TECHNOLOGY, CREATIVITY, IMPLEMENTATION

SPHERONIZER WITH THE STUDY OF DYNAMIC CHARACTERISTICS OF GRANULES

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Summary

The article contains a description of the technological process in which the spheronizer is located on the basis of the extruder-spheronizer, its purpose and place in the technological scheme are considered. The study presents technical characteristics, considered the design and principle of action of the unit for spheronization, performed certain calculations that confirm the efficiency and reliability of the machine.

The purpose of this article is to consider the spheronizer with the study of the dynamic characteristics of the granules. The spheronizer extruder, or spheronizer, is widely used in the granulation of spherical parts and granules. The working material for the spheronizer is non-spheroidal solid particles that turn into spheroids during the spheronization process. To optimize the production of spherical particles in a spheronizer, it is necessary to know all the intricacies of this process, therefore, in this work, the stress-strained state of extrudates, which undergo certain changes during the spheronization process, is investigated using the "finite element" method.

The research is based on actual data obtained by different scientists, and on the results of the authors' own observations.

Key words: spheronization process, finite element method, extruder-spheronizer, spheres, granules, strength, productivity, mixing, polymers, pellets.

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1. Introduction

The spheronizer extruder, or spheronizer, is widely used in the granulation of spherical parts and granules. The working material for the spheronizer is non-spheroidal solid particles that turn into spheroids during the spheronization process.

To optimize the production of spherical particles in a spheronizer, it is necessary to know all the intricacies of this process, therefore, in this work, the stress-deformed state of extrudates, which acquire certain changes in shape during the spheronization process, is investigated using the "finite element" method *(Kuvshynov, Gondlyakh, 2020: 9)*.

Extrusion-spheronization is a multi-step process that includes dry mixing, wet granulation, extrusion, spheronization, drying, and sieving.

The extruder, having certain dimensions of the matrix, produces extrudates, which are then fed to the spheronizer, which forms them into spheroids (balls) with the same size and flow characteristics.

2. Aim and Objectives

The aim of the research is to study, according to the technical task, the spheronizer with the analysis of the dynamic characteristics of the granules based on existing research and the determination of their capabilities.

The object of the study is a spheronizer with an analysis of the dynamic characteristics of the granules.

3. Results

The spheronizer is equipped with a specially designed rotary mechanism that can process dry and wet dispersed material, forming granules of almost perfect spherical shape from it. This granulation equipment is used for such industries as: 1. chemical industry; 2. pharmaceuticals and food industry; 3. production of cosmetics, dyes; 4. production of ceramic products.

Spheronizers have the following characteristics: 1. the ability to produce granules with a diameter of 0.5 ~ 2.0 mm; 2. the ability to process dry and wet material in order to produce homogeneous granules in the form of balls; 3. ease of use and efficiency.

Extrusion-spheronization is a multi-step process that includes dry mixing, granulation, extrusion, spheronization, drying, and sieving. There are two main processes of spheronization, so-called wet and dry, for spheronization, dry material or wet raw material is loaded, which is then processed with a rotating centrifugal disc, air blower and pneumatic nozzle, resulting in dry spherical granules.

Technical characteristics contain information about the device *(Deb Ratul, Ahmed Abdul Baguec, 2013: 93)*. It is based on these indicators that the sample is compared with similar ones and for the next choice and justification of the chosen option. Let's consider the main technical characteristics of different types of spheronizers:

– spheronizer QZL (manufacturer Ukraine)

Table 1.

Specifications	QZL-230	QZL-400	QZL-700	QZL-1000
Power (kW)	0.75	2.2	3.7	5.5
Production capacity (l/h)	10–30	40–120	200–600	500–1500

– spheronizer JW (manufacturer Ukraine)

Table 2.

Specifications	Productivity (kg/h)	Granule diameter (mm)	Power (kW)	Dimensions (mm)
5	3–5	0.6–3.5	4.2	900*680*1100
10	5–10	0.6–3.5	8.6	1550*950*1350
30	10–30	0.6–3.5	17	1850*950*1400

– spheronizer JZL (manufacturer Ukraine)

Table 3.

Model	JZL60	JZL130
Distance between two screws (mm)	60	130
Productivity of wet material (kg)	20–50	20–350
Finished product size (mm)	₵ 0.5– ₵ 3	₵ 0.5– ₵ 3
Speed of extrusion rods (rpm)	15–16 stepless	35, 47, 60
Motor (kW)	1.5	5.5
Weight (kg)	300	500
External Dimension (L × W × H) (mm)	890 × 650 × 1460	900 × 660 × 1530

– spheronizer BEXROLLER BR300 (manufacturer Belarus)

Table 4.

Model	Power, kW	Quantity, approx., dm^3*
BR150	0,55	0,1–0,4
BR300	1,5	0,3–2,5
BR450	1,5	2–9
BR600	3,0	7–23
BR900	5,5	20–70

– spheronizer model 15 SPHERONIZER G.B.Caveva LTD (England)

Table 5.

Employment	Power, kW	Productivity, kg/h
250гр. – 5 кг	2,2	50

Fig. 1 SPHERONIZER G.B.Caveva LTD

The main indicators of spheronizers of various types are also given in the table 2.6.

Table 6.

The diameter of the working chamber	Power, kW	Productivity, kg/h
Ø230 (CJM-23) (Ukraine)	0.75	10 ~ 100
Ø400 (JCD-40) (Ukraine)	2.2	20 ~ 150
Ø700 (CJM-70) (Ukraine)	3.7	30 ~ 200
Ø1000 (JCD-100)(Ukraine)	5.5	40 ~ 300

The spheronizer is widely used in the granulation of spherical parts and granules *(Kuvshynov, Gondlyakh, 2020: 10)*.

The use of a spheronizer consists of four main stages:

1. formation of dry mass (granulation);
2. formation of dry mass into cylinders (extruder);
3. disintegration of extrudate and formation of fragments into spheres (spheronizer);
4. drying of granules.

Production of granules using a spheronizer begins with mixing and dry mixing of the ingredients.

The extruder, having certain dimensions of the matrix, produces extrudates.

The extrudates are then fed into a spheronizer, which forms them into spheroids (balls) of the same size and desired flow characteristics.

Granules undergo further processing to form capsules or tablets.

Usually, the extrusion process helps compact the dry mixture to the point of saturation. We take into account that spheronization is mainly a forming operation that supports the hydrotextural state.

As can be seen from Figure 3, the spheronizer extruder is an assembly of various parts and components. Obviously, each part and component performs different functions, which is described below *(Kuvshinov, Kuvshinova, 2022: 56)*.

Let's proceed to the description of the main parts of the extruder:

1. The loading funnel is a cone-shaped hopper into which raw materials are fed and the ingredients are delivered to the working space. Preferably, the location of the hopper is above the table and the auger portion is present at the lower end of the hopper. The speed of the screw, the cross-sectional area of the matrix and the characteristics of the material flow determine the method of adjusting the feed rate.

2. The auger working space is a hollow cylindrical steel body with a screw auger that passes the loaded materials through the loading hopper. In most cases, the trunk consists of a supply unit, a compression unit and a dispenser.

The compression of the ingredients inside the cylinder turns them into a homogeneous mass before entering the die. To achieve shear and compression in a cylinder with a constant diameter, it is necessary to reduce the pitch of the screw or use a conical screw. The dosing device allows uniform mixing of the compressed mass by adding uniform pressure.

3. A limited opening located at the bottom of the barrel forms the required cross-sectional shape for the extruded product. After leaving the dosing device of the cylinder, the mixed mass experiences a pressure drop at the entrance to the die.

Fig. 2. Extruder – spheronizer

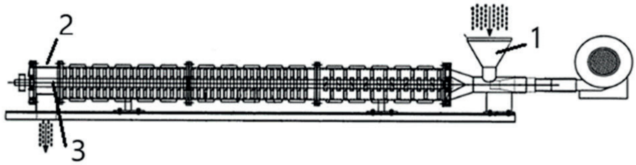


Fig. 3. Extruder – spheronizing machine 1 – loading funne l, 2 – working space, 3 – limited opening

The matrix can have one hole or several holes. To obtain a good quality extruded product, it is important to use a matrix without defects and scratches.

Now we will describe the main parts of the spheronizer as part of the Extruder-Spheronizer machine *(Kuvshinov, Kuvshinova, 2022: 56)*.

The spheronizer consists of three main parts:

1. circular friction plate;
2. a vertical cylinder with an outlet port;
3. variable speed drive that rotates the plate.

Figure 4 below shows the details and assemblies of the spheronizer.

A-A – axis, 1 – apparatus (device), 2 – rotating spindle, 3 – vessel, 4 – lid, 5 – water jacket, 6 – friction plate, 7 – air spaces, 8 – lever, 9 – blade.

The basic spheronizer machine has a round disk with a rotating drive shaft. It rotates at high speed near the base of a stationary cylindrical bowl.

The friction plate is the main part of the spheronizer with a grooved surface to increase the friction force. The shape of the friction plate, which is used in the spheronization of extrudates, affects the properties of the granules.

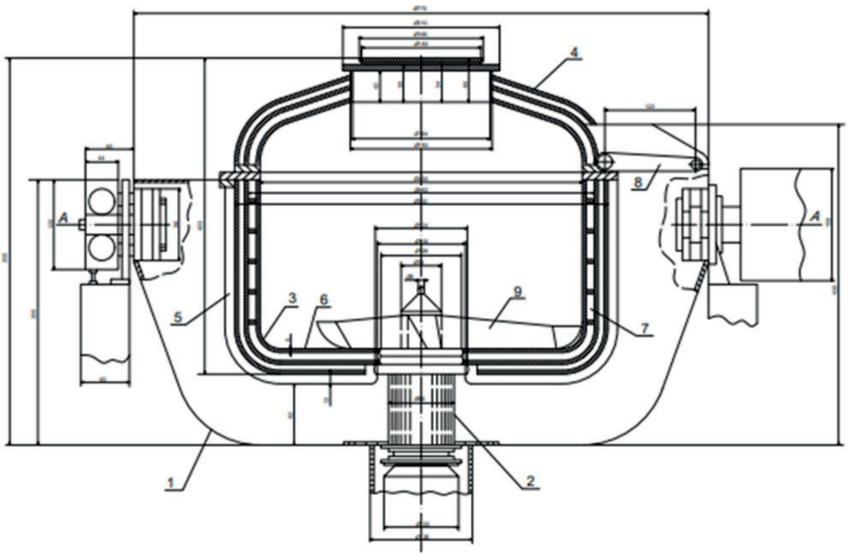


Fig. 4. Spheronizer

The scraper is a component of the spheronizer intended for the operation of cleaning dust particles from the wall of the bowl and the friction plate.

A water jacket is a spheronization chamber. It has a water jacket, which facilitates the cooling of the equipment.

The effects of various aspects of granulation or mixing may be underestimated. In most cases, mixing may have little effect on the spheronization process. Of course, this can also refer to the end product result. During development, it is desirable to maintain constant granulation / mixing parameters.

Extrusion is an important process for the preparation of particles that enter the spheronization process. The diameter of the extrudate applied during the spheronization process determines the final size of the granules.

For example, to get spheres with a diameter of about 1 mm, you need to use a 1 mm die on the extruder (Fig. 5). However, it is recommended to use dies with slightly larger diameter holes to compensate for shrinkage after drying *(Harshada Dattatraya Dalvi, 2018: 608)*.

In a spheronizer, it is convenient to make spheres with a diameter of approximately 0.4–10 mm.

The process of spheronization (Fig. 6) begins with the addition of extrudates to the spheronizer, which fall onto the rotating plate (Fig. 6a). During the early interaction of the friction plate with the cylindrical granules of the extrudate due to the occurrence of bending and tensile stresses, the destruction of the long cylindrical granules of the extrudate into sub-fragments occurs, the length of which reaches from 1 to 1.2 times their diameter (Fig. 6b). These fragments then collide with the wall of the bowl, which in turn throws them back into the middle of the friction plate. Centrifugal force pushes materials outward from the disk.

These cylindrical fragments are gradually rounded, bumping into each other, the wall of the bowl and the plate. Continuous collision of particles with the wall of the bowl and pushing back inside the friction plate develops through the wall of the bowl (Fig. 6c). Typically, this collision will gradually transform the cylindrical fragments into spheres. This will happen as long as the granules are plastic enough to facilitate deformation without breaking. It is important that continuous movement is necessary for the formation of optimal spheronization.

During the process, the shape of the fragments constantly changes and, when they have reached the required spherical shape (Fig. 6d), the spheronization chamber opens its outlet valve and the granules are removed from the spheronizer. In this connection, it is possible to obtain a narrow distribution of particles by diameter.

Fig. 5. Filliera

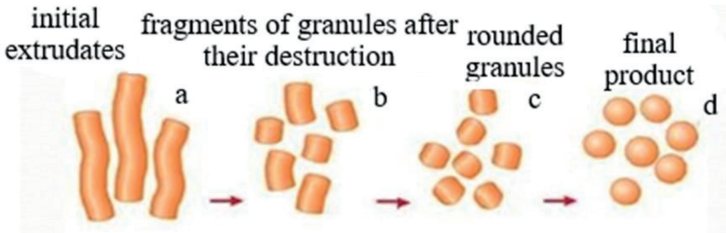


Fig. 6 Process of spheronization:
a – initial extrudates, b – fragments of granules after their destruction, c – rounded granules, d – final product (granules in the form of spheres)

The purpose of the research is to determine the dynamic characteristics of the granules. Nowadays, the finite element method is widely used to solve this kind of problems *(Kuvshinov, 2021)*. In this work, a study was conducted to determine the dynamic characteristics of a polymer spherical particle, which is in a spheronizer, within the framework of the Abaqus system. A calculation scheme was built for effective modeling by the method of finite elements of the contact interaction of a polymer granule made of Tecamid 66 material with a friction plate of a spheronizer.

As a calculation model, a scheme was chosen, the general view of which is shown in Fig. 7, which consists of: friction plate 1, polymer particle 2 made of Tecamid 66 polymer material and contact layer 3 to simulate the effect of polymer particles that surround the studied granule in the spheronizer.

A finite element model is built in the Abaqus system (Fig. 8). To simulate the process of movement of the pellet along the radius of the friction plate, a finite-element model with a plane of symmetry, which is presented in Fig. 8a. A finite-element model without a plane of symmetry (Fig. 8b) was built to study the dynamic characteristics of the granule when it moves along the circumferential coordinate of the friction plate.

As a result of the performed numerical experiments, graphs of the dependence of the reaction at the point of contact of the granule with the friction plate and the reduced Mises

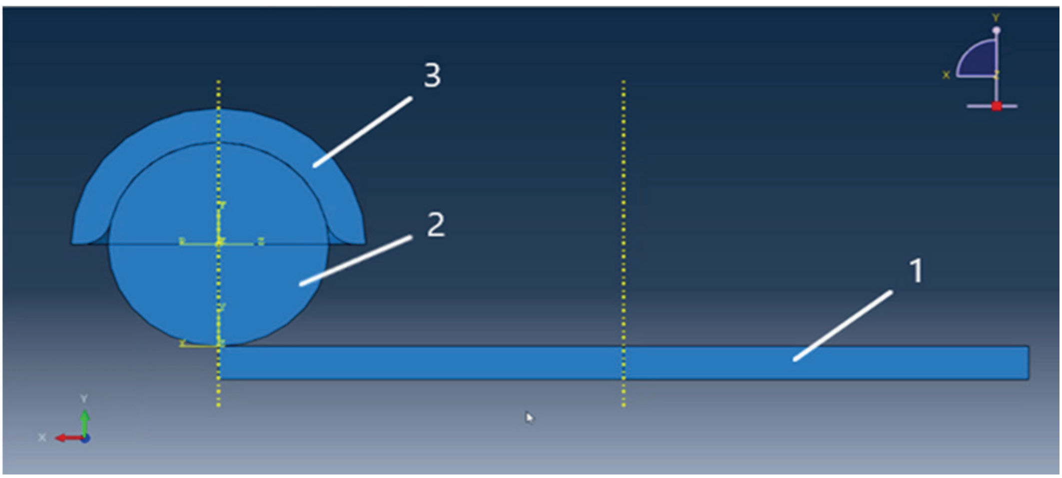


Fig. 7. Calculation model: 1 – friction plate; 2 – polymer particle; 3 – contact layer

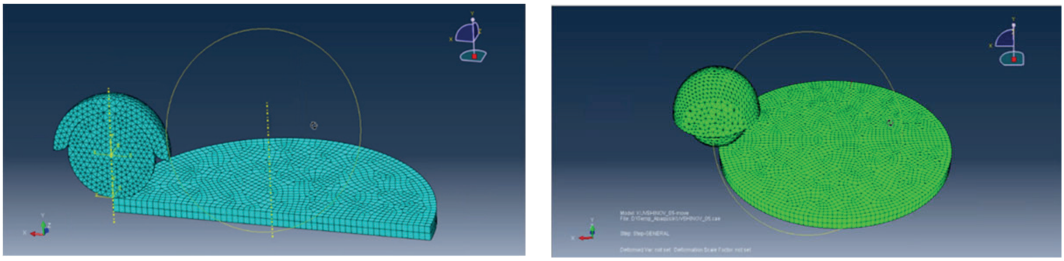


Fig. 8. Finite element models: a – finite element model with a plane of symmetry, b – finite element model without a plane of symmetry

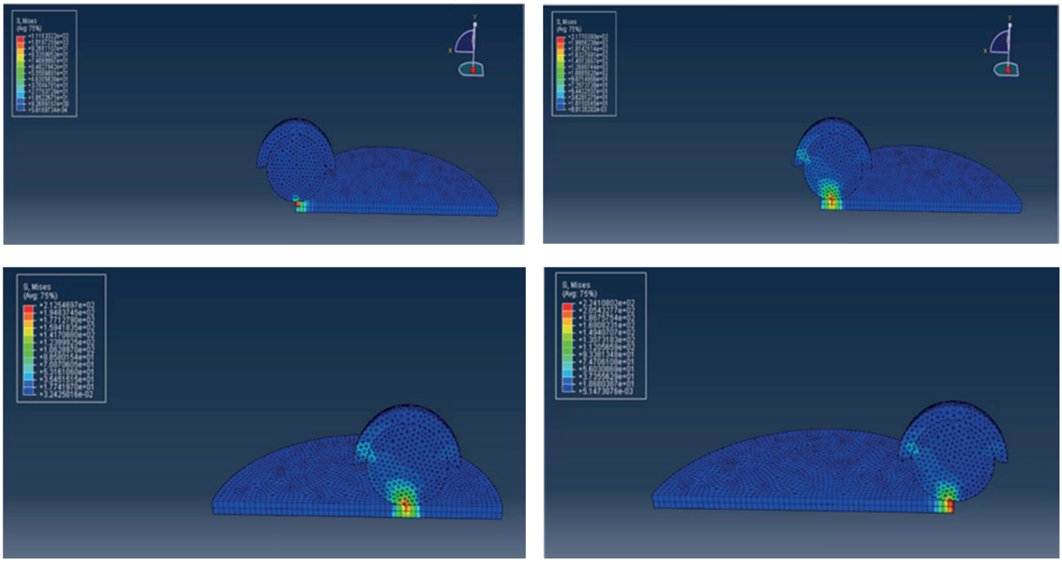


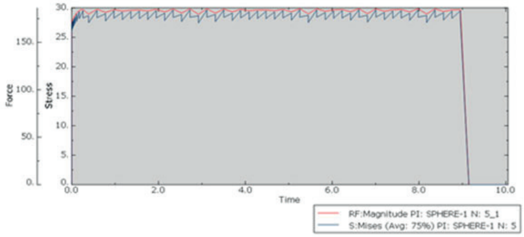
Fig. 9. Evolution of the process of contact interaction of the plate with the polymer granule: a − distribution of reduced stresses according to Mises at the first time step, b − distribution of reduced stresses according to Mises at the third time step, c − distribution of reduced stresses according to Mises at the eighth time step, d – distribution of reduced stresses according to Mises at the tenth time step

stresses, taking into account the friction coefficient, were obtained. The results of these studies are shown in Fig. 10.

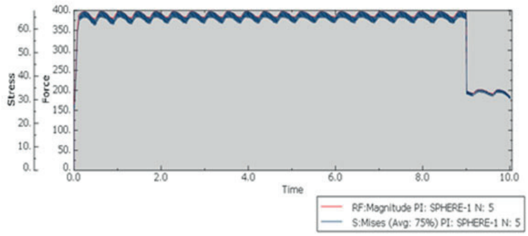
Analysis of numerical simulation results shown in Fig. 10, shows that the dependence of the reduced Mises stresses on the friction coefficient is significantly non-linear (red curve in Fig. 11). The interpolation function (Approximating dependence), which is built on the basis of the maximum values taken from the diagrams of fig. 10, is well described (up to 2%) by a fourth-order equation.

The analysis of these results allows us to draw the following conclusions: 1 − when the coefficient of friction is less than 0.1, linear deformation of the granules occurs; 2 – if the coefficient of friction is in the range from 0.1 to 0.27, significant plastic deformations occur when the granule is deformed; 3 – starting with a friction coefficient of 0.3 and more, at the

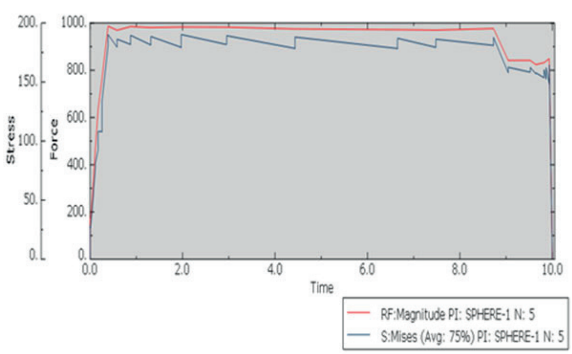
When the coefficient of friction = 0



With the coefficient of friction = 0.2



With the coefficient of friction = 0.6



With the coefficient of friction = 0.8

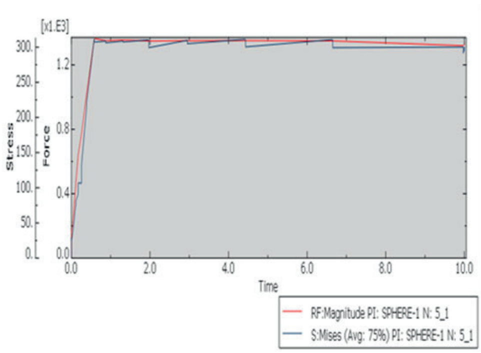


Fig. 10. Diagrams of the dependence of the reaction (Force, H) at the point of contact and the reduced stresses according to Mises (Stress, MPa) depending on the coefficient of friction (reactions are marked in red, and stresses in blue)

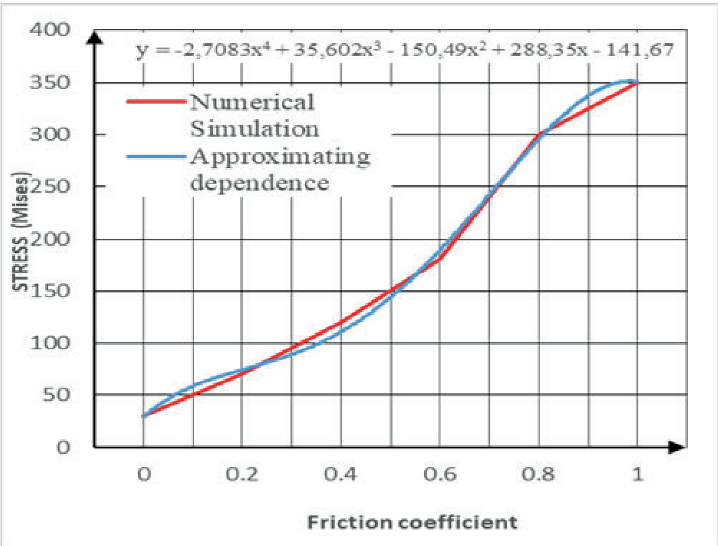


Fig. 11. Interpolation function of the dependence of the Mises-induced stresses at the point of contact of the pellet with the friction plate on the friction coefficient

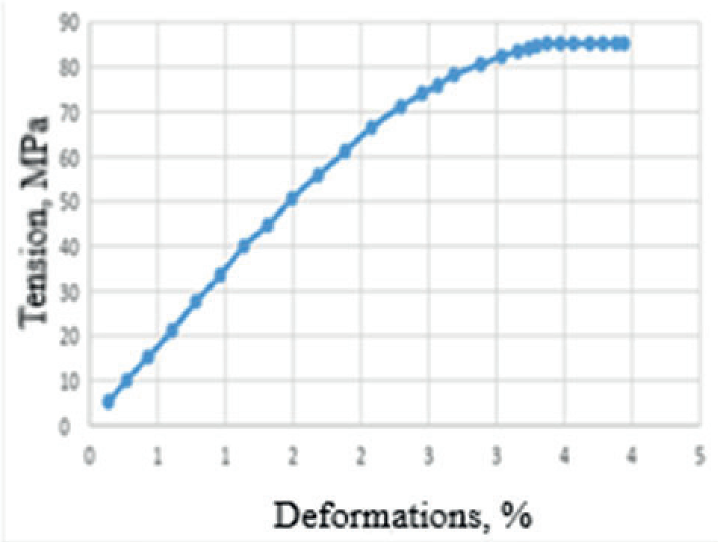


Fig. 12. Tecamid 66 plasticity diagram

point of contact of the granule with the friction plate, stresses are reached that exceed the limit of the bearing capacity of the Tecamid 66 material, which leads to the appearance of fracture zones.

4. Conclusion

In the work, the spheronizer was considered with the study of the dynamic characteristics of granules in a polymer suspension.

The article examines in detail the field of application and purpose of the spheronizer and describes its technical characteristics.

Granules or beads made using extrusion-spheronization provide the following advantages over conventional drug delivery systems:

1. Generates spheroids with a high loading capacity of active components without creating excessively large particles.
2. Produces particles of a constant size, with a narrow size distribution and exceptional flow characteristics.
3. Allows to successfully cover spheroids due to their low ratio of surface area to volume and spherical shape.
4. Involves mixing and assembling granules containing different drugs in one dosage form. This allows the delivery of two or more drugs.
5. Pellets are often used in a controlled release delivery system. This is due to the fact that there is a possibility of dispersion of free spheroids in the gastrointestinal tract.

In addition, it provides flexibility for further improvement.

6. Increases the safety and effectiveness of active components.

Therefore, the considered equipment is fully operational.

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