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ANALYSIS OF INJECTION MOULDING OF CERAMICS COMPOUNDS BY THE THEORY OF SYSTEMS

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ABSTRACT
The main purpose of this paper is to present the theoretical systemic analysis of injection moulding of ceramic compounds (CIM) with Rophol's theoretical definitions. The systemic analysis also includes the making of a basic model of CIM. The main principles of CIM and all phenomena connected with the process are represented by means of inputs, outputs and relations. This systemic analysis will be used as a base for easier understanding of this new technology of injection moulding.
Keywords: injection moulding of ceramic compounds, systemic analysis

1. INTRODUCTION
The continuous strides forward in science and technology lead to ever increasing demands on materials. Ceramics have significant advantages characterized by their outstanding physical, chemical, mechanical, thermal and/or electrical properties. The inherent hardness of ceramics means that manufacturing complex shaped ceramic components by standard machining processes can be expensive. CIM offers an economic solution for delivering repeatable, ultra high precision ceramic components. But because of complexity of CIM it is sometimes hard to understand how this process works. Due to this fact, it was decided to make a systemic analysis of injection moulding of ceramic compounds.

2. INJECTION MOULDING OF CERAMIC COMPOUNDS
The CIM process begins with very fine ceramic powders. Using sophisticated mixing technology the powders are compounded with different binder systems to produce a homogeneous palletized feedstock. The binders form a liquid medium which carries the ceramic powders into the mould during the injection stage. Using an injection moulding machine similar to that used in conventional plastic moulding, the molten feedstock is forced into a mould cavity forming a net shape part. Moulds can be single or multi-cavity configurations. After forming the part it then goes through two thermal processes. First step is to remove the binder, followed by sintering in a high temperature furnace to form a fully dense ceramic component. During sintering the component shrinks uniformly by as much as 20 % while retaining the complex shape. With good process control close tolerances can be obtained, therefore machining of the part after sintering is usually not necessary. Figure 1 shows steps and equipment of CIM process [1].

3. GENERAL MODEL OF CIM
The following section is based on book Systematic Analysis of injection moulding [2] and article The systemic analysis of metal injection moulding [3].

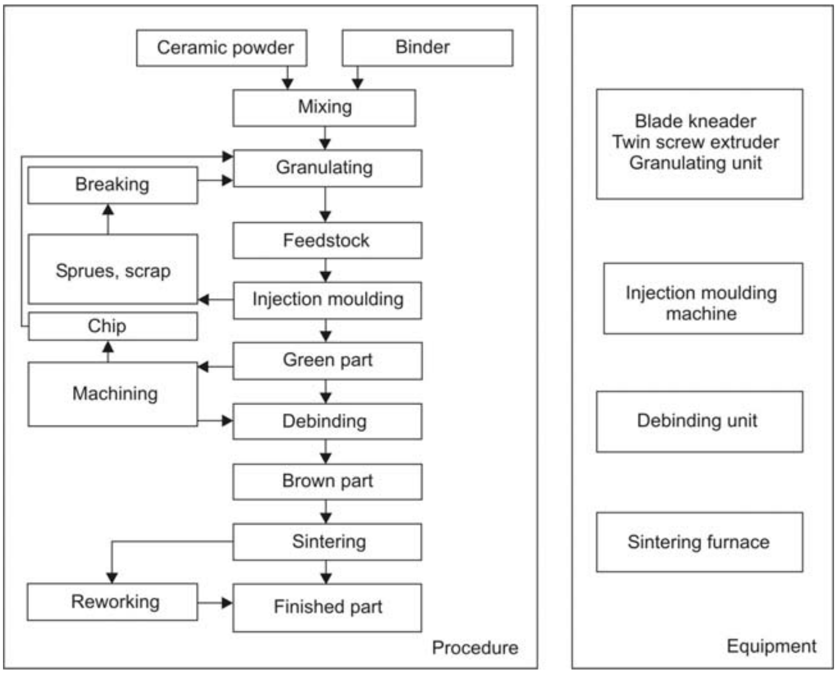

Figure 1. Steps and equipment of CIM process [1]

Based on the general definition of injection moulding of materials, systemic concepts and specifics of injection moulding of ceramic compounds, an injection moulding model of ceramic compounds was made, as well as the symbolic representation of marking the model of injection moulding of ceramic compounds, based on the law of systemic theory (Figure 2).

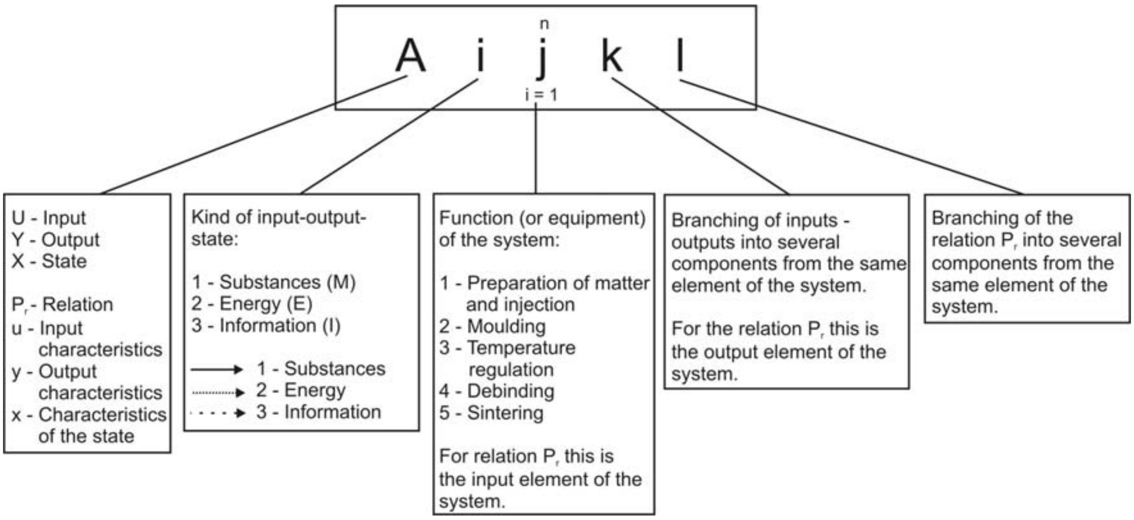

Figure 2. Symbolic representation of injection moulding of ceramic compounds

The injection moulding system of ceramic compounds presented in Figure 3 consists of the following functions: the function of preparing the matter and injection, the function of moulding, the function of tempering, the function of debinding and the function of sintering.

The frame which contains the injection moulding model of ceramic compounds marks the environment in which the system acts, and with which it is connected by inputs and outputs. The environment conditions that directly or indirectly influence the injection moulding process of ceramic compounds are air pressure, air humidity and its temperature. In designating the flows of matter, energy and information the markings presented by the symbols to designate attributes and connections have been retained. The description of the model contains the attributes: inputs (u), outputs (i) and conditions (x), whereas the attributes of time and space have been left out.

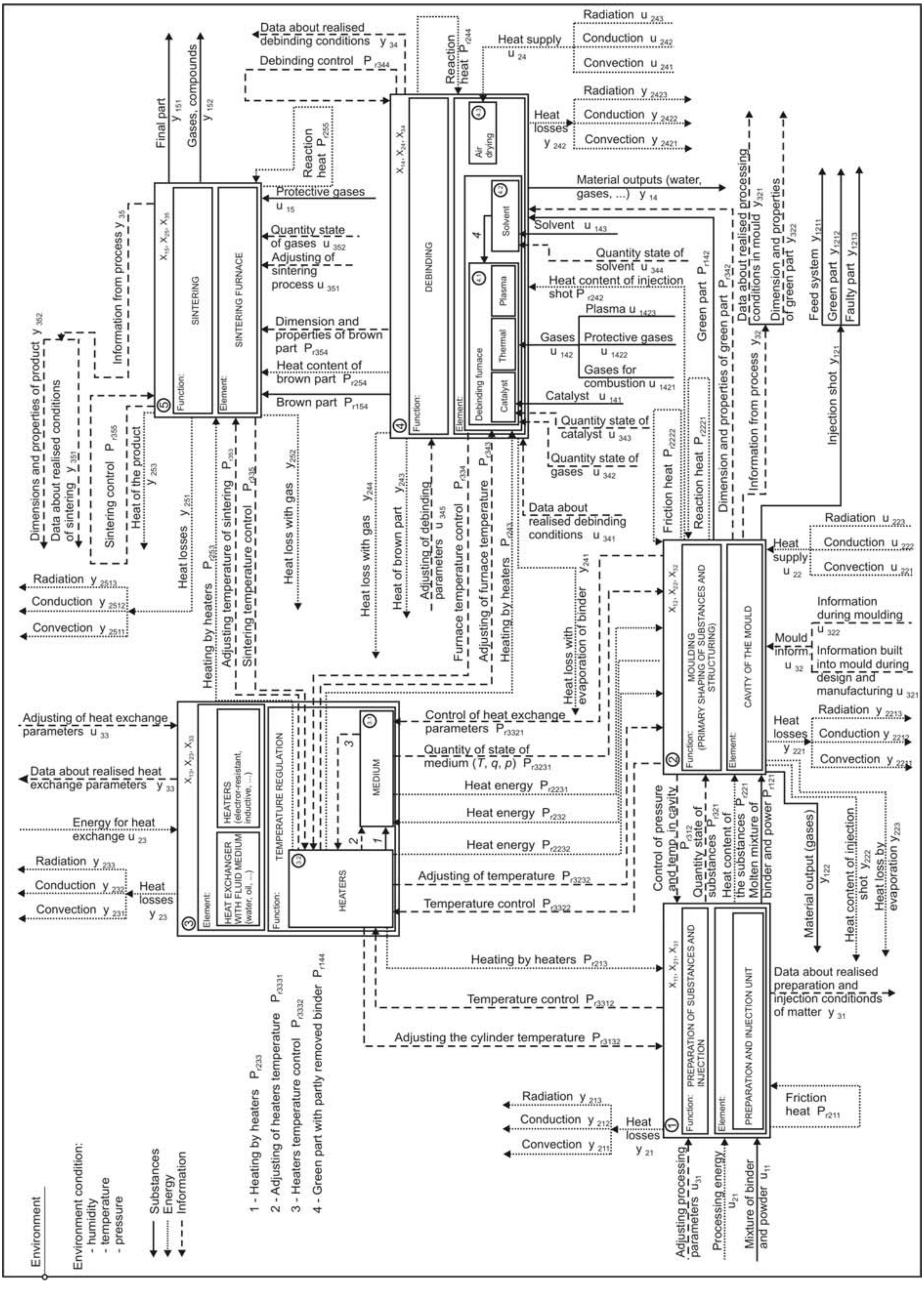

Figure 3. General model of CIM

4. SYSTEMIC ANALYSIS OF CIM

The system of matter consists of attributes A_i, sets of functions F_j which can be realized on the basis of natural laws, sets of artificial, concrete subsystems s'_S and sets of relations P_m. Attribute A_j of the system for injection moulding of ceramic compounds includes material M_i, energy E_i and information I_i attributes, coordinates of space S and time flow T of inputs U, outputs Y and conditions X, as well as the relations among subsystems.

In the system for injection moulding of ceramic compounds there is the function class of change F_C. This function is divided into two sub-functions: manufacturing function F_{CM} and processing function F_{CP}. The injection moulding of ceramic compounds refers to the function of creating the connection among particles F_{CMps} (injection moulding and sintering), but also to the function of maintaining, decreasing and increasing connection and to the function of reshaping F_{CMrs} (debinding). At the same time, the functions of structuring occur; the functions of primary structuring at molecular level F_{CPpsm}, functions of primary structuring at supra-molecular and higher levels F_{CPpss} and the function of re-structuring at molecular level F_{CPrsm}. These functions are the result of chemical reactions in case of applying thermoset binding, as well as chemical reactions in debinding and sintering process. This means that during the injection moulding of ceramic compounds the macrogeometrical shape of the product as well as the structure is obtained. Thus, we speak of the production of ceramic products using the procedures of reaction primary shaping with achievement of usable properties of the product by strengthening outside the mould.

The transfer function F_T occurs in filling the mould with the matter of required shear viscosity, material flow due to the rotation of the screw, transfer of green and brown moulded parts while debinding or sintering, etc. The storage function F_S occurs in several ways. It can refer to the storage of matter or energy, as e.g. in achieving the stipulated temperature field in the mould or achieving the stipulated temperature of the debinding furnace. In all the considered systems there is a function of the change of state F_{CS}. Injection moulding of ceramic compounds is a non-stationary process. The function of maintaining the state is possible only in the case when it refers to isolated unit for matter preparation from the unit for injection, e.g. mixing of components that is not related to injection.

The relations between subsystems for injection moulding of ceramic compounds are defined by the set of relations which makes the structure of the system for injection moulding of matter. This leads to the conclusion that the system structure consists of material, energy, and information connections, as well as space and time relations. Every system is surrounded by the environment of matter. This refers more precisely to the environment of matter in a narrower sense, on the technical environment of matter system.

5. CONCLUSION

The paper analyses the injection moulding system of ceramic compounds by systemic theory. The obtained model presents in a unique way the injection moulding of ceramic compounds, thus providing theoreticians, as well as practitioners with a large volume of information related to the process itself.

6. REFERENCES

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