Influence of compaction times and pressures on rheological properties of kaolin and sawdust powder mixtures

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Abstract. In this research, the compacting process and rheological properties of kaolin and bio-original additive (sawdust) mixtures were investigated based on compaction pressures and times. Relative compaction curves as a function of forming pressure and time were determined, the authors enabled to precisely specify the changes of the rheological models and rheological characteristics of these powder mixtures which have variable particle compactions and size distributions. Varying the compression pressure and changing the composition ratio of the kaolin and sawdust powder mixtures leads to considerable changes in the rheological properties of the prepared mixture.

1. Introduction

Nowadays there are many research work in the theme of ceramic materials which have a great importance [1-22]. Many parts of the ceramic products are formed by cold die compaction, hot pressing and hot isostatic pressing. Studying and understanding the behavior of the powders, granulates or mixtures during the compaction process is an important factor toward the successful forming of ceramic specimens [23-27]. The modelling of compaction is a challenging process. Several research works have been conducted regarding the study of the rheological properties of different mixtures using finite element modelling [28-29]. The mechanical properties of the prepared ceramics products are highly influenced by the grain size distributions of the used powders and the conditions of compaction like compression pressure [30].

The mechanical behavior of the materials can be studied based on the force causing the deformation, the nature of the deformation and the time [31-32].

In this work, the authors have demonstrated that the compacting deformations of cylindrical ceramic discs are highly correlated to the forming pressure and time. Based on their research, the authors have clearly shown how the rheological models and behaviors of kaolin-sawdust ceramic powder mixtures are correlated to the forming pressure.

2. Materials and experiments

For the experimental research work Zettlitz Sedlecky ml kaolin and fine grain oak sawdust (additive) were used. To prepare different mixtures kaolin was milled and mixed with the sawdust as additive in
a Retsch PM 400 planetary ball mill trough 20 min of each at 200 rpm. The grain microstructures are shown in Figure 1.

![Figure 1. Surface micrograph of the kaolin (a) and sawdust (b)](image)

The prepared powder mixtures were compacted through one-side pressing in a cylindrical die cavity with 15 mm in diameter uniaxial hydraulic press. The displacement and pressure data were automatically recorded, which can be seen on Figure 2-4.

3. Results and discussions
During the compaction process, the hydraulic press continuously increases the load forces (pressures), which caused the powder mixture to deform and compact (Fig. 2).

![Figure 2. The compacting deformations of cylindrical specimens are depended on forming pressure and time](image)
As a result of the load reduction, stress relaxation equivalent to elastic deformation of the mixture is observed. The height of the compacted specimen increases and this behavior of the powder mixture is due to Voigt-Kelvin "elastic-viscous" material model.

Figure 3 shows how the pressure in the powder mixture have been changed during the compaction process. The tested powder mixtures are characterized by 5 different rheological material models during the compression process as shown in Figure 4.

**Figure 3.** The compacting deformation of the different powder mixtures depended on the forming pressure at the beginning (a) and the whole compacting process (b)

**Figure 4.** The compression chart (a) with the determined rheological behavior (b)
In the first stage of compaction, the deformation increases quickly under load, the particles move in the direction of pressing, which is characterized by a Newtonian viscous material model. In the second phase, the degree of deformation continues to increase due to the material reaching its yield point and the plastic portion beginning to deform. The initial deformation is caused by the placement of the granules and their rolling into the gaps as they fill the space available to them. In the third stage, the filling of the gaps and cavities continues with the disintegration of the agglomerates. In the fourth stage, the friction between the particles causes tension in the material which results in a significant increase in pressure. Finally, the damaged and broken particles are brought closer together, which also causes an increase in pressure and leads to delayed deformation. In the fifth phase, the load was released. The stress relaxation is visible as the elastic part continuously decreases the degree of deformation. This phenomenon can be explained by the fact that the compacted product cannot be returned into the tool after taken out from the die because of the characteristic geometric dimensions are changed.

Throughout the compaction process, the powder mixtures can be characterized by the complex material model shown in Figure 5 developed by L. A. Gömze in 1983 for rheological characterization of asbestos-cement masses [33-34]. Later, it has been successfully applied in the study of asphalt mixtures and asphalt concrete made with bituminous binder [35] and in the stress relaxation of hetero-modulous, hetero-viscous complex ceramics [3, 36-37].

![Rheo-mechanical model](image)

**Figure 5.** The developed rheo-mechanical model [38]

### 4. Conclusions

Using a hydraulic pressing machine, the authors carried out compaction tests to determine how kaolin and biological additive (sawdust) powder mixtures behave during the compaction process. In their research work, 5 different rheological material models were used to characterize the studied powder mixtures. During uniaxial compaction of ceramic powders, the mechanical stress relaxation has already started inside of the die cavity.

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