Glaze Calculation Software Based on the Seger Method with Recipe Mixing Utilities, Limit Formulas and Toxicity Measurements

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Abstract: - Most of the Ceramic SMEs face problems with numerical and chemical aspects of glaze calculations. These problems arise for the differentiations of the available in the market raw materials and the need to combine the existing ones in order to produce a non problematic glaze (changing a frit for another) and with low toxicity. The presented work is a solution for Ceramic enterprises to overcome these problems and produce quality products by learning how to build the desired glazes using the available in the market raw materials. This publication describes a glaze calculation software based on the Seger Method enhanced with advanced features, developed in a friendly and easy to use graphical interface were the ceramists can create recipes, mix recipes between them, upload images of the outcomes, search for existing recipes, and simulate the results changing a number of parameters (e.g. temperature). It is a useful methodology that undertakes to perform a great deal of the required calculations, helping the ceramists to learn how to make recipes following international standards and mixing different materials for the development of cost effective quality products.

Key-Words: - Seger Method, ceramic glaze recipes, glazes, raw material, ceramic mixtures

1 Introduction

In a worldwide level the countries that produce ceramic items are mainly countries from Asia (China) and Eastern Europe. Currently, products of those countries cover the biggest part of the international market. Their cost is especially low and this is mainly due to the particularly low labor cost existing in these countries and the big production volume. China is evolving into the biggest competitor. Chinese porcelain is found within the first choices of the consumers for its quality. Other dominant countries in the Ceramics sector are England and France. These countries hold the scepters concerning the production of artistic products in the last 200 years.

To fight competition, ceramists all over the world need to invest in quality and safety of their products. To do this they need to be aware of the chemical composition of their recipes and the toxicity of the produced glazes.

Seger method is a solution to this problem, but it requires approximately 4 hours of calculations for each recipe and the possibility of mistakes is often and obvious.

In this work we present an assisting software to help ceramists not only with calculations but also as a program consultant in making glazes. In section two a description of the calculation formulas the ceramists use are presented. In section three several existing similar software tools are presented along with the innovative aspects of this work. In the fourth section the overall functionality is depicted and in the fifth section some future works are described. In the final section conclusions are following.

2 Problem Formulation

Ceramic glazes are mixtures of oxides: silicon (SiO_2), aluminum (Al_2O_3) and other easy to melt oxides (mainly PbO, K_2O, CaO, Na_2O).

These oxides are positioned in the form of suspension in the surface of the already baked clay (biscuit) and during firing they melt (due to chemical changes). When dry, they create the glassy

permanent coat. This coat (Hard glassy coating) makes the ceramic product:

- Mechanically durable,
- Chemically Inactive,
- Water Proof, and
- Prettier with the use of the suitable coloring substances

The most common oxides that consist the synthesis of the ceramic glaze (baked or not) are: SiO_2, Al_2O_3, B_2O_3, Na_2O, K_2O, CaO, MgO, PbO. These are imported in the not baked glaze with the form of raw materials. These materials, available in the market, are mostly clays and Frits. Mixing the aforementioned oxides we have a specific glaze. This mix requires specific quantities from each material, different for different baking temperatures. These quantities in percentages are the recipe of a specific glaze.

2.1 Seger Method

Herman Seger [1] categorized in three groups the oxides that constitute a ceramic glaze:

- Easy melting: RO, R_2O
- Ambiguous: R_2O_3
- Acidic: RO_2

When the Seger Molecular Type of a ceramic glaze is known, that is when we know the quantity of each oxide in moles, and then it is sure that we can create it from different raw material and in different quantities, taking under consideration the cost, the ecological impacts and the availability of each raw material.

2.2 Existing software for Glaze Calculations

The calculation of a ceramic glaze recipe according to Seger method using relevant software, compared to the previous, empirical way of making calculations, offers added value services to the ceramists, minimizing time required and trials needed. Additionally the software offers raw material alternatives (substitutes), limit formulas and update of recipes when new raw materials arrive.

There exist in the market several calculation software tools addressing glaze problems with aim to help ceramists in glaze calculations. These tools were well examined by Malmgren [2], but today they are all improved and there are some new ones not included in his report. These available software tools are:

- **GlazeMaster** is a glaze calculation software program designed specifically for studio potters. It runs on both Windows (98 up to and including XP) and Macs (OS 8.6 -10.4). The OS X version for Macs runs in native mode.
- **HyperGlaze** is easy-to-use glaze software designed for artists who use ceramic materials, *HyperGlaze* can be used as a database to store clay and glaze recipes and to list raw materials and their analyses. It also has many powerful tools for glaze calculation. It runs on both Windows and Macintosh.
- **Insight** is a classic ceramic chemistry calculator; it interactively converts recipes to formulas and back. The main INSIGHT window shows side-by-side recipes and their formulas, you can make chemistry changes to one while comparing it with the other. INSIGHT is also a library and a teacher: It puts at your fingertips a huge amount of information to help you learn the principles of ceramic chemistry and it teaches you how to adjust, fix and formulate glazes. It runs on both Windows and Macintosh.
- **Matrix** is essentially a software package which converts a glaze recipe into a Seger formula and which can reverse that process by allowing you to turn a Seger formula into a glaze recipe. Glaze or clay recipes expressed as Seger formulas may be intelligently compared and interpreted such that conclusions may be drawn about the nature of the glaze in it's fired state.

Insight announced that in Jan 2010 a multi-user software will be published [3]. Regarding limit formulas, according to Hesselberth review [4] all of the above programs have such formulas of one kind or another built into them and some of them include some specialized ones.

2.3 Innovation of the presented work

The proposed work, offers the basic functionalities like the similar software tools presented above, but also implements user friendly interfaces for innovative aspects like toxicity reduction consulting tools for the ceramic glazes, price calculation of recipes based on real market costs, the possibility of mixing several existing recipes to create new ones useful for the development of mat glazes using mat mixtures and the ability to exchange recipes between ceramists by simple XML files [5].

The software is developed using the Microsoft tools and exploits all the capabilities offered from the .NET framework. All the recipes are exported in

XML files for future interoperability and easy exchange of recipes between ceramists. An XML schema [6] tailor made for glaze recipes has been developed to describe the content and semantics of these XML documents in order someone to be able to import and export recipes from a system to another. Apart from descriptive metadata, Learning Object Model's (LOM) metadata, a standard that specifies the syntax and semantics to fully and adequately describe a Learning Object, have been added to help ceramists to make the identification of the most adequate glazes, based on difficulty, motivation and goals of training [7].

3 Problem Solution

The presented work is a set of algorithms and electronic tools for the analysis and calculation of ceramic glazes using the Seger method. Through the tools, the user on one hand can check the chemical composition and the attributes of the glazes, analyzing their recipes and on the other can build new recipes for ceramic glazes with goal to reach the desired chemical composition.

For making the calculation a data repository (Fig.1) with the available raw materials is used. It is a relational database where the chemical compositions of all raw materials available are stored.

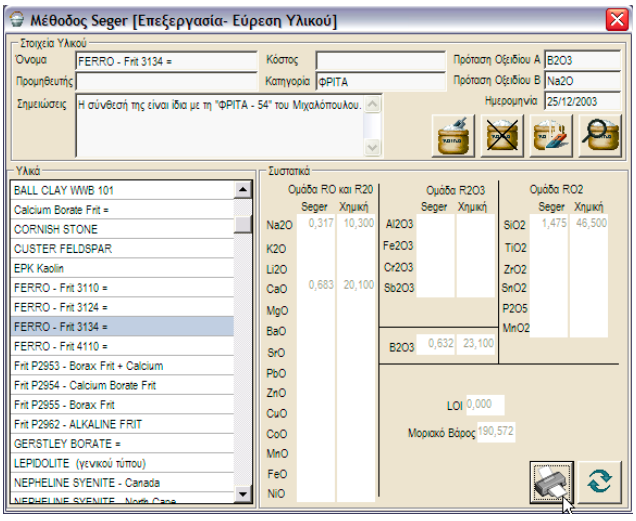

Fig. 1: Materials and their chemical composition

3.1 Making a recipe based on the available raw materials.

The selection of the raw materials and the quantity that they will be mixed is the key data for the calculation of the chemical composition of the constructed glaze. When one of the raw materials that are used is not available in the market, the algorithm proposes substitutes that can produce the same or a similar outcome. Mixing these materials in different quantities the chemical composition of the mixture is calculated and presented to the user. Using limit formulas, as we will see in section 3.4, the user can see if the recipes that create are inside the proposed limits for non-problematic products.

3.2 Making a recipe based on the desired chemical composition

When the desired chemical composition is known, the ceramist selects one by one the oxides of the new glaze. The algorithm retrieves the raw materials that include these oxides and suggests the quantities that should be used to achieve the desired outcome (fig 2). The system suggests alternative material with purpose either to improve a recipe or to substitute non available or expensive materials on the market or to reduce toxicity of the final products.

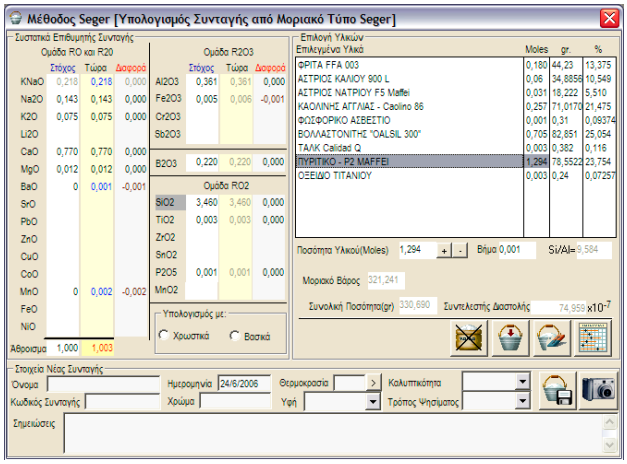

Fig. 2: Building a recipe

3.3 Combining recipes

One of the most innovative features of the presented work is that the system can compose new glazes by mixing existing recipes. The system allows the mixing of up to 4 recipes in the quantities the ceramist will select. The resulting recipe of the mixture is depicted in Fig. 3. This algorithm is very useful for the development of mat glazes using mat mixtures.

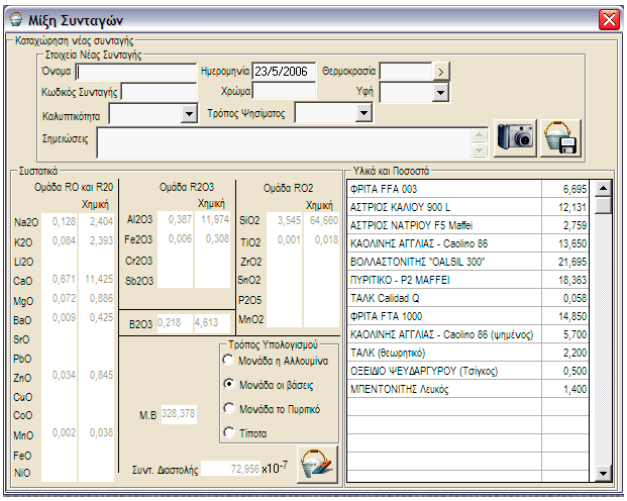

Fig. 3: Mixing of recipes

3.4 Limit formulas

Limit formulas plays the role of a guide that helps the ceramists to compare created recipes with exemplary standard glaze compositions combining different types and temperatures in order to prevent the composition of problematic products (Fig 4).

The ceramists compares their recipes with best practice well known limit formulas [8] in order to see if he conforms to some basic standards for making ceramic glazes in order to be non problematic during baking or use (e.g crazing, blistering, settling, clouding, scratching, leaching, crawling, marking).

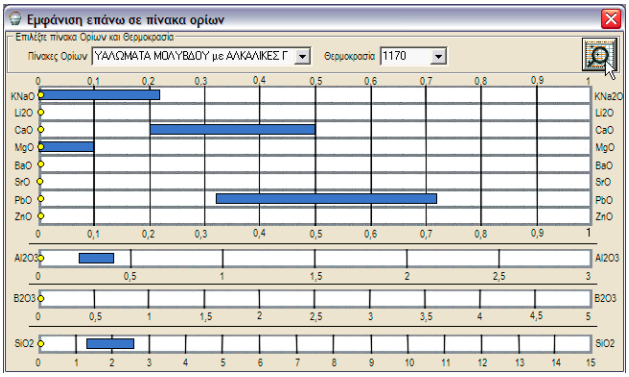

Fig. 4: Limit formulas

3.5 Reducing toxicity

The toxicity of the glazes that contain lead can be reduced through the use of the tools of the specific application by:

- The configuration of the RO and R_2O (easy melting) in the molecular type of the glaze. This is achieved by suggestions made by the software for replacement of these substances with other easy melting oxides like CaO, BaO, ZnO.
- The replacement of raw materials containing the lead with other frits ($PbOSiO_2$, PbO_2SiO_2).

4 Future Works

Next step in this work is scheduled the development of a web version of the tools, where the ceramists apart from creating their own recipes, they will be able to collaborate, exchange experience on problematic materials, improve published recipes, discover new raw materials, discuss toxicity levels and allowable limits of substances. This work will follow the methodology presented from Karadimas et al [9] for an integrated, ontology based e-service for public networking.

This platform is envisaged as a web 2.0 environment enhanced with collaboration tools and ontology based content. The ontology will be built around ceramic products and their connection to Customs, manners and folklore. The adoption of OWL [10] for the development of the ontology is rather justified; not only due to the need of developing an ontology that will be WWW exploitable, but mainly due the semantic power of OWL's representation mechanism, which has been unanimously recognized among the knowledge engineering community. There is a vastly growing community working on OWL and new OWL tools emerge on a day to day basis. Among these, Protege [11], the open source ontology editor, which has an OWL plug-in that facilitates creating and reasoning with ontologies specified in OWL through a graphical user interface.

5 Conclusion

Glaze calculation software is not a new issue for the ceramic sector society. There exist a limited number of software tools for helping potters in making their calculation when making ceramic glaze recipes. The presented work is such software with some innovative features that were presented in this paper like the toxicity reduction consulting tools, price calculation of recipes based on real market costs, the possibility of mixing several existing recipes and the ability to exchange recipes between ceramists by simple XML files. Web 2.0 on the other hand offers great opportunities for expanding such tools to act as collaborative on line portal for the exchange of experience and ideas between ceramists. The improvement of the efficiency of the created recipes and the creation of low toxicity products are the

values that can help ceramists to survive in the strong competitive environment.

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