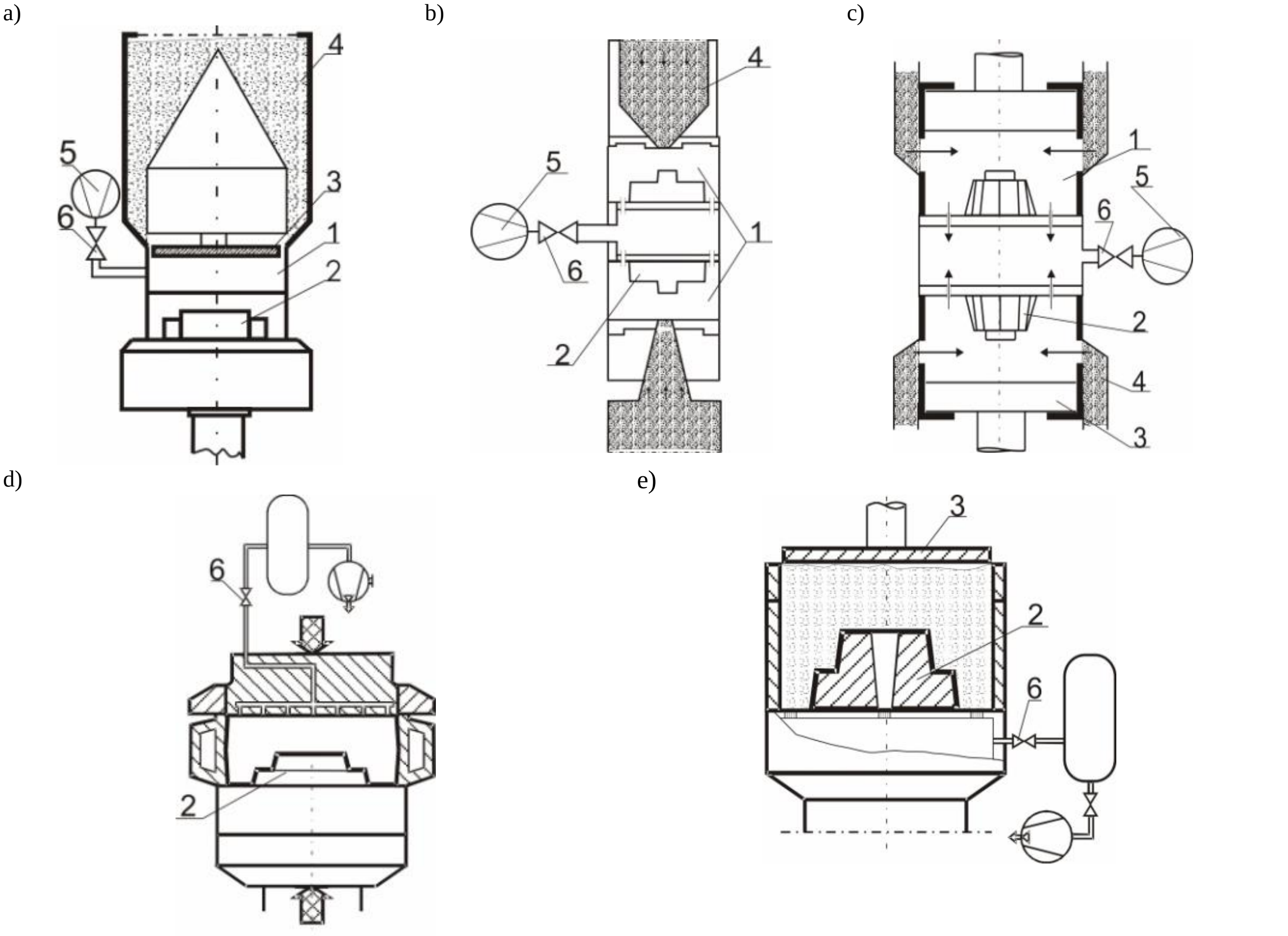

Fig. 5. Simplified diagrams of vacuum-assisted moulding systems [3, 8]: a)d) Kuenkel –Wagner- Vacupress version; b) Disa Forma; c) Haflinger; e) version of the process developed by the Authors;; 1- working space, 2- pattern plate, 3-pressing plate, 4- sand container; 5- vacuum installation; 6- valves

On that basis simplified airflow models are developed, taking into account the technical specifications of the machines. The relevant models are shown in Fig 6.

The components that prove to be of particular importance are: the valve, the sand flow channel and airflow channel [9].

As regards the analysed solutions, there is still a potential of optimising the process parameters through improving the moulding performance and mould quality. The optimisation should involve the selection of the following parameters:

- the size of vacuum tanks;
- cross-sections of conduits in the vacuum line;
- the number of layout of vents in the pattern plate;
- duration of the mould-making process;

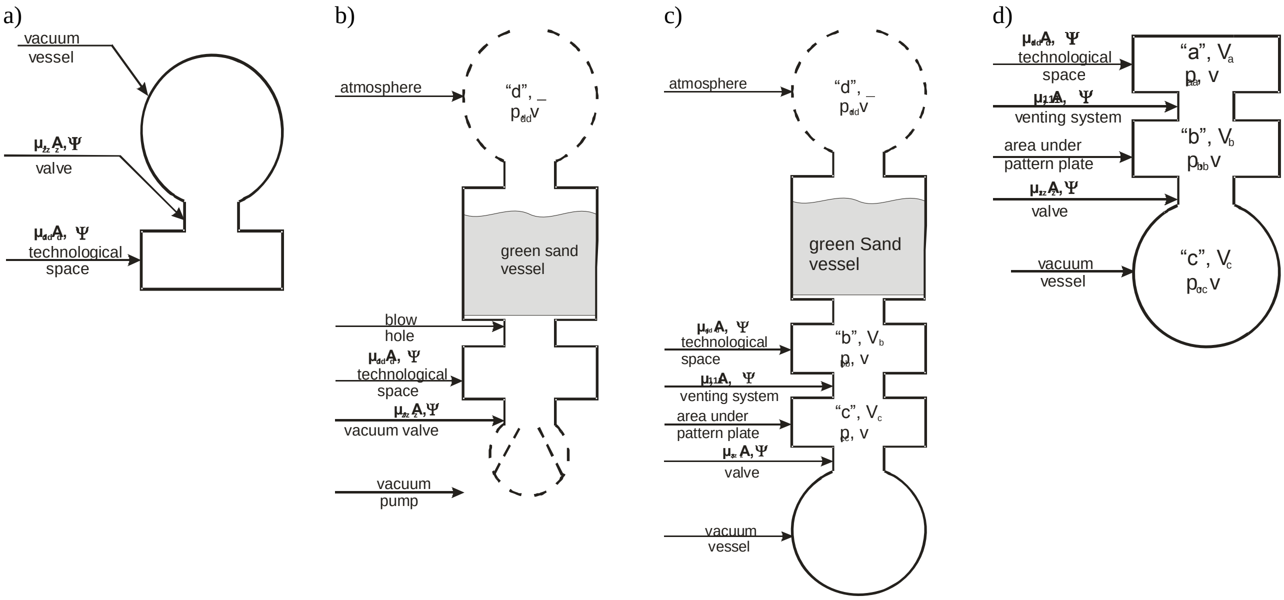

Fig. 6. Models of vacuum- assisted forming system corresponding to the structural diagrams: a & b) Kuenkel-Wagner (Fig 5 a, d); c) DISA Format (Fig 5 c); d) model developed by the Authors (Fig 5e)

To successfully optimise the system, it is required that each mould-making machine should be given separate treatment because of various aspects and unique features present in particular solutions [9].

The comparative analysis of the Authors's model and currently available solutions shows that manufacturers of those solutions achieve good effects, often without revealing the methodology of machine design. It is reasonable to suppose that there exist some analytical solutions to support and supplement the trial and error method. Though this method is rather costly and time-consuming, it still predominates in innovative developments. Working out the criteria for the analysis of parameters of vacuum-assisted moulding machines will further new advancements, paving the way for a new approach to the design of moulding machines and processes. The principal goal, which can be achieved through the analytical solution, is optimising the conversion of energy of vacuum (air pressure) into the compaction effect.

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