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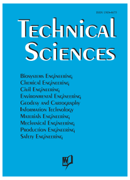

DETERMINATION OF CORES ELECTRIFICATION DURING THE FLOW IN THE MODIFIED WURSTER APPARATUS

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Abstract

The purpose of this paper was presentation of the value of cores electrification during their flow in the modified Wurster apparatus, applied for dry encapsulation of pharmaceutical materials. Previous works of the authors dealt with vulnerability of the particles of different diameter, produced by SYNTAPHARM (Cellets 1000, 700 and 100) on electrification in laboratory conditions. The presented work gives the results of examination on particles electrification in real conditions of their stable circulation in a column. The measurement system, that was applied, allowed determination of electrification potential and electrification current. Those quantities, which are the measures of charge accumulation on cores were determined for several particles (Cellets 1000, 700 and 500) with the different humidity, for different mass of the bed and spouting gas velocities.

Symbols:
d – particles diameter [μm]
I – particles electrification current [μA]
m – mass of a bed circulating in a column [g]
U – particles electrification potential [kV]
$\dot{V}$ – volumetric flow rate of the spouting gas [l/min]
X – initial humidity of the bed [%]
ρ – bulk density of particles [kg/m^3]

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Introduction

In the course of fluidization and spouting of particles built of dielectric material the occurrence of the phenomena connected with their electrostatic charging is practically unavoidable. The first reports describing those kind of phenomena appeared in the literature in forties of the twentieth-century and from that time many researchers dealt with this subject (PARK et al. 2002, MEHRANI et al. 2005). It is justified, because electrostatic charging of the bed very often affects its flow hydrodynamics in decisive way. High value of electrostatic charge collected on moving particles leads to series of negative processes. The most important among them is particles agglomeration on the walls of the equipment and its internals (control and measuring elements), which entails the necessity of frequent apparatus stopping and its cleaning. Under the influence of electrostatic forces large agglomerates could be created inside the bed, reducing an efficiency and productivity of some unit processes e.g. drying or coating. Uncontrolled electric discharging leads frequently to the damage of control and measurement instruments and creates fire or explosion risks (CHENG et al. 2012).

Mechanism of charge creation on the particles moving in a bed is quite complex and it has not been explained completely yet. The electric charge is created in the course of particles mutual friction or the friction between particles and the walls of the column, alternatively during particles collision with equipment elements. There is also effect between continuous and dispersed phases (ionization of fluidizing gas) (MEHRANI et al. 2005, MOUGHRABIAH et al. 2009). Literature review provides great deal of information concerning the methods of the measurement of charge, its dependence on a bed parameters, fluidizing air and the equipment construction. However all those data concern only classical or circulating fluidized beds and model-based particles, made frequently of glass and plastic (polyethylene, polypropylene, polystyrene) (GUARDIOLA et al. 1996, CHENG et al. 2012). There is a lack of a report describing electrostatic phenomena in a spouted bed apparatus, although this equipment is successfully applied for years in many branches of economy e.g. in drying and pharmaceutical industry.

Among many known equipment applied to particles (cores) and tablets coating, spouted bed apparatus seems to be the optimal construction (TEUNOU, PONCELET 2002). In the fifties of the twentieth-century coating was realized in spouted bed apparatuses, in which spraying nozzle was placed in the upper part of the chamber with a bed. Although both the yield of such a process and the quality of produced coat were low. Since that apparatuses with a spraying device, placed in the bottom part of the bed were introduced. In this system probability of collisions of particles with drops of coating solution and the yield of the process are higher, drying time is shorter, although high risk of agglomeration takes place, because of high concentration of wetted particles close the nozzle (WURSTER 1950). Some type of modification of the design described above is the Wurster apparatus (WURSTER 1950, WURSTER, LINDLOF 1966). Wurster apparatus is a spouting device with a draft tube and an additional fluidizing air stream (spout-fluid bed). At the bottom of the chamber there is a mesh used to distribute hot air stream. A spraying nozzle is positioned in the center of the distributor, placed at the bottom of the bed. Coating solution is sprayed through the nozzle or several nozzles and deposited upon particles at the time, when they flow through the entrainment zone. Every particle obtains a small part of the coat during its flow through the spraying zone. Particles are dried inside draft tube, flow into fountain zone, and next in the annulus they settle down again to the entrainment zone. Repeated movement (regular circulation) of particles leads to creation of a solid layer on their surface. Wurster apparatus is considered as the best device for periodical coating of grain materials (TEUNOU, PONCELET 2002, KARLSSON et al. 2006).

Wurster apparatus of unique construction was designed and built during former research. It enables obtaining very high particles velocity and because of that high coating yield (SZAFRAN et al. 2012). Unfortunately, proposed design solution causes several negative phenomena connected with cores electrification. It occurs during particles friction with the walls of the draft tube and the apparatus as well as during rapid impact on deflector. It leads to agglomeration of the particles and accumulation of the bed on the wall surface of the equipment, which interfere with circulation and reduce effectiveness of coating process. The authors have carried out investigations on counteracting those negative phenomena. One of the preparatory stages is the work presented here.

The purpose of the work presented in this paper was examination of the impact of the process variables (spouting velocity, mass of the bed) and particles humidity and diameter on electrification of a bed in the modified Wurster apparatus, together with an elaboration of a simple method of electrostatic effects measurement, with minor interfering in equipment construction. On this basis it will be possible to draw conclusions on restrictions or elimination of uncontrolled electrostatic particles charging during their circulation in the apparatus.

Experimental equipment

All the measurements were carried out in the installation presented in Figure 1. Air was pressed by rotary-screw compressor 1, equipped with refrigeration aggregate (*2*) and went through filters system (*3*, *4* and *5*), which removed oil droplets and through pressure reducer (*6*) enabling flow rate control. Afterwards gas flowed through rotameter (*7*) to the bed spouting nozzle in conical bottom of the apparatus (*8*) made of aluminum.

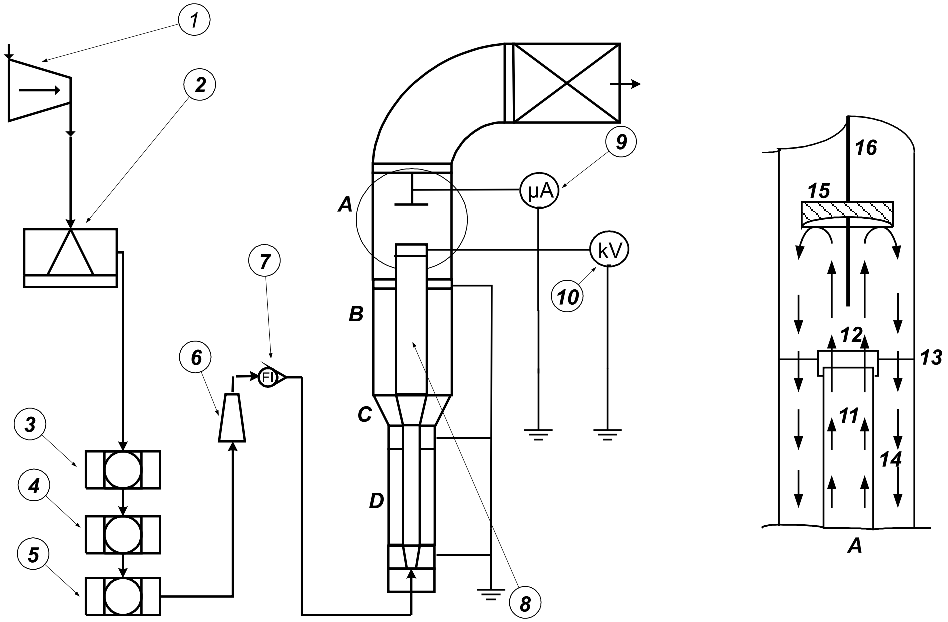

Fig. 1. Schematic diagram of experimental installation with details of the upper segment of the apparatus (arrows show trajectories of particles): *1* – compressor, *2* – freeze-air drying unit, *3* – coarse air filter, *4* – accurate air filter, *5* – carbon air filter, *6* – pressure reducer, *7* – rotameter, *8* – spout-fluid bed column (*A* – upper segment with the deflector, *B* – middle segment, *C* – cone with the spraying nozzles, *D* – lower segment with the spouting gas nozzle), *9* – microammeter, *10* – kilovoltmeter, *11* – draft tube, *12* – clamp, where the voltmeter was connected, *13* – mounting of the clamp, *15* – deflector, *16* – mounting of the deflector, where the ammeter was connected

The column (Fig. 1) consisted of three main parts: cylindrical glass segments *A*, *B* and *D*, aluminum cone *C*, in the axis of which the nozzles introducing air, plasticizer and coating substance were placed. Plasticizer and coating agent were not used in the examination presented in this paper. Above and below the lower segment of the apparatus there were aluminum rings with apertures applied for particles loading and removal. Draft tubes were placed in the segments axes, and joined together with the use of aluminum clamps. The upper segment *A* was equipped with deflector (*15*), which constricted escaping of the particles outside the installation. Electrostatic kilovoltmeter (*10*) (C196) was connected to upper, electrically isolated clamp (*12*) of the draft tube (*11*) using the high-voltage cable, to enable voltage measurement. Microammeter (*9*)

(Metex M-3270), which measured electrification current of striking particles, was connected to electrically isolated metal element, supporting aluminum deflector (*16*). All metal elements of the column, except those applied for measurements, were grounded to prevent uncontrolled electrical discharge.

Measurements were carried out at constant temperature 25°C, changing volumetric flow rate of spouting gas at constant bed mass (500 g) or changing bed mass at constant volumetric flow rate of spouting gas (1200 liters/min.) for different initial humidity of the particles (Tab. 1). Cellets® cores made of microcrystalline cellulose, produced by SYNTAPHARM and used in pharmaceutical industry were applied as particles (Tab. 2).

Table 1

Ranges of operating variables

Parameter	Minimum value	Maximum value
Bed humidity [%]	0	15
Spouting gas volume flow rate [l/min]	930	1200
Mass of the bed [g]	200	900

Table 2

Properties of investigated particles

Particles	d [μm]	ρ [kg/m^3]	Sphericity	Geldart class
Cellets® 500	500–710	800	0.95	*A*
Cellets® 700	700–1000	800	0.95	*B*
Cellets® 1000	1000–1400	800	0.95	*B*

Specific mass of particles, which were electrically uncharged and possessed specific humidity, was introduced into experimental equipment and then volumetric flow rate of the spouting gas was set up, making the bed stable circulation. After the time necessary to stabilization of measured quantities (5 min) electrification potential was read out as well as electrification current. Subsequently, the gas flow was stopped and the bed was electrically discharged through the grounded bottom of the apparatus made of metal. In the next stage another portion of the bed (100 g) was added or another circulation velocity was established (changing the pressure of the gas by 0.5 bar). Particles of specific humidity were prepared by the material saturation with water. Material humidity measurement was made applying gravimetric method with the use of moisture analyzer Radwag MAX 50.

Results and discussion

As a result of examination the dependences between electrification potential and electrification current for different particles were obtained, depending on the velocity of the spouting gas (particle velocity) and the mass of the bed with different initial humidity. Electrification potential achieved high values in the range of 13–41 kV, while electrification current varied in the range of 0.5–3.1 μA.

Together with the growth of the bed mass electrification potential increased, however the differences were higher at the beginning of measurements series – at smaller amount of the circulating bed (Fig. 2). It could be caused by the growth of particles concentration, which led to smaller electrification by friction on apparatus walls. Together with the growth of the mass of the bed there is also augmentation of its quantity collected on the grounded bottom of the apparatus, as movable packed bed, which makes longer the residence time of particles in this zone and favors their electrical discharging. Along with growth of the volumetric flow rate of the spouting gas, and as a result the augmentation of the particles velocity, the electrification potential decreased (Fig. 3), which was probably caused by the lower contact time of the particles with the apparatus walls. The growth of electrification potential with the growth of initial humidity of the bed was observed (Fig. 2, 3), despite the humid bed circulates better, because its charge relaxation time is short and greater electric charge could be quickly took away (quick discharging).

Together with the growth of the bed humidity electrification current grew (Fig. 4, 5), which is connected with the drop of particles resistivity (from about 10^9 Ωm to 10^5 Ωm) and relaxation time (from about 10^{-1} s to 10^{-5} s) (MĄCZKA 2015), which causes the growth of the charge exchange rate. Along with the growth of the volumetric flow rate of spouting air there is a growth of electrification current, which is related to the growth of the particles impact velocity on the deflector. Together with the growth of the bed mass the electrification current grew, achieving the maximum value for the bed mass between 600 and 800 g (Fig. 6). At the mass of about 600 g the number of cores in the fountain is so high, that some part of them do not reach the deflector, which causes reduction of electrification current. Besides that, there is augmentation of the bed mass in the bottom of the apparatus, which leads to its partial discharging.

Together with the decrease of particles diameter both electrification potential and electrification current increased (Fig. 6, 7). However in the first case the differences between particles are small especially with small masses of the bed. More significant differences arise only with masses of the bed greater

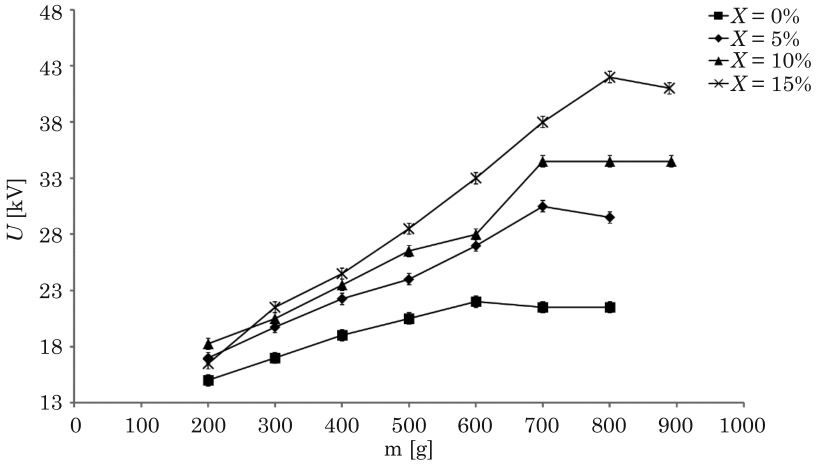

Fig. 2. Dependence of electrification potential on the mass of bed for its different initial humidity ($\dot{V}$ = 1200 l/min, Cellets® 1000)

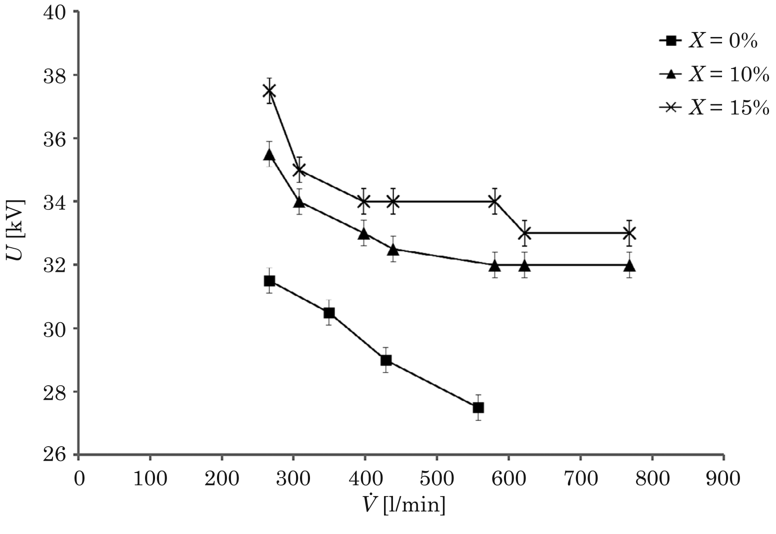

Fig. 3. Dependence of electrification potential on the volumetric flow rate of the spouting gas for different initial humidity of the bed (*m* = 500 g, Cellets® 1000)

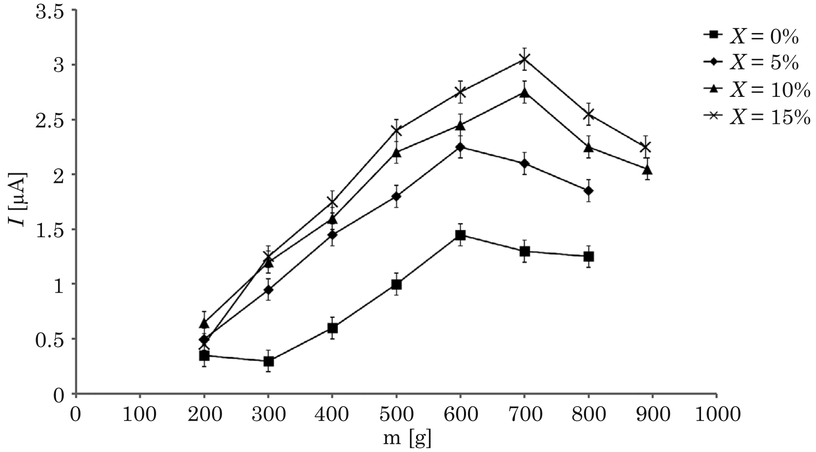

Fig. 4. Dependence of electrification current on the mass of bed for its different initial humidity ($\dot{V}$ = 1200 l/min, Cellets® 1000)

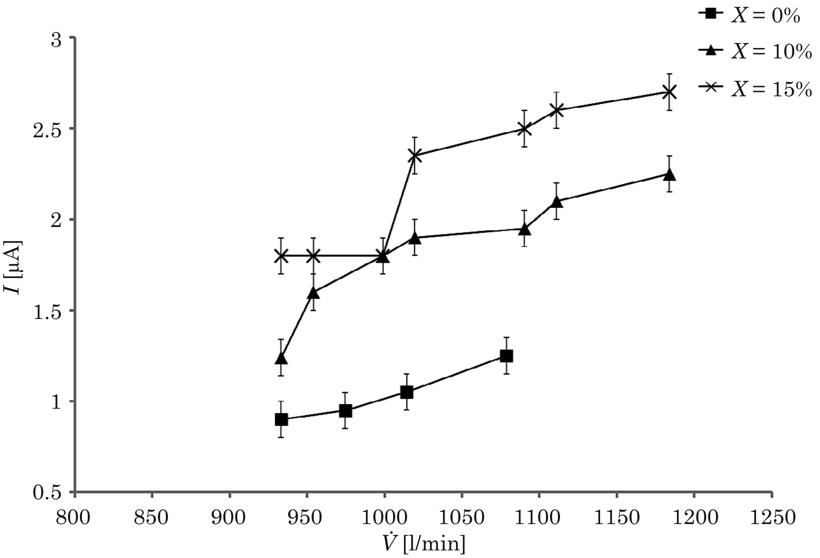

Fig. 5. Dependence of electrification current on the volumetric flow rate of the spouting gas for different initial humidity of the bed (m = 500 g, Cellets® 1000)

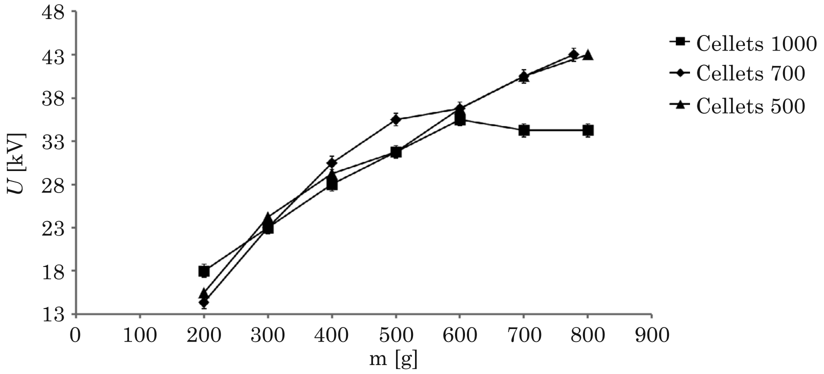

Fig. 6. Dependence of electrification potential on the bed mass for different particles ($\dot{V} = 1200$ l/min, $X = 0\%$)

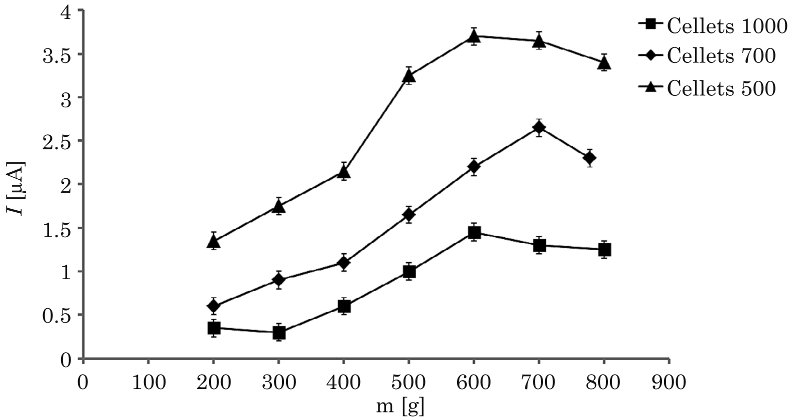

Fig. 7. Dependence of electrification current on the bed mass for different particles ($\dot{V} = 1200$ l/min, $X = 0\%$)

than 400 g. Particles with smaller diameter develop larger surface, and because of that they can accumulate greater charge, additionally at the same time higher number of them strike on the deflector.

Conclusions

Parameters of electrification such as electrification potential and electrification current were determined applying relatively simple measuring system, taking advantage of elements of the inner part of the apparatus, without any significant changes of the equipment construction.

It was established that the potential difference in the column, despite grounding of its metal elements, achieved very high values – from a dozen or so to tens of kilovolts, which confirmed the primary hypothesis on electrostatic mechanisms of negative phenomena such as material sticking to inner parts of the column, which often precluded the correct work of the equipment. The measurement device, that was applied, unfortunately did not enable to determine directly the basic quantity from the point of view of electrostatics – the amount of electric charge collected in the bed. It could be calculated on the base of gathered data and additionally knowing the concentration and particles velocity in the draft tube. At this stage of preliminary research authors did not have the possibility to determine those two parameters.

Owing to this fact, in further part of examination, it is predicted to rebuild the equipment at its lower part, in order to determine the total electrical charge, applying Faraday cage method. On this base it will be possible to draw final conclusions, concerning optimal hydrodynamic parameters and modification of the bed properties, that constrict uncontrolled electrical charging of the cores.

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