NOVEMBER-DEZEMBER 2019 www.cfi.de ISSN 01739913 E 5270

DKG 11-12/2019

Berichte der Deutschen Keramischen Gesellschaft

cfi ceramic forum international

PROCESS ENGINEERING – Intelligent Data Preparation, Crack Prediction in Sanitaryware Formulations | **TECHNOLOGY NEWS** – Pre-Engineering, Dryers and Calcining Ovens for Converters and Diesel Particulate Filters, Carbon/Sulphur Analyser | **REPORTS** – Meeting of the CIM Expert Group/DE, 1st ceramitec Conference/DE, Ceramics UK 2019/GB | **HCC SPECIAL** – KELLER HCW/DE, Bedeschi/IT, RIETER MORANDO/DE+IT, Officine SMAC/IT

ISSN 01739913
Publisher and Publishing House
Göller Verlag GmbH
Aschmattstraße 8, D-76532 Baden-Baden
Phone: +49 (0) 7221-502-200, Fax: +49 (0) 7221-502-222
Internet: www.goeller-verlag.de, E-mail: cfi@goeller-verlag.de
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Phone: +49 (0) 7221-502-200
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Registered in the Institute for Scientific Information®

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Subscription Rates
7 issues per year + 1 special edition
(single copy: EUR 17,00 + postage)
Abroad: annually EUR 164,00 + VAT 7 % + postage (EUR 19,10; air mail EUR 47,00). Subscription orders remain effective for a minimum subscription period of 12 months. Cancellations of subscriptions are only possible at the end of the subscription period.

Circulation
Control of the number of copies printed is made by the German Information Society for Determining the circulation of Advertising Media Rdg. (IVW). The international circulation is German ABC audited.

Dear Readers,

Since 2013, the implementation of Industry 4.0, that is real-time networking of all industrial processes from supply through production to maintenance, has been driven forward in a range of fields. The maintenance and checking or control of production elements poses a big challenge in times of the smart factory: cyber-physical systems, Artificial Intelligence (AI) and the Internet of Things bring with them a new degree of networking and complexity.

Our trade fairs and conferences would be unimaginable today without the topic of digitalization, but we are still very much at the beginning. In this connection, readers are referred to the paper "No Fear of Detail Work – Towards Intelligent Data Preparation" (E 9). Established supply companies are now adapting the topic to the needs of ceramics and powder metallurgy.

A new study by acatech – Germany's National Academy of Science and Engineering and the Fraunhofer Institute for Material Flow and Logistics IML/DE is now providing information on how far German companies have generally progressed in the implementation of "intelligent maintenance" – and it gives indications of how smart maintenance can be performed expediently. The study has elaborated that most companies have no or only a very weak database that can give information on faults likely to occur soon or the necessity of maintenance measures. In addition, knowledge of how elements in a factory can be maintained, checked and controlled is often buried in the heads of individual employees. The interaction of AI and people is not yet functioning properly.

In a new publication, the Research Advisory Board of the Industry 4.0 platform describes topics in which research and development are urgently necessary. The Advisory Board Spokesman Reiner Anderl commented: "There exists not only the necessity for the research of more advanced technological and methodical pioneering processes for Industry 4.0. We have also identified a need for research and development in economic and sociological context of Industry 4.0. While technologies and methods promote the realisation of Industry 4.0, the development of new business models and impact on work and society are increasing in importance. The role of people will change, but also take centre stage in the future in terms of design and control."

We therefore don't need continuous improvements of our processes, but comparatively "radical" innovations for which people, however, need to be prepared.

Yours

Karin Scharrer
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CONTENTS:

#A **CERAMIC COMPANY AND MARKETS**

#B **CERAMIC TILE AND CONSTRUCTION**

#C **CERAMIC TILE MANUFACTURE**

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Cover Page

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Company News

Germany

QSIL Acquires FCT Ingenieurkeramik

■ The Thuringian material specialist QSIL AG from Ilmenau continues the strategic expansion of its technology and solution competence with the acquisition of FCT Ingenieurkeramik GmbH/DE. With the positive experience from the integration of QSIL Ceramics GmbH from Auma Weidatal/DE at the beginning of this year and the tailwind of the core business, customers of the QSIL Group are now able to choose from a range of non-oxide ceramic products including aluminium nitride, silicon carbide and silicon nitride.

FCT Ingenieurkeramik GmbH (FCTI) offers tailor-made ceramic materials and custom products from prototypes and small- and medium-sized series, up to high specification mass produced products. Thus, FCTI fits perfectly into the QSIL Group brand. All customers and sites of the QSIL Group will now benefit from the authoritative know-how of the Group's ceramic experts. The acquisition of FCTI, sees QSIL Group expand its engineering ceramics product range to a one stop shop solution for its customers. The business fields of semiconductor technology, mechanical engineering, life science and aerospace are all strengthened with QSIL Group acquiring FCTI.

QSIL is already very well positioned in the fields of diagnostics and safety technology. The range of solutions is complemented by the quartz glass locations in Ilmenau and Winschoten, which are very well positioned in the semiconductor industry and fibre-optics.

FCTI represents more than 30 years of experience and expertise in the production of high-performance ceramic materials and composites. The specialty is silicon nitride and silicon-carbide based ceramic materials. With modern systems, components with different shaping and sintering technology are manufactured, usually according to application-specific requirements of customers and partners. The complete process range from powder to ready-to-install ceramic components is available at the locations in Rauenstein and Sonneberg. From optimised or tailor-made ceramics, prototypes, special components and small to medium series are produced. Even very large, complex and high-precision components are more a challenge than a problem. With state-of-the-art equipment optimised in day-to-day operation, a large number of different services will continue to be offered.

The QSIL Group is an innovative, international material specialist specialising in the production of quartz glass and technical ceramics. The most important markets are the semiconductor industry, the light source industry and other industrial applications in mechanical and plant engineering, the chemical industry, analytics and glass fibre production. QSIL has a globally diversified customer base. Customers include major companies from Europe, Asia and America. QSIL generated sales of more than EUR 100 million in 2018 with approx. 600 employees. With the acquisition of the special ceramic manufacturer FCT Ingenieurkeramik GmbH, the Thuringian Group is growing to 750 employees and more than EUR 115 million sales.

Germany/China

International Cooperation of Refratechnik Ceramics and Trend

■ As part of a market development programme, Trend/CN has recently been cooperating with Refratechnik Ceramics, the Germany-based company that was founded in 2013 with the takeover by Refratechnik Holding of the renowned refractory manufacturer BURTON GmbH & Co. KG/DE.

After a number of discussions to explore possibilities for a joint approach, a team from Trend visited Refratechnik plants for the first in a planned series of mutual exchanges between the two companies. In Melle/DE, the visit was workshop based, and the Refratechnik personnel informed about ordering, quality, technical and sales procedures as well as controls. The Trend team was kindly hosted by the highly experienced Sales Director, Jörn Böke, over a period of three days.

The future plan is for Trend to organise reciprocal training in Tianjin/CN – perhaps in January 2020 – with the goal of assisting both companies to develop their respective technologies and markets, and to further understand how Trend and Refratechnik products can work together for the ultimate benefit of the heavy clay ceramics manufacturing sector.

The Melle site in Germany has been operational for more than 125 years, important refractory product technology has been central to the efforts at this facility since around 1955. The BURTON brand name is well established all around the world, with these refractory products predominantly being used by manufacturers of roofing tiles, clinker and backing bricks, as well as blocks.

Italy/Brazil/Poland

SACMI Technology for Sanitaryware in Brazil and Poland

■ Deca, Brazil's biggest sanitaryware manufacturer and part of the Duratex Group, has strengthened its long partnership with SACMI/IT by installing a new ALS pressure casting machine at its plant in Recife, the capital of the Pernambuco State. This strategic investment regarding technological renewal and modernisation strengthens a long-standing partnership between SACMI and Deca as SACMI supplied the company over the years with the complete manufacturing plants from kilns over casting lines and glazing lines.

The machine is able to cast a daily capacity of 1050 pieces split between wash-basins and pedestals thanks to the installed 15 multi-cavity moulds. Already fully operational since several months, the new casting machine reinforces the role of the Recife production plant in the Duratex Group's ongoing growth and development plans in Brazil and, indeed, across the whole Latin America.

Cersanit Poland (Rovese Group) is also investing in SACMI high-pressure casting technology for sanitaryware production. Following the successful installation of the first robotized casting centre for manufacturing complex WCs in 2017, the company has acquired eight new AVI casting modules for its Krasnystaw Plant. Arranged to form two casting centres, the casting modules will be equipped with robots to perform the complete mould handling, transfer of the cast pieces to the pre-dryer and loading the kiln cars.

Each centre is equipped with an FPV pre-dryer, a SACMI solution that due to the controlled moisture-related shrinkage immediately after de-moulding reduces energy consumption and limits space requirements. This makes the subsequent product handling easier and is particularly advan-

tageous when managing WCs of complex shape and considerable size. Alongside, the casting centres assure higher daily productivity which is quantified following the modules testing at approx 380 cast pieces.
The SACMI modelling unit, including two new moulds, will saturate the output capacity of one of the new casting stations, all of which equipped with a laser-guided mould alignment system to make replacement tasks even faster and more precise. Part of a wider plant renewal plan, this investment in SACMI technology goes hand in hand with the already-operational robotized glazing solutions i.e. the new, recently tested SACMI-Gaiotto 2-coat glazing units.

Italy/Serbia

Bedeschi's New Project for Mladost Group

■ Mladost Group/RS, which is continuing its collaboration with Bedeschi S.p.A./IT, is one of the major producers of construction materials in Serbia. Among its wide range of products, the Serbian company also manufactures roofing tiles and large-format blocks. For this supply, Bedeschi's task was the renovation of the Mladost roofing tiles factory in Leskovac with the aim of improving product quality, and increasing the already high level of automation.
The project includes the implementation of several machines in the preparation line, a new automation system for the formation of roofing tiles bundles and their loading on kiln cars as well as an automatic separation device for fired roofing tiles with suction cups. These all are innovative machines, developed by Bedeschi, and recently successfully placed in the market.

Italy

Officine SMAC Celebrates its 50th Anniversary

■ Officine SMAC, a company specialising in the supply of plant and equipment for the ceramic tiles and heavy clay ceramics industries, is preparing to celebrate its 50th Anniversary. Just like 50 years ago, the company is still managed by Chairman Sergio Masini, one of the founding partners, who together with his son Fulvio continues to pursue the company's development. Combining an illustrious past with a future-oriented vision, the Fiorano Modenese-based company stands out for its task to take on ever new challenges and remain constantly at the forefront of the ceramic industry.
Throughout its long history, it has expanded and excelled in all international markets, establishing itself as a key player in the field of ceramic glazing technologies and introducing important developments and cutting-edge solutions for the entire sector. Ever since it was founded in 1969, Officine SMAC has been committed to R&D activities aimed at creating exclusive ceramic surface effects. From the first brush application machines developed in the 1970s (a technology evoked in the historic logo) to the first roller decorating machines for roofing tiles over the first machines for tiles decoration as well as roofing tiles and bricks, Officine SMAC has continued to renew and extend its production range. The Italian specialist is now preparing for the next step i.e. digital glazing.
With a highly qualified team and the constant investment in advanced technology, Officine SMAC is an efficient and dynamic partner capable of supporting ceramic companies with customised solutions. The company thanks all partners and suppliers, including all employees who worked over the years, and of course all customers who have always supported and rewarded its efforts.

The Netherlands/China

Verder Scientific Aquires EZ-mat

■ Verder Group/NL is a family owned group of companies in the second generation, with 2200 employees and sales of approx USD 500 million. The Group is already deeply engaged and well reputed in the

global development, manufacturing and distribution of products and services of state-of-the-art scientific applications.
The Group comprises the Scientific Division, Verder Scientific, (high-tech laboratory and analytical instruments) and the Liquids Division (positive displacement pumps). Verder Scientific consists of the manufacturing companies ATM GmbH (instruments for materialography), QNESS GmbH (hardness testing), RETSCH GmbH (sample preparation and particle analysis of solids), RETSCH Technology GmbH (optical systems for particle characterisation), Microtrac Inc (equipment for particle characterisation based on light scattering), Microtrac Bel Corp (surface and porosity analysis), ELTRA GmbH (combustion analysers for elemental analysis) and CARBOLITE GERO (laboratory and industrial furnaces and ovens).
Verder Scientific has formally agreed to acquire all shares of the Chinese company EZ-mat and become its sole owner. EZ-mat is a distributor of material testing equipment in China and, amongst others, already represents two of the Verder Scientific product lines for metallographic preparation and hardness testing, ATM and Qness.
With its 35 employees, EZ-mat has an excellent reputation for providing customers with the full range of material testing solutions. In addition to comprehensive knowledge regarding products and applications in the field, EZ-mat will provide Verder Scientific with direct access to the according customer segments. Verder Scientific is already represented with its own company, Verder Shanghai Instruments and Equipment Co., Ltd., which currently maintains four offices with a staff of 50 in China. With the combined EZ-mat workforce, Verder Shanghai will become a major player in the distribution of quality control equipment.

Sweden

Höganäs AB Uses 83 % of All Side Streams

■ Metal powder manufacturer Höganäs AB's production plants all over the world create vast quantities of byproducts (side streams). The company is working to ensure that as much of this material as possible is used as new raw material in its own production processes or by other industries. A large proportion of these side streams is returned to Höganäs' production processes, while some is used as raw material for other manufacturing companies – as a raw material for asphalt, insulation or as load-bearing layers in groundworks. In 2018, 83 % – or 155 400 t – of all side streams from Höganäs were reused in the company's own production or by other industries.
"Side streams from Höganäs can replace materials that are otherwise blasted out of rock for use in roadbuilding, for example. Höganäs is part of the circular economy in that we provide industries with raw materials from our side streams and largely use scrap as raw material in our own production processes. The more side streams we can use in society, the less virgin material is needed," says Björn Haase, who is responsible for Höganäs' work with side streams.
Finding potential applications for Höganäs side streams has not always been quite that simple. Björn Haase is a pioneer in the field, and his insistent efforts and cooperation with other companies are one of the main reasons why Höganäs manages to use so much of its side streams.
"We are successful in pursuing technical development and projects that the entire steel industry can benefit from, thanks to cooperation with companies in the steel industry and other industries. We also link together industries that do not normally come into contact with one another. Water treatment with slag for the water treatment industry is just one example of successful projects of this kind.
We have a number of products from our side streams, but we have to come up with new options the whole time. This is why we carry out extensive sampling procedures in order to analyse and control the qualities of our material and work out the industries for which the material might be useful," says Björn Haase.

Germany

Pilot Plant for Construction Material Recycling in Operation

In March, IAB – the Weimar Institute of Applied Construction Research opened the doors of its new pilot plant for construction material recycling to some 100 industry experts. The new plant is dedicated for use in research on the reprocessing and recycling of residual construction materials.

IAB Director Dr-Ing. Ulrich Palzer introduced the recycling pilot plant to the audience within the framework of a forum on resource efficiency in the construction industry. Dr-Ing. Ulrich Palzer emphasized the new plant's capacity for processing a wide variety of residual construction materials in a way that was not previously possible.

Until now, the quality of most recycled residual construction materials has been considerably inferior to that of the starting materials.

As Dr Palzer reported, though, IAB's new recycling center has succeeded in achieving what up to now has only been possible for less than 5 % of all residual construction materials: turning waste material into recycled material of at least equivalent or even superior quality. The lightweight aggregates obtained via high-tech recycling are one-third less expensive than those made from natural raw materials. Lightweight aggregate is obtained from a mixture of construction waste comprising bricks and other sundry wall-building materials together with various mortars and plasters.

In the newly perfected process, gypsum is decomposed by heat treatment and recovered as recycled gypsum. In addition to lightweight aggregate, the process can also yield calcined clays for use in substituting cements and modifiers in the concrete production.

The core component of the plant is a rotary kiln that IAB developed in cooperation with the Weimar-based company IBU-tec advanced materials AG/DE. The IAB pilot plant serves as a model for additional plants potentially destined for use at recycling companies.

The entire process, from the primary crushing of construction waste in a jaw crusher, through its classification, grinding and shaping in a dish granulator and, finally to its heat treatment in the rotary kiln, can be tested in actual practice.

The plant belongs to the Thuringian Innovation Center for Recyclable Materials, which is currently under construction on the University Campus in Nordhausen/DE. The hall itself and the technical infrastructure cost around EUR 2 million each. IAB received approx. EUR 3,6 million in funding from the State of Thuringia and the Federal Government.

Italy

Marcheluzzo Ceramics in Asia

The expansion of Marcheluzzo Ceramics/IT in Asia continues with new air-conditioning, pre-drying and drying plants. More and more, in countries with high temperatures and high humidity levels the installation of systems able to evacuate internal humid air is required, guaranteeing greater people well-being and always controlled drying conditions. The daytime thermo-hygrometric conditions to be maintained in the casting room normally vary between 30–32 °C and 60–65 %.

However, with similar values outside and considering the production of internal water steam, the internal humidity reaches values that can exceed 90 %. This, together with an increase in temperature, can lead to extreme internal conditions that must be specifically managed to guarantee production and human well-being.

The air-conditioning systems of the casting rooms are not so frequent in small- and medium-sized companies manufacturing ceramic sanitaryware: mistakenly, it is thought that, being high temperatures, it

is not necessary to air-condition the rooms. But in this way, the relative humidity is not managed: relative humidity is the one that regulates drying of the pieces immediately after demoulding. The use of refrigeration units to reduce humidity in a ceramic production room is unthinkable due to extremely high electricity consumption. Other dehumidification systems, such as silica-gel rotaries, are not suitable due to high water quantities to be removed under high dust conditions.

Therefore, the casting rooms need a continuously injection of a certain amount of external air with an absolute humidity lower than the internal one. At the same time, the same quantity of air must be punctually extracted. The system must also guarantee the air homogeneity in order to avoid shaded areas or excessive flow speed over the pieces. If then the casting room is traditional, during the night the mold must be recovered and temperature rises up to 40 °C, but the relative humidity must be kept around 45 %.

In countries where temperatures are usually close to 30 °C, there are two systems that regulate thermo-hygrometric parameters: systems that control only humidity (ventilation), and systems with the possibility of temperature management (air handling units with heat generator). These systems also greatly improve the environmental conditions: lower humidity means better working conditions, while the filtration systems give a higher air purity degree. Normally, the pieces stay in the casting room for a longer or shorter period of time, precisely because the used dryer do not allow product loading before the contraction phase of the products completed.

Marcheluzzo Ceramics dryers are designed to perform both pre-drying and drying phases with the same machine. On the other hand, if this is not possible, the chamber pre-dryers are mostly recommanded: even in this case, the relative humidity control becomes fundamental, adjusting the pieces contraction homogeneously and controlled.

Events

Tecnargilla 2020: Increasingly International

■ The international promotion of the leading trade fair for supplies to the ceramic and brick industries Tecnargilla has been launched. After inviting visitors and exhibitors to Fiera di Rimini/IT, organised by the Italian Exhibition Group and ACIMAC – Association of Italian Manufacturers of Machinery and Equipment for the Ceramic Industry, from 28 September to 2 October 2020 in Rimini, the 27th edition of Tecnargilla has already launched all its overseas promotional activities, with a view to ensuring that this edition of the fair is even more international, with the presence of the leading operators in the sector.

Internationalisation is one of the biggest challenges facing suppliers of the ceramic industry and Tecnargilla continues to be a key player in penetrating and safeguarding the most remote markets with the highest potential. With this in mind, activities will range from participation in the world's leading fairs to direct contact with trade associations, international institutions and leading operators. A constant presence will be maintained in the international media, with regular updates to the website, and this will be accompanied by web marketing and social network activities. The aim is to implement targeted actions in order to ensure that the high value is promoted and maintained.

Tecnargilla 2020 will bring together the widest range of products in the world from the major companies in the sector, who will be welcoming customers from all countries that produce ceramics, along with the main buyers from the most important international companies.

In 2018, more than 1000 B2B meetings were held during the exhibition, giving rise to innumerable commercial agreements and partnerships. 16 653 foreign visitors attended the last edition of the fair, representing 48 % of the total. This is a key figure, which portrays a top-level, high-profile visitor and is the result of numerous incoming buyer programmes aimed at attracting new buyers from emerging countries and consolidating relations on existing markets.

Technology in general, but especially technology Made in Italy, has become increasingly attractive thanks to constant investment in R&D. The companies operating in the field are concentrated in one of the districts that best succeeded in facing the challenges of the market, thanks to innovation, design and the ability to adapt both process and product. This technological culture also attracts Italian customers, who still account for half of the visitors to Tecnargilla.

https://en.tecnargilla.it/

No Fear of Detail Work – Towards Intelligent Data Preparation

H. Gröbl, A. Stolz, I. Weiß

How do I find the right data, and how can I reduce the data volume so that the data can be processed quickly and usefully? The research project M@OK[1] at the Technical University of Munich/DE is investigating these questions among other things. The project aims to find ways to increase the availability of production facilities with the help of data mining.

The age of big data consists of euphoria as well as disillusion. On the one hand, for the first time, it became computationally feasible to look into individual components and processes of a machine, make data-driven diagnoses that can offer higher precision and then to optimise them or eventually move towards predictive maintenance. On the other hand, it has been shown that it is not so easy to extract the decisive data in such a way that a measurable benefit is created for the user.

As a result, many data ends up unused on servers, in clouds or is not captured at all. Especially the detail work in the data preparation has a deterrent effect on many companies. At the Chair of Automation and Information Systems (AIS) at the Technical University of Munich, the detail work is carried out quite differently. A wide variety of data sets are examined and concepts are developed to prepare the data sets in such a way that even practitioners can use them. Overall Equipment Effectiveness (OEE), i.e. the product quality, performance and availability of a system, is the focus of the 2-year project M@OK (Machine@OnlineKnowledge). In this project, data analysis approaches are combined with expert knowledge about the machines of manufacturers and operators as well as process and alarm data. Supplemented by machine learning methods, further optimisation potentials are to be uncovered and thus made usable. The primary goal of the research project is to reduce machine downtimes. One approach: finding correlations in sensor, actuator and message data of a machine through data mining and machine learning techniques that indicate wear of individual components.

Increasing availability

One practical partner in this project is the powder press manufacturer DORST Technologies GmbH. The company from Kochel am See /DE brings ceramics and metal powder into shape and insists to exploit the new possibilities of digitisation, especially with regard to Industry 4.0 or Industrial Internet of Things.

DORST's self-proclaimed goal is to develop new services for its products based on the digitisation. A new department was set up specifically for this purpose, which is to promote digitisation internally, but also to develop novel products and services for customers. Here, the availability or increase of OEE is also at the top of the to-do list because the company has to make sure that its machine is doing well. In concrete terms, this means knowing at an early stage when which maintenance is necessary or which spare part has to be procured. After all, powder presses are complex machines whose components cannot be bought off the shelf.

In the past, many spare parts, including expensive ones, were kept in stock. Today, of course, the company tries to avoid this. Predictive maintenance is therefore the order of the day. However, data analysis and the detection of anomalies in data records are basically not part of a machine manufacturer's core business.

Online testing instead of a testing laboratory

DORST Technologies therefore sought cooperation with the AIS. It quickly became clear that there were several tasks to be performed. The first step of the investigations was to identify the differences between perfect articles and articles with quality defects during the production. It is important to know that the quality requirements for the parts produced on a DORST press are very high. There are very few outliers per se. The subsequent quality monitoring is correspondingly complex. This is done manually in most of the times, as there is no adequate way to automate this test procedure so far.

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Keywords: ML – Machine Learning, OEE – Overall Equipment Effectiveness, predictive maintenance, IoT

[1] Online Knowledge Management, Data-Mining and Machine Learning in Mechanical Engineering; funded by the Bayerische Staatsministerium für Wirtschaft und Medien, Energie und Technologie/DE, and supported by VDI/VDE/IT within the research program „Informations- und Kommunikationstechnik"

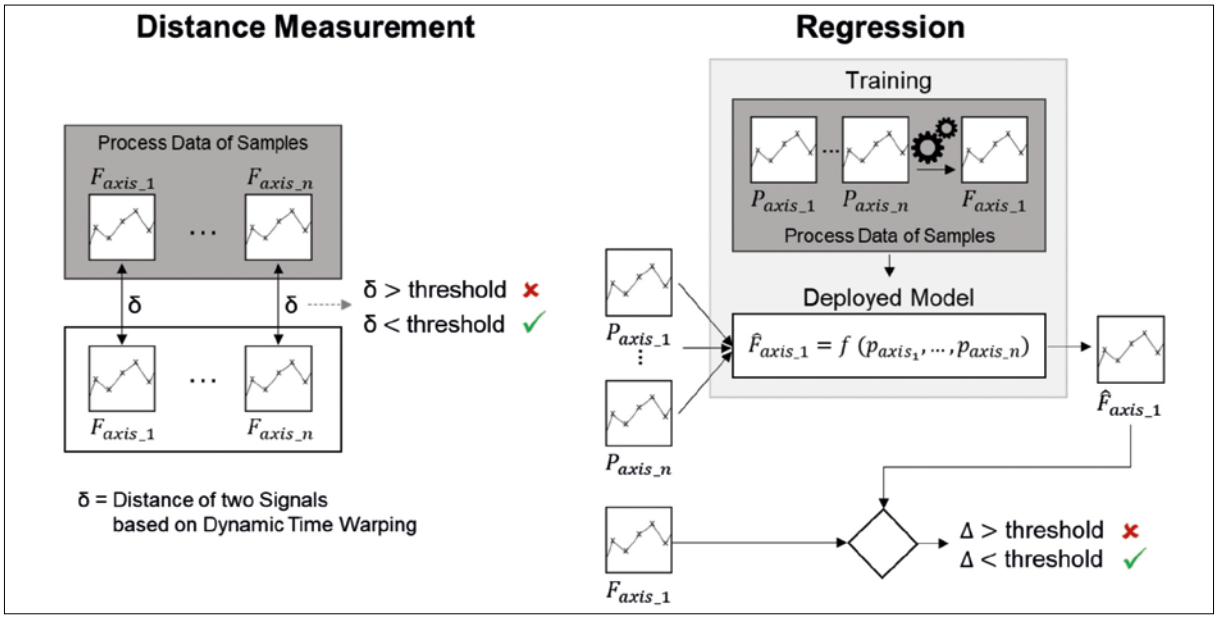

Fig. 1 Methods for data compression and data analysis

It would therefore be helpful if the data collected during the production process could be used to determine whether a workpiece meets the quality requirements.

The AIS has therefore taken a closer look at the data generated during the production of test samples. Relevant data of the production line is compared per cycle. The data of the samples evaluated as positive are labelled as good. The challenge here is that the boundaries between a good and a bad article are very narrow. In addition, the decision must be made quickly so that a bad article can be ejected before it leaves the DORST press for further processing. Different from the popular, classical anomaly detection algorithms such as statistical classification, the approach chosen in the project relies on speech recognition algorithms to quantify the similarity of two processes.

Thus, it can be detected whether the production of the current part resembles the production of the test products and therefore a good quality can be assumed. Furthermore, an approach with regressions models is taken as addition information source.

The method was evaluated on data gathered by carrying out manipulated process cycles at DORST Technologies. Another finding: the decision as to whether an anomaly is critical for the component and thus a component defect can be assumed, or whether the data has changed due to an external circumstance, is a challenge for the ML (Machine Learning) methods.

Fig. 2 DORST spindle and hydraulic presses are the target and the data sources for the digitisation methods

What is actually interesting?

In the course of the project, however, further challenges arose in data analysis, for example, the sheer amount of data. Although there are procedures for data compression, they are largely exhausted. This raises the question of how far data can be further reduced without information being lost.

In the further course of the investigations, it turned out that there are important and less important phases in one single production cycle. In the "important" phases, it might be better not to compress or reduce the data at all.

So far so good, but it is not so easy to determine these sections, since an individual sequence is programmed on the production machine for each type of product.

The AIS is therefore working on models that can precisely determine these relevant periods in the data. The aim is to work out characteristic features that can be used to identify the decisive process phases. Until now, the data was recognised manually and then evaluated. Another challenge is to generalise this approach and determine characteristics that are of a general nature. Otherwise, it would be necessary to develop a new model for each new workpiece or geometry.

Because the signals always change slightly depending on the product. The AIS team doesn't want to find an individual solution, but a way that is able to withstand changes in operation.

The algorithms for data reduction themselves are tested on laboratory data and the data of a hydraulic powder press. A combination of time series models (ARIMA) and linear regression is used. A reference model was used for comparison, which only transmits data if a certain change in the value occurs. For example, it was shown in a laboratory plant with a servomotor that a considerable amount of data points of a position value can be saved and that a high information content can be ensured. The same conclusion could be made for the hydraulic powder press.

Outlook

The first investigations and the data analysis of the production process of an article give grounds for optimism that a way can be found to increase the OEE of systems even in complex processes with the highest quality requirements. The procedure is not only of interest for powder press manufacturers. Many manufacturing processes offer similar application scenarios. In addition, the processed data provides further opportunities: if, for example, the processes are compared over several years, it may be possible to find completely new relationships and indications of gradual changes in the process.

Crack Prediction in Sanitaryware Formulations

M. Kernick

Cracking is an age old problem in whitewares production. The Cracking Tolerance Number (CTN) is an empirically derived index invented by Imerys/FR to assess the tendency of a sanitaryware body to crack during the drying process [1, 2]. The CTN value helps guide the choice of formulation to allow a production process that has a high yield and productivity. The CTN is focused on cracks that are due to the generation of stresses and strains in the green piece as a result of volumetric drying shrinkage, particularly in the mould and applied as part of the demoulding process. These cracks are often small and easily missed during green inspection, leading to catastrophic failure during firing. While the original version of the CTN has proved extremely useful in guiding the formulation development of sanitaryware bodies, there are some aspects to the process and calculation that can be put on a more rigorous footing.

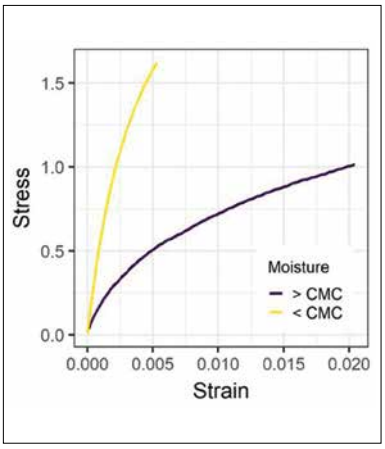

Fig. 1 Typical breaking curves for bars of significantly different moistures; stress and strain are normalised force and deformation equivalents

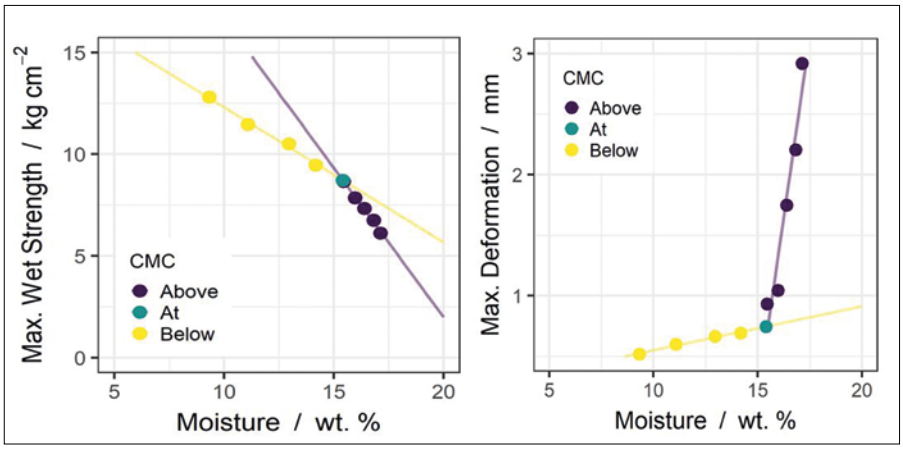

Fig. 2 a–b Maximum wet (bending) strength (a), and maximum deformation (plasticity) (b) as a function of moisture content

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Keywords: crack prediction, sanitaryware formulations, high yield and productivity, mechanical properties, critical moisture content

1 Mechanical properties

The first stage of the Cracking Tolerance Number (CTN) gives information regarding the resistance a formulation has to all types of cracks. To generate the required mechanical properties data, cast bars are dried to varying moistures and then broken on a 3-point bending device.

Imerys uses a device that records stress (force) and strain (deformation) values during the whole test, generating breaking curves similar to Fig. 1. These curves are for bars that are above and below the Critical Moisture Content (CMC), the moisture at which shrinkage ceases due to particles just beginning to touch. This is the point of maximum shrinkage when stresses and strains ought to be maximum and historic works suggests cracks tend to appear.

The resulting values of strength and deformation are plotted as a function of moisture (Fig. 2 a–b). In the historic version of the *CTN*, only the maximum values of these breaking curves are used.

Moreover, it is the maximum bending strength [kg/cm^2] and maximum deformation [mm] that are recorded, rather than normalised stress and strain. This is con-

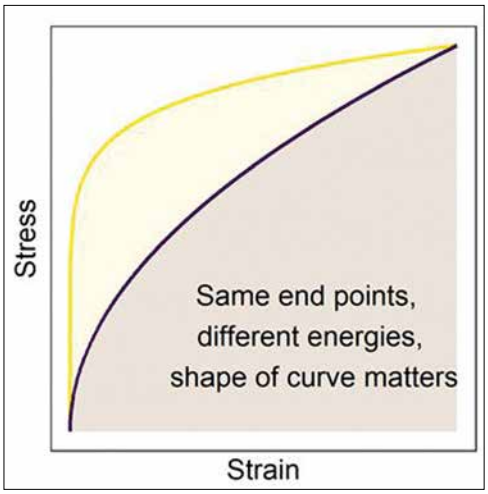

Fig. 3 When only the maximum values of strength and deformation are used, one cannot differentiate between these curves. A better assessment is to use the area under the curve, which is the work energy the bar can absorb before cracks begin to appear

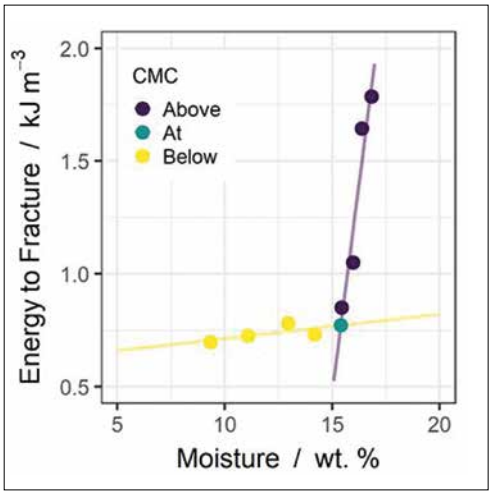

Fig. 4 Energy to fracture as a function of moisture. Using normalised stress and strain allows the CTP_{New} to have sensible units

venient when the same geometry is being used for all tests but in the new advanced *CTN*, stress and strain are used instead. Maximum bending strength will be used synonymously with wet strength.

The strength indicates the ability of the piece to resist the build-up of crack generating stresses. The deformation indicates the ability of the piece to dissipate some of the stresses that may have built up by deforming slightly, often loosely term plasticity, which will be used interchangeably with deformation. Strictly, plasticity is an irreversible deformation with zero stress increase, which is not quite what happens here [3].

The maximum strength and deformation values at the *CMC*, where cracking should be worst, are multiplied together to generate what is called the Cracking Tolerance Product (CTP), the numerator of the *CTN* equation.

$$\mathrm{CTP_{Old}} = \mathrm{Wet\ Strength}\rfloor_{\mathrm{CMC}} \times \mathrm{Deformation}\rfloor_{\mathrm{CMC}}$$

Because this value is essentially a force multiplied by a distance, it represents the energy the piece can absorb before fractures/cracks start to appear.

When generating the plots in Fig. 2 a–b, the use of only the maximum values of the breaking curves is pragmatic, but doesn't exactly relate to the resistance of the bars to breaking, as highlighted in Fig 3.

Fig. 3 demonstrates that two bars can give the same maximum bending strength and deformation but have very different shaped breaking curves.

If this difference exists between two formulations, they will certainly have different resistances to cracking. Yet the historic *CTN* would value these bodies equally because it is effectively calculating the area of the whole plot rectangle in Fig. 3.

A better way to characterise the breaking of the bars is to integrate the area under each curve. If done using correctly normalised stress and strain, rather than strength and deformation, this is the work energy the bar can absorb before the formation of cracks. It is sometimes called the toughness, and is a well-known measure of a material's resistance to fracture in materials science. The higher the amount of work energy the bar, hence body, can absorb the more resistant it is to crack formation caused by shrinkage/demoulding.

This energy to fracture is thus a convolution of the strength and deformation values. An example of a plot of the energy to fracture, as a function of moisture, is given in Fig. 4. It produces a graph visually similar to the deformation curve already shown in Fig. 2 b, highlighting the importance of plasticity in the resistance of a ceramic specimen to fracture.

However, it is still important to consider strength because the resistance to fracture is a balance and combination of the two: a specimen made using a formulation with very high plasticity but negligible strength would not be able to support its own weight. Thus the *CTP* now becomes the energy to fracture:

$$\mathrm{CTP_{New}} = \mathrm{Energy\ to\ Fracture}\rfloor_{\mathrm{CMC}}$$

Although this is a more formally accurate way to represent the energy the bars can absorb the resistance to cracking stresses, it is often useful to continue looking at the strength and plasticity separately because they can give information as to why the energy is changing. Using the historical approach also allows comparison with previous laboratory studies, if this becomes required.

Moreover, if it is known that a part of the process results in more stress applied to the piece than strain, then it may be beneficial to consider increasing the strength, rather than the plasticity, as a means to increase the energy overall.

The *CTN* focuses on the energy to fracture at the critical moisture content rather than the maximum achievable value, workability [4], which occurs at higher moistures. It is no surprise that a variation on the same measurement turns out to be relevant to two different production processes, given that the mechanical properties and crack formation of all green specimens are determined by the same physical processes.

2 Shrinkage

Now that the numerator of the *CTN* is defined, the denominator can be addressed, which attempts to characterise the build-up of stresses and strains due to shrinkage. While the assessment of mechanical properties was relevant to all green cracks, shrinkage is much more specific in that it is only relevant to the types of cracks that occur due to volumetric shrinkage.

To characterise the denominator, Imerys considers the shrinkage that the piece undergoes from slip moisture to cast moisture, and then from cast moisture to the *CMC*, all in one.

While it might seem strange to choose the slip as the starting point for shrinkage rather than the cast piece, it is more correct than using the cast moisture as the casting process itself is a form of shrinkage. Indeed, it is the starting point for the constant rate period of the Bigot curve, if it was extrapolated to the slip moisture. Nevertheless

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Tab. 1 Summary of CTN parameters for formulations A and B

Parameter	A	B
Mechanical Properties		
Wet strength [kg·cm^{-2}]	7,16	8,72
Deformation (plasticity) [mm]	1,04	0,75
CTP_{Old} (strength × deformation) [mm·kg·cm^{-2}]	7,42	6,51
CTP_{New} (energy to fracture) [kJ·m^{-3}]	0,81	0,77
Shrinkage Properties		
Slip moisture [%]	27,4	29,9
CMC [%]	15,8	15,4
Shrinkage factor (linear) [%]	3,87	4,83
True shrinkage (volumetric) [%]	25,1	30,4
Resulting CTN		
CTN_{Old} [mm·kg·cm^{-1}]	19,2	13,5
CTN_{New} [kJ·m^{-3}]	32,4	25,4

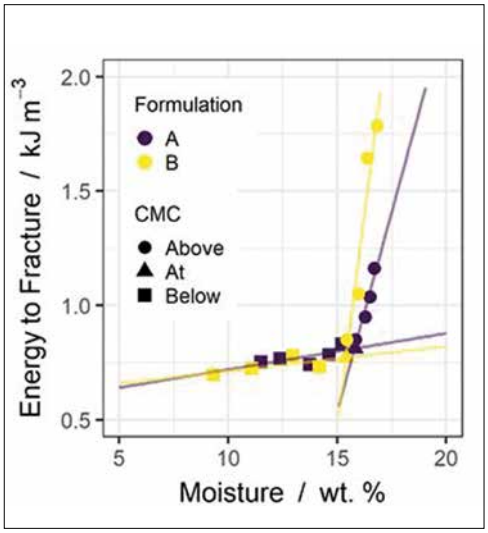

Fig. 5 Energy to fracture (CTP_{New}) for two formulations A and B

the cast moisture can be used instead, if preferred.

The original *CTN* used a calculation that is approximately proportional to the linear shrinkage and is called the equivalent linear shrinkage (S_L):

$$S_L\ (\%) = \frac{1}{3} \times (\mu_i - \mu_{cmc})$$

where S_L is the equivalent linear shrinkage (highlighting that it is not the actual linear shrinkage), μ_i is the initial moisture (usually slip moisture, or cast moisture if preferred) and μ_{cmc} is the moisture at the *CMC*.

In fact, it is relatively easy to calculate the true volumetric shrinkage (S_V) from slip to *CMC*. This can be done using the below equation:

$$S_V(\%) = 100 \frac{(\mu_i - \mu_{cmc})}{(100 - \mu_{cmc})} \frac{100SG}{100 + \mu_i(SG - 1)}$$

where S_V is the true volumetric shrinkage and *SG* is the average specific gravity of the raw materials in the body – usually 2,64 is appropriate for all materials in a sanitaryware formulation.

In both cases, a larger moisture difference means more shrinkage, hence, more stress and strain generation that can cause cracks if the specimen is not sufficiently tough.

3 The old and the new CTN

At this point, two things are achieved. First, the mechanical properties aspect of the *CTN* is on more rigorous foundations. Second, it is possible to use the actual volumetric, or linear, shrinkage directly, rather than an approximate proxy.

To summarise, the "old" *CTN* was calculated using:

$$CTN_{Old} = 10 \frac{\text{Wet Strength}|_{CMC} \times \text{Deformation}|_{CMC}}{\frac{1}{3} \times (\mu_i - \mu_{cmc})} = \frac{CTP_{Old}}{S_L}$$

The "new" version of the *CTN* is given by:

$$CTN_{New} = 1000 \frac{\text{Energy to Fracture}|_{CMC}}{100 \frac{(\mu_i - \mu_{cmc})}{(100 - \mu_{cmc})} \frac{100SG}{100 + \mu_i(SG - 1)}} = \frac{CTP_{New}}{S_V}$$

In both cases, the numerator of the equation characterises the ability of the body to resist crack generating stresses and strains at the *CMC*, the new *CTN* being more rigorously correct, but the old version allowing the separate consideration of strength and plasticity. The factors of 10 and 1000 in the equations have no physical meaning; they are simply used to give convenient magnitude numbers. The *CTP* is relevant to all forms of cracks.

The denominator characterises how much stress and strain are likely to be generated at the CMC due to shrinkage – a bigger number is worse. Other cracking problems, for example poor drainage or moisture gradients, must be considered without this part, or by using other methods [5]. Thus, a higher *CTN* number overall is suggestive of formulations that are less likely to crack during production as a result of shrinkage/demoulding.

4 Interpretation of the CTN

Now that the rationale behind the new *CTN* has been reviewed, let's elucidate how to interpret the results the *CTN* yields. Tab. 1 summarises the results obtained for two formulations A and B, prepared at the same rheological condition, for both the old and new *CTN*.

4.1 Mechanical properties

From these results, one can see that formulation A is weaker than formulation B, yet the plasticity values are the opposite. Indeed, because the plasticity parameter decreases proportionally more for B than its strength increases compared to A, there is a significant drop in the CTP_{Old} parameter for B.

This is actually an artefact of the slightly incorrect process of multiplying the strength and plasticity parameters together. The more correct approach of integrating the two tells us something more nuanced, as one can see from the CTP_{New} parameter. The CTP_{New} is still lower for B, but the difference is much smaller, implying both formulations actually have similar mechanical properties overall. Furthermore, while the results are summarised in Tab. 1, Fig. 5 shows the full energy to fracture (CTP_{New}) results for both formulations, which give us more information than the summary Tab. 1 alone.

From Fig. 5, one can see that the energy to fracture for B improves in strength more quickly than A for moistures above the *CMC*. The *CTN* derives from previous work

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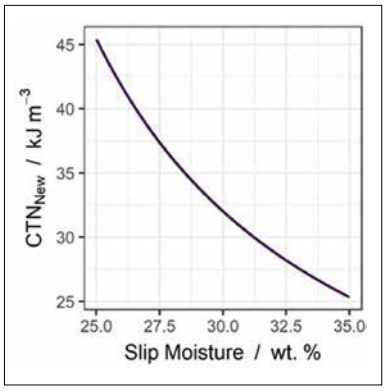

Fig. 6 CTN as a function of slip moisture, with all other parameters constant

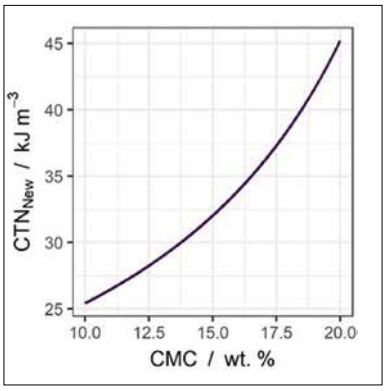

Fig. 7 CTN as a function of CMC, with all other parameters constant

showing that most cracking happens at the *CMC*, when shrinkage is maximum but, if this is not correct and cracks happen at higher moistures, formulation B would be expected to be more tolerant than A. It shows the importance of viewing all data in full context and not only using summary results.

One can still use the strength and plasticity values separately to understand that A will tend to prevent crack formation by deforming subtly, higher plasticity, whereas B will tend to survive crack formation by being stronger, higher wet strength. This is an important information when considering production process. B is likely to be better suited to pressure casting where stresses are large in the casting, with short timescales and releasing stages of the process.

Conversely, A is likely to be better for more complex designs using conventional casting, where the demoulding can occur more gently, but where tighter angles in the design are required, which may generate extremely large stresses during drying if the specimen is not allowed to flex slightly.

It is important to note, that the author is only talking about small permanent plastic deformations that will not lead to a faulty product, such as the minor deformations that result when the specimen pulls away from the wall of the mould during shrinking in the consolidation stage and/or demoulding.

4.2 Shrinkage

The results show that the shrinkage parameters are larger, which is worse, for B than for A. This may be clearer by considering the values of the slip moisture(s) and *CMC(s)* separately, in conjunction with the *CTN* and shrinkage equations above. Regardless of whether one utilises the simplified equivalent linear shrinkage or the "true" volumetric shrinkage, the driver of shrinkage is the difference in moisture between the slip, or cast moisture if preferred, and the *CMC*.

4.3 The influence of slip moisture

From the shrinkage equations, we see that the shrinkage is proportional to slip moisture, therefore the *CTN* is inversely proportional to slip moisture. In the range of moistures likely in a sanitaryware slip, this gives an almost linear relationship as shown in Fig. 6: the lower slip moistures, i.e. higher slip densities, leads to higher *CTN*.

Imerys' ball clays and kaolins have typically high fluidity, which allows achieving high slip density, good rheology, and hence low slip moisture. All else being equal, the previous equations show that low slip moisture leads to low shrinkage, which in turn leads to high *CTN* for both the old and new methods.

In reality it is usually not possible to modify the slip density without impacting on the bulk density of the cast specimen. High slip density tends to lead to high packing density in the cast piece, which does not just lead to low shrinkage, it often also leads to high *CTP* and therefore an even higher *CTN* than what would be expected just by reducing the wet-to-dry shrinkage.

In addition, the better packing of the cast piece means the green specimen has lower porosity and therefore lower firing shrinkage. This gives yet another reason why high slip density products are an important advantage to the sanitaryware producer, allowing production to be obtained at high production rates at the same time as high yields and complex designs. Of course, raising slip density without using good fluidity products will be a disaster as it will be impossible to maintain good rheology, so it should rarely be done without a concurrent change in formulation – and vice versa.

4.4 The influence of the CMC

The importance of the *CMC* on shrinkage is also very high, but in the opposite sense to slip moisture. The shrinkage is lower when the *CMC* is higher, therefore the *CTN* is proportional to the *CMC*, as can be seen in Fig. 7.

For this reason, fast casting formulations, with high permeability, tend to have lower wet-to-dry shrinkage. Because of the increased green porosity, they will tend to have higher fired shrinkage giving similar or, maybe, larger total shrinkage. However, the lower packing density of such formulations can also lead to very poor mechanical properties, therefore it is better to try and reduce shrinkage by using formulations that allow high slip density, low slip moisture, rather than by formulations with high *CMC*.

4.5 Shrinkage summary

With these discussions in mind, we can come back to the results in the summary table and understand why formulation B is worse for shrinkage than formulation A: it has a high slip moisture and a lower *CMC*.

4.6 Final interpretation

It can be said that formulation A has higher *CTP* and lower shrinkage than formulation B. Therefore the final *CTN* for both methods is best for formulation A, but the new method suggests they are closer performing formulations than the old method. All else being equal, the results would suggest that formulation A will tend to be more tolerant to the formation of any cracks, higher *CTP* and to the cracks specific to drying shrinkage and demoulding, higher *CTN*, than formulation B.

It is not always the case that a formulation with higher *CTP* will always have lower shrinkage and hence higher *CTN*. It may be the case that a formulation with slightly lower *CTP* has a much lower shrinkage, resulting in a better *CTN* overall. It is quite possible that this will be the better performing formulation. Shrinkage was used as a

proxy for the stresses and strains that build up within a specimen as it dries and shrinks, but it is not necessarily true that shrinkage has a perfect 1:1 relationship with the formation of these stresses and strains. For this reason, it may not always be appropriate to take the simple ratio of the mechanical properties to the shrinkage as this implies their magnitudes are directly 1:1 related to cracking tolerance.

Therefore, it is always wise to consider mechanical properties and shrinkage separately, as well as looking at the overall *CTN*. The *CTN*, whether the old or new method, gives extremely useful information, but should always be considered as part of the global analysis of a given formulation and process and never considered in isolation. The entire *CTN* curve – similar to Fig. 5 but plotting *CTN* vs. moisture – should often be considered, not only the value at the CMC.

Imerys presented its recent developments on the *CTN*, in order to put it on a more rigorous foundation, by introducing the energy to fracture and the true volumetric shrinkage. It has been discussed in detail how to interpret both the old and new *CTN* in the context of a real world example, highlighting what each of the parameters means and how they influence the final *CTN* value. The importance of considering these parameters independently has been emphasised, in the context of the production processes being used and not only looking at the final *CTN* value.

All else being equal, the *CTN* suggests the importance of a high slip density, using fluid products to maintain good rheology as well as a balance between high CMC and good mechanical properties. This will allow the production to have high yield at the same time as good casting rate, leading to high productivity, and the production of complex and profitable designs.

This knowledge, and more is available on Tech Connect, Imerys' online technical support platform for ceramic manufacturers. The platform offers four dedicated services:

- Troubleshooting: an online area which allowing to research a wide range of solutions for some of the most common technical issues;
- Trainings: for its customers, Imerys shares its mineral understanding, how to control raw materials and how to get the maximum out of them;
- Testing capabilities: Imerys makes its laboratories available, equipped with an extensive range of test equipment to characterise products in details and consequently help get the most out of them;
- Technical documentation: free access to a wide selection of Imerys' most popular products and numerous specialised articles from magazines and journals.

These services can be accessed by visiting Imerys' online platform on hiip://www.imerys-ceramics.com/technical-support.

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AZO Pre-Engineering – Everything from a Single Source

Apart from customised solutions for automating raw materials and processes, AZO/DE also offers the possibility to support the customer in planning production logistics by conducting concept studies.

This service is performed by the engineering & services division (AZO®e&s) as part of the pre-engineering process, tailored to the customer's existing or planned new system. Parallel to the plant design, additional process equipment is harmonised and planned with potential vendors. Apart from systems and process engineering, the logistics, media supply and staff rooms also play an important part.

They can, if necessary, also be taken into consideration early on during this phase in order to create an ideal basis for further procedures (architecture, planning of budgets etc.).

Regardless of whether it concerns an existing brownfield plant, where the aim is to refurbish existing buildings and/or equipment in accordance with the latest state-of-the-art technology (retrofit) and include possible expansion, or whether the project is at the greenfield stage where the priority is on dimensioning and ensuring investment for the entire facility. This independent planning service combines systems expertise with process-oriented layout design, thus ensuring a comprehensive engineering phase.

Logistics and layout are adapted to suit the (core) process engineering so constraints and bottlenecks can be averted or kept to a minimum. Planning is carried out entirely in-house, this simplifies communication and organisation.

Various planning and digitalization tools allow us to additionally support specific planning processes whilst including this service in our portfolio. In addition to the usual 3D-design, there is the option of preparing systems and components designed using CAD so that they are available for the virtual environment (VR technology). Models

are given a realistic, tangible character. This helps to make things more understandable for people not directly involved in the project and offers the advantage of not having to wait for the unit to be completed. This means, for instance, that operator training courses can be held in advance, saving the customer time and money.

In particular, VR technology can be integrated into the planning for future equipment. However, then questions are raised; "Is the existing space large enough?", "Where is the best position" and so on. Limits are often reached in existing plants, especially when making adaptations or expansion. In order to counteract such problems, 3D-scanning is becoming increasingly important as an as-built documentation. Here too AZO offers you this service, either as a service provider or by integrating it in ongoing projects. A simple 3D-scan which offers a range of potential options for creating added value through the data collected, allowing a digital transformation and so providing the customer with maximum assistance in the planning process.

The main output of this technology is a point cloud, which depicts the collected data in the form of thousands of three-dimensional point coordinates. Preparing this file makes it possible to directly plan the current situation.

In addition to documentation of the current state of the plant, collision-free planning with 3D-CAD is possible. The time saved by control, reference and interface procedures can be invested in more detailed and accurate planning. In addition to the point cloud, a 360° photographic view is an additional benefit resulting from this service. A complete 3D-scan avoids incomplete documentation for supposedly unimportant areas and thus also possible additional work for other measures.

Generating and analysing data as well as creating added value will remain the focus of AZO within Industry 4.0 and will be pushed further in the future.

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Optimization of Dryers and Calcining Ovens for Catalytic Converters and Diesel Particulate Filters

As part of an internal research project, Münstermann/DE has developed a new generation of dryers and calcining ovens for catalytic converters and Diesel particulate filters.
The aim of the project was to optimize ovens and dryers for the production of car exhaust catalysts and Diesel particulate filters by constructive changes to the plants so that shorter heating and cooling times are achieved.

Fig. Ceramic honeycombs on oven belt

Starting point for the optimizations

The length of the production process is largely determined by the heat exchange between the process air and the ceramic honeycomb bodies. The more warm or cold air passes through the vertical channels of the components, the faster the drying, heating or cooling process. The challenge is that the ceramic body with the thin channels is a high air resistance and therefore the air preferably flows around the components.

Everything is much faster

As a result of the study, the heating and cooling rates can be speeded up by factors through targeted mechanical changes in the plants. The parts are still placed freely on the belt.
In addition, a design program was developed. With a few measurements on a reference part, temperature curves within the parts can be simulated.
This dryer and ovens for the honeycomb body or similar parts can be designed and optimized based on fewer measurements. With the help of the new development, the process times are shortened many times over. The achievable customer benefit (smaller plants, shorter processes, energy savings and higher production flexibility) quickly recovers development costs.

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Keywords: ceramic honeycomb bodies, dryers and calcining ovens for car exhaust catalysts, Diesel particulate filters

New Carbon/Sulphur Analyser Measures both Organic and Inorganic Samples

When using conventional elemental analysers for carbon and sulphur determination in solids, the user must decide whether to use a resistance furnace to analyse organic compounds or an induction furnace for inorganic compounds.

Fig. ELTRA's new analyser ELEMENTRAC CS-d

Not with ELTRA's unique analyser, the ELEMENTRAC CS-d which combines both techniques. Thus, the user only needs one analyser to examine organic as well as inorganic matrices for their carbon and sulphur content directly without cumbersome sample preparation. The analysis time of the ELEMENTRAC CS-d is impressively short: analysis of steel, for example, only takes about 40 s; for coal it is about 90 s.

Carbon and sulphur are measured simultaneously with an accurate infrared detection system. Up to four measuring cells can be customised according to the user's requirements. Dual infrared detectors for C and S allow reliable detection of both parameters from ppm levels to high percentages.

Benefits of the new analyser, are as follows:

- Unique Dual Furnace Technology allows analysis of both organic and inorganic samples;
- Individual measuring ranges for C and S from low ppm levels to high percentages;
- Very short analysis time;
- Easy-to-use ELEMENTS software;
- Automated sample feeding (option);
- Robust design for use in production and lab.

ELTRA is one of the world's leading manufacturers of elemental analysers for rapid and accurate analysis. Starting with combustion analysers for carbon and sulphur determination in the early 1980's ELTRA has extended its product range over the years with analysers for oxygen, nitrogen and hydrogen as well as thermogravimetric analysers which ELTRA exports customers worldwide.

ELTRA GmbH
42781 Haan, Germany
www.eltra.com

Keywords: carbon and sulphur content, combustion analysers

Germany

Annual Meeting of the Ceramic Injection Moulding Expert Group

On 22 April 2008, the "Expertenkreis Keramikspritzguss in der DKG e. V." (Ceramic Injection Moulding Expert Group with the German Ceramic Society) was established in Hanover. The Ceramic Injection Moulding (CIM) Expert Group is a network of companies and institutes united in the objective of innovative further development of the entire process chain of ceramic injection moulding. At the annual meeting on 21.–22.03.2019 in Meissen, the attendees reflected on the activities over the last decade and took up fresh impetus for further work. In the Expert Group, partners cooperate who have the entire CIM process chain in-house and can make an active contribution to projects.

Fig. 1 CIM experts at the river banks of Elbe

Research projects

Collectively initiated technology developments, for example based on IGF projects (Industrial Collective Research for SMEs, funded by Germany's Federal Ministry for Economic Affairs and Energy), are the focus of the Expert Group's activities coupled with publicity work to communicate the advances in technology to potential users of CIM components. Most work has been initiated through IGF projects.

In 2011, with the "ProCIM" project, fundamental developmental work was conducted for the largely non-destructive testing of CIM components. These findings were later channelled into the preparation of a corresponding DKG guideline for the assessment of CIM components. In addition came the development of a disk compression test for sintered components and tests on the definition of suitable storage conditions for feedstocks.

In 2012, with the "GlasPIM" project, for the first time, a bridge was built to the manufacturers of sintered glasses. The introduction of know-how from CIM technology led to the development of suitable processes for large-scale production of glass components. An interesting finding was that, with the new process route, microstructures can be realised without etching. The work was continued in 2014 with the "2K sintered glass" project. Work was conducted on re-

cycled glass powders in some cases, with the focus being on the functionalization of components with appropriate measures during injection. One example is an intrinsically heated nozzle, e.g. for glue guns that consist of electrically conductive and insulating sintered glass.

With the work on "KombiPIM" in 2016, tape casting and CIM as well as injection moulding of "lost" core materials in one process step. With this concept, it was possible to avoid metal casings that have a different thermal expansion than the LTCC ceramics used in a pressure sensor being needed. LTCC tapes were inserted in the CIM mould, with polymer material as the component, which is burned out, defining the necessary cavity, overmoulded and then completed with LTCC material for the sensor casing.

In the year 2013, the "ExtruFol" project, which was funded by Germany's Federal Ministry of Education and Research, had the objective of developing improved sintered plates for injection moulded components that enable faster furnace cycles with lower thermal load.

Besides tape casting, thermoplastic extrusion was used to shape the plates which then have to be marked and reshaped.

New IGF projects focus on electrodes made of titanium suboxides for cold plasmas ("PlasmaEle") for applications in the disinfection of poorly healing wounds or for purifying air. The electrodes have to have a wide variety of shapes and are therefore an interesting challenge for CIM.

In the "Hygiene First" project, the objective is the development of novel hygienic operating elements for sensitive public areas on the basis of injection-moulded sintered glass components. Here, cooperation exists with experts on wood and design, as it is a matter, for example, of fittings and handles

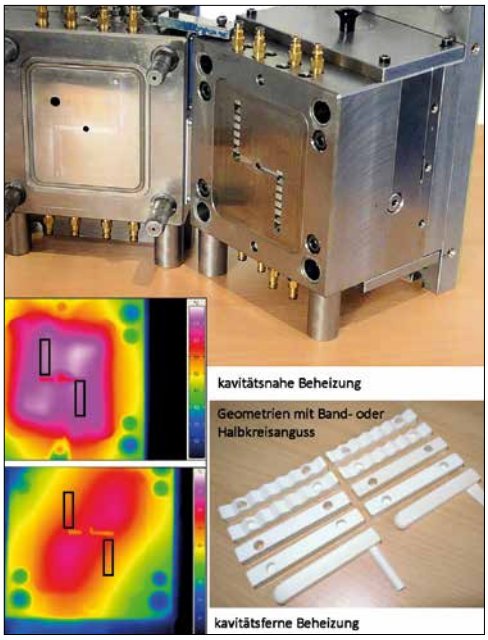

Fig. 2 CIM-tool developed for tests in the IGF projects

for use in public areas in an environment where biofilms must be avoided and easy cleaning made possible.
As focuses for the future, the following issues have been defined: injection moulding of large-size components, hybrid fabrication (combination of thermoplastic 3D-printing with CIM or combination of Fused Filament Fabrication – FFF with CIM). The optimisation of the process and quality assurance is an ongoing task.

Publicity work

The fact that all members of the Expert Group have expertise at different points in the value creation chain (research institutes, machine manufacturers, materials producers and component manufacturers) adds up to a wide expert knowledge from which every individual member company can benefit. Especially the Technology Development working group is crucially driving process development forwards. For example, an injection moulding tool commissioned and fabricated by the Expert Group enables wide-ranging tests in respect of new materials and their optimised machining options and methods. In numerous bachelor dissertations and master theses, different questions have been examined and made available to the members as technology recommendations. Interesting papers by external experts, participation at trade fairs and symposia or injection moulding training sessions for members of the Expert Group round off the cooperation and are used to increase awareness of ceramic injection moulding but also to provide training in university and field seminars.
In future, the Group wants to take up technologically interesting topics from neighbouring fields. Joint visits during members' meetings or working group meetings at other companies, e.g. hard finishing contractors, suppliers and end-users will support this work.
Contact partners are Dr Tassilo Moritz/ Fraunhofer IKTS (Chairman), Hartmut Walcher/Arburg (Technology) and Jens Graf/ Kläger (Marketing). Details are available at: www.keramikspritzguss.eu

Germany

1st ceramitec Conference: Future of Ceramics

The ceramitec conference, the new conference format of ceramitec, the world's leading trade fair for the ceramics industry, celebrated its successful premiere on 19 and 20 September 2019 in Munich/DE with over 200 attendees from 21 countries. The focus of the agenda was on new opportunities for the use of ceramic components and the associated new (additive) manufacturing processes in industry.

Fig. 1 Karin Scharrer (CERAMIC APPLICATIONS, Göller Verlag/DE, r.) welcomed the experts (f. l. t. r.) Jens Graf (Kläger/DE), Richard Gaignon (3DCERAM SINTO/FR), Iris Heibel (Cerix Bosch/DE), Johannes Homa (Lithoz/AT) and Hans-Christian Schmidt (DORST Technologies/DE) to the panel discussion headlined "AM – Ready for Industrial Production?"

Introduction

"Ceramic components offer attractive opportunities for more and more applications and sectors. But they are still frequently hidden champions. To improve access to solutions using ceramic for new user sectors in particular, we wanted to give the material an additional forum alongside our trade fairs," said Gerhard Gerritzen, Board Member of Messe München/DE, explaining the motives behind the new event. "The good public response and the quality of the agenda are evidence that we have struck the right chord with this in the 40th Anniversary year of the ceramitec fair", said Gerhard Gerritzen.

The agenda of the ceramitec conference was divided into two tracks. The track entitled "Shape the Future powered by AM Ceramics" organised by Lithoz GmbH/AT took a detailed look at the use of Additive Manufacturing (AM) processes in high-performance ceramics. The second track was headlined "Industrial Applications".

Plenary talks were presented by Linda Klopsch (DLR/DE) on "Space Aviation Engines Made of Black Ceramics" and Jon Goldsby (NASA/US) on "Concepts and Opportunities for the Application of Additive Manufacturing in Aviation" e.g. for ceramic anodes, electrolytes and cathode cells.

AM Ceramics at the ceramitec conference

The "Shape the Future of Ceramics" talk focused on the different applications for ceramics, including their uses in industry and medicine, as well as in research with speakers from multiple different companies and institutions from around the world, such as from Germany, the USA, Sweden and the Great Britain.

Cathleen Hoel (GE/US) concentrated on the practical considerations for AM from conception to production in her "Insights from AM experts" lecture for complex ceramic components.

Carl Fruth (FIT/DE) expanded upon this topic and spoke about his experiences and offering product solutions. He stated that progress in AM calls for radical innovation.

Dieter Nikolay (WZR/DE) compared different AM technologies – vat photopolymerisation, binder jetting and material extrusion – and shared his expertise of best practice.

The point of view from the industrial side of things was offered by Mirna Bechelany

(Safran Group/FR), Iris Heibel (Cerix Bosch/DE) and Alan McLelland (Morgan Advanced Materials/GB). They were all very open in their presentation about the challenges there are in implementing a completely new technology in production processes, but also explained how they have overcome these difficulties and focused on the new opportunities created by this freedom of geometry.

Josef Schweiger (LMU Munich/DE) and Heinz Redl (LBI/DE) discussed their experience with 3D-printing, not only for dental applications, but also for bone replacements. Their findings highlighted that there is a wide range of favourable possibilities still to be explored.

The first day ended with a panel discussion headlined "AM – Ready for Industrial Production?" moderated by Karin Scharrer (CERAMIC APPLICATIONS, Göller Verlag/DE), who welcomed following experts: Jens Graf (Kläger/DE), Richard Gaignon (3DCERAM SINTO/FR), Iris Heibel (Cerix Bosch/DE), Johannes Homa (Lithoz/AT), and Hans-Christian Schmidt (DORST Technologies/DE).

They shared their ideas on the industrialisation of ceramic 3D-printing. Experiences from established technologies were related to and compared with those of the AM sector. A special aspect was the digitalization of ceramic process where AM as a digital technology has specific advantages. CIM and AM show similarities regarding their implementation in the industrial sector, which for CIM started 30 years earlier. Further development is on the track for AM production of large-size parts and multi-material components,

The conclusion was that AM is now on the verge of serial production, with the first investments by industries in multiple machines and pre-orders of larger quantities of material.

The second day started with Advenit Makaya (ESA/FR), who discussed developments in the space agency with regards to AM with the focus on saving costs and manufacturing time for space products and improving their performance.

Uwe Scheithauer (Fraunhofer IKTS/DE) drew attention to the ways in which 3D-printing is supporting and advancing challenging projects. But solutions on thermal processing, mechanical characterisation and optimisation of software tools for the design AM products need further work.

Carlos Grande (Sintef/NO) focused on new potential applications for 3D-printed filters in pharmaceutical development.

In the material characterisation and testing discussion, Tanja Lube (Leoben University of Mining/AT) emphasized that testing must always take the future use of the part into account, because – unlike other technologies – the building direction has an important impact on the strength, and therefore optimisation, of 3D-printed parts.

Holger Friedrich (Fraunhofer HTL/DE) spoke about his experiences with optimising the thermal treatment of green bodies and compared different technologies in this area.

For the final talk of AM Ceramics 2019, Kambiz Kalantari (Lucideon/GB) summarised the experiences of the British ceramic industry with different technologies and shared his outlook on the future of AM while Thomas Gradl (EOS/DE) spoke about the metal 3D-printing industry and shared some success stories in the medical market.

Industrial Applications

The second track entitled "Industrial Applications" examined new uses for high-performance ceramics in industry.
AM processes were also very prominent in this track with contributions from Dror Danai (XJET/IL) on "Use of Ceramic AM in Preventing Breast Cancer" and the ability of this technology to make existing antenna technology for 5G less expensive.
Guillaume de Calan (Nanoe/FR) presented a new line of ceramic filaments for the filament 3D-technology.
"Multi-Material 3D-Printing of Technical Ceramics for Industrial Fabrication of SOFC-Cells" was discussed by Aitor Hornés (IREC/ES).
Jürgen Blumm (Netzsch Gerätebau/DE), Chairman of the Advisory Board of ceramitec, reported on "Digital Transformation in the Ceramic Industry", and explained that AM in particular is increasingly finding its way into the production of ceramic materials.
Further aspects discussed in this track were: new mixing technologies (Eirich/DE), laser processing of ceramics (Fraunhofer ILT/DE), transparent ceramics (MagSpin/TR), laser-induced direct metallization (IFKB/DE), data-driven approaches to material and process development (Lucideon/GB), powder technology for lithium ion batteries (KIT/DE), and CFD modelling for ceramic heat treatment processes (SGL Carbon/DE).

Accompanying exhibition

The conference agenda was accompanied by an exhibition in which a Who's Who in the international ceramic scene presented their solutions and products. Exhibitors with stands included 3DCERAM SINTO, Bayern Innovativ with its initiative Additive Bavaria and the New Materials Cluster, CERAMIC APPLICATIONS, cfi, Linseis, Lithoz, Nanoe, Netzsch, PresTEC, Schenck Process, Springer Nature and Steinbach AG.
After the first day, the ceramitec conference hosted a reception with dinner and music, which was greatly enjoyed and led to lots of eager networking. KS

Remark:
The next event to be held in Germany from Messe München's ceramic trade fair portfolio is the ceramitec trade fair which will take place from Monday 17 May to Thursday 20 May 2021 in Munich. The start of the trade fair has been brought forward by one day and will not take place, as previously announced, from 18–21 May 2021.

www.ceramitec.de

Great Britain

Ceramics UK 2019

Ceramics UK 2019 exhibition and conference focused on advanced ceramics and technical glass for a range of applications. It was held in Telford/GB, 10–11 July 2019, and co-located with the Advanced Materials Show. The event hosted 200 exhibitors and 100 speakers at a four-track conference.

Fig. 1 Lithoz/AT at the CERAMIC APPLICATIONS booth

Introduction

CERAMIC APPLICATIONS organised at this first edition of the event a combined booth with 3DCERAM Sinto/FR, Alumina Systems/DE, Lithoz/AT, maxon/DE, International Syalons Ltd./GB, Inmatec/DE and Rauschert/DE to represent this technology group. A session with six technical presentations completed this activity.

Conference Track of CERAMIC APPLICATIONS

Karin Scharrer (Editor-in-Chief CERAMIC APPLICATIONS, Göller Verlag/DE) explained CERAMIC APPLICATIONS – the Platform for Innovations with Technical Ceramic Components and acted as moderator.

Ben Melrose (Technical Director, International Syalons Ltd./GB) presented the potentials of "SiAlON Ceramics for Improved Efficiency". For many years, SiAlON, silicon nitride, and zirconia have been the unsung heroes of advanced ceramic engineering. He introduced these ceramic materials and discussed their outstanding high temperature strength, hardness, and corrosion resistance properties with case studies of how they can be utilised specifically to improve overall efficiency across a range of industrial applications, including: automotive production, chemical processing, molten metal handling, extrusion and metal forming, and pump systems.

Ulrich Werr (Sales Director, Rauschert Heinersdorf-Pressig GmbH/DE), focused his talk on "Technical Ceramics in Electrical Heating Applications". Technical ceramics of various materials are frequently used in electrical heating applications. Depending on the requirements, ceramic material with high or low thermal conductivity can be used. This allows the distribution of heat to areas where it is needed and to keep it away from areas that should stay cool. Several industries, such as plastics, automotive, analytical equipment, medical applications, household appliances etc. use electrical heating elements based on technical ceramic products. The presentation introduced some applications and the use of technical ceramics in these areas.

Fig. 2 a–b International Syalons Ltd./GB (l.) and Kyocera/JP (r.) at the exhibition

Fig. 3 a–c Dr Karin Hajek (Inmatec/DE, l.), Arnaud Roux (3DCERAM Sinto/FR, centre) and Ulrich Werr (Rauschert/DE, r.) holding their presentation at the conference

Arnaud Roux (Sales Director, 3DCERAM Sinto/FR) reported on "Ceramic 3D-Printing: from Lab Scale to Mass Production". Ceramic 3D-printing market is constantly evolving. According to the needs of flexibility and productivity of the customers, 3DCERAM Sinto have developed a complete range of printers. 3DCERAM Sinto's objective is taking 3D-ceramic printing to another level. Thanks to several equipment options using the same technology, the customers has now the possibility to scale up the process step by step.

Isabel Potestio (Business Developer, Lithoz/AT) gave an overview on "Materials and

Applications for Additive Manufacturing of Ceramics". Lithographic AM is the most widespread technology for high-performance ceramics, due to the high precision and good materials properties.

The parts produced using this technology have very similar mechanical properties as classical formed ceramic parts. To date available ceramic materials for this process include alumina, zirconia, Tricalcium Phosphate (TCP), silicone nitride and many more to cover a broad application range. Different successful applications from medical implants over classical ceramic parts to cores for investment casting will be shown.

Dr Karin Hajek (Head of Sales, Inmatec/DE) explained "New Demands – New Feedstock Systems". The development of specially dedicated and defined ceramic powders is driven by the demands the market has on the final ceramic parts. The market also is asking for the possibility to produce high quality ceramic parts based on the new powders by means of Ceramic Injection Moulding (CIM). Ceramic feedstocks have to fulfil these increasing requirements. This challenge has been accepted, new binder-systems for ceramic feedstocks have been developed successfully. This ceramic feedstock collection – INMAFEED, INMAFLOW and INMAPOM – was presented.

Walter Kuhn (Head of Sales, maxon/DE) reported on "Smart Solutions for Driving Systems". maxon is specialised in the manufacture of precision drive systems for a wide variety of industries. 20 years ago, they started to use ZrO_2 ceramic in small drive systems due to the improved properties for low friction and wear and tear. Products range in size from small watch parts through to M8 screws. maxon ceramic parts are used in long life optical adjustment mechanisms which need only small forces and for driving high pressure pumps which have high bearing forces. The combination of these drive systems with tailored ceramic parts gives customers unique opportunities for high performance. A standard programme of shafts and leadscrews is offered within the maxon catalogue. Also a standard range of linear drives utilising ceramic leadscrews and ceramic axles which achieve extraordinary long lifetimes can be found.

Next year this conference and exhibition on ceramic and other advanced materials launched by Event Partners Ltd./GB will be held on the 8–9 July next year, and will be co-located with Battery, Cells and Systems Expo and Vehicle Electrification Expo in Stoneleigh, Coventry/GB.
www.event-partners.org

Latest Cutter Technology for Extruded Products

In many different industrial branches, products are nowadays extruded and cut to the requested length. For this purpose, a variety of cutting and punching systems of manual, semi-automatic or automatic type are available.

Based on its long experience in the manufacture of cutting systems for the ceramic industry, KELLER/DE developed a cutter for such products according to the principle of universal cutters, which meets the requirements in terms of technology and investment.

This cutter is a compact machine with a Siemens TIA control system and a box PC, which stores format-related parameters and which allows adaptation. Moreover, KELLER provides worldwide support via the installed Teleservice system.

The cutter is equipped with a servo drive for the cutting table movement and with a pneumatically operated cutting device. Cutting is done with a rigid cutting knife or alternatively with a wire which is protected against wire breakage by means of an automatic wire feeding system. The speed of the extruded strand is measured by a measuring roller. The cutting output is variably adjustable and depends on the size of the product to be cut and on the properties of the product.

For the Laggenbeck company with its long-standing tradition, this development is a further contribution to react to the changes of our time with solutions that ensure the competitiveness of its customers through optimised production technology.

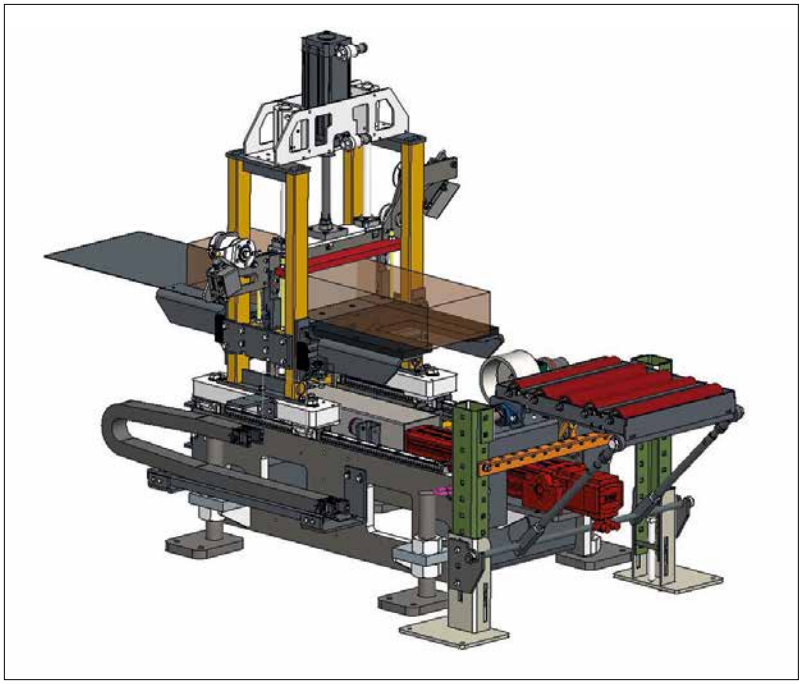

Fig. 3D-image of KELLER's new developed cutter

KELLER HCW GmbH
Intelligent Machinery Solutions (IMS)
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Germany

www.keller.de

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TILE OF SPAIN

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Bedeschi for Nexe Group: the POLET Plant in Novi Becej in Serbia

Nexe Group, the well-known manufacturer of bricks and roofing tiles with various plants in Bosnia and Herzegovina, Croatia and Serbia, continues its collaboration with Bedeschi S.p.A., the Italian company which has a tradition in the Veneto region since 1908.

Fig. 1 Gripper for unloading roofing tiles into U-cassettes

Fig. 2 Gripper for roofing tiles group re-forming

This is a collaboration that has lasted for decades with mutual satisfaction. The collaboration started with the supply of several important machinery for the group`s cement plant in Nasice, Croatia, and continued with various deliveries of machines for the production of bricks and blocks.

Currently, a new supply of a series of automatic equipment began, for the POLET Plant, located in Novi Becej, Serbia, where roofing tiles are produced.

After a careful technical analysis, the innovative Bedeschi solutions have fully convinced the renowned customer – solutions were already implemented in recent months with maximum satisfaction on both sides. The development of the new supplied automatic system was based on the possibility of improving loading/unloading of the U-cassettes support frames of the roofing tiles on the drier cars in order to limit maintenance costs. Therefore, two robots were installed, equipped with special double grippers able to fully load the cars for the total height.

Another focus of the project was to implement a delivering gripper, able to divide packets in single roofing tiles. The gripper is equipped with suction systems and an innovative vacuum pump able to adapt with limited mechanical adjustments to any type of roofing tiles.

To complete the supply, a new line for loading dried roofing tile bundles into U-cassettes was implemented as well as a new packaging line for fired roofing tiles. The packaging line is equipped with a quality control system, a re-forming line and a subsequent packaging line on pallets.

Once again, Bedeschi proved to be a serious and reliable partner, ready to face new challenges focusing on the interest of its client.

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TITAN Roller Mills – Maximum Rigidity, Compact Construction

The well-known and proven principle of the sliding support roller mills has been once again revised and re-proposed by RIETER MORANDO in the evolution of the TITAN series.

These roller mills clearly stand out from the traditional system due to the details, result of accurate studies and design, transposition of the practical experiences and collaboration with customers.
TITAN roller mills have been conceived as universal roller mills: they can, in fact, be used as roughing mills and as refiners, for operating distances between rollers up to 0,7 mm.
For a constant refining result, great rigidity and minimum clearance of the entire machine is required. The RIETER MORANDO solution is characterised as unique on the market for distributing the stresses resulting from rolling into the structure and for direct coupling of the beam to the structure, without the use of tie-rods, potential source of elastic deformations.
The RIETER MORANDO shells are secured to the hub by means of the tested double-cone fixing system, of proven reliability during operation and practicality in case of replacement. The scraping system, based on articulated levers with short arm, enables to obtain an optimal rigidity and heat dissipation. The scrapers are easy to pull out from the side, without the need for tools.

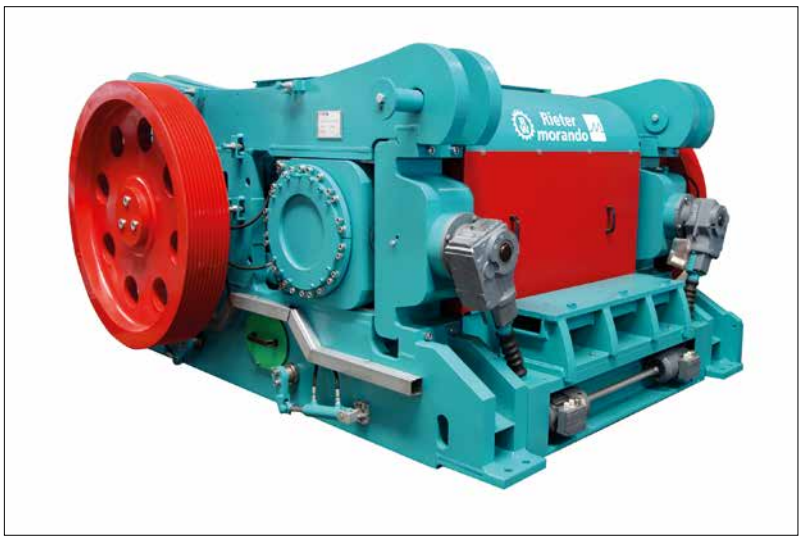

Fig. 1 TITAN roller mill developed by RIETER MORANDO

Fig. 2 TITAN roller mill in operation

RIETER MORANDO s.r.l.
14100 Asti (AT), Italy

RIETER MORANDO GmbH
78467 Konstanz, Germany

E-mail: info@rietermorando.com
www.rietermorando.com

Two gear motors installed in protected position, each equipped with a double cardan shaft, transmit in synchro the movement to the automatic adjusting device of the distance between the rollers.
For simple manual adjustment, in particular with reference to the roughing mills, mechanical adjustment is the right answer. The RIETER MORANDO well-known precision is ensured by using high-quality and precision screw-nut systems.
The adjustments required for turning the shells are incorporated in the base of the machine, making the surface restoring process easy and fast.
Thanks to these characteristics, the TITAN roller mills become synonymous of flexibility and maximum efficiency in the clay rolling.

Compact Modules for Decorating Facing Bricks Directly after Extrusion

Fig. 1 Facing bricks decorated using the uniform coating method

Fig. 2 Facing bricks decorated using the MULTICOLOR spraying system

Fig. 3 Facing bricks decorated using dry engobe powders

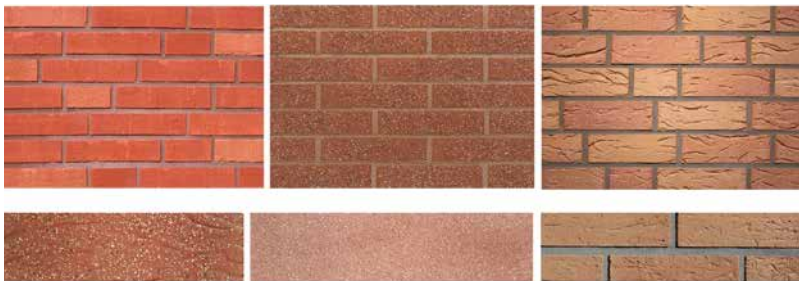

Fig. 4 Facing bricks decorated using sand application

Decoration of facing bricks is currently increasing relevant. In fact, the market is now more sensitive for enriched and diversified products. This allows manufacturers to attract the customers increasingly demand by informing them extensively about various decoration possibilities.

One of the biggest problems for brick manufacturers is that they do not have adequate facilities and space to install a decorating line at the exit of the dryer. Therefore, they often limited themselves to a few and poor final decoration effects, obtained with second-best solutions.

In recent years, SMAC/IT has been committed to develop compact modules that along few meters combine different decoration methods in order to achieve final effects with considerable impact and enriched surfaces. The most widely used methods for decorating facing bricks directly after extrusion are presented in the following.

Uniform coating

The most well-known and simple method of decorating bricks is certainly the uniform single-colour coating using liquid engobes. The application is made by means of slinger cabins, called SIT models, performing centrifugal diffusion of the engobe.

The process is carried out by means of high-speed rotating disc packs of different diameters and design. The rotation can be clockwise or counterclockwise in order to

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www.smac.it

have more control over the colouring direction. The centrifugal units are fed through perforated pipes, connected to a centrifugal pump.
This method is widely used being recognised as the best one for uniform coating, both for standard pieces and special pieces which are manufactured in ever-increasing variety.

MULTICOLOR system

MULTICOLOR is a SMAC patented system based on a spraying booth equipped with special spray-guns allowing to apply up to four different colours using the same nozzle. The system is managed by a control unit with PLC in order to choose different interval sequences of colours to be sprayed over the products. The set sequences can be saved and easily recalled for future production cycles. The spraying action is random.
The standard booth for facing bricks is equipped with two upper spray-guns and four lateral spray-guns each with two different colours. In this way, the number of possible combinations is very high, and minimum two different colours on each side of the single brick can be assured.
The final effect is a chromatic variation with gradual blending from one colour to another, with no apparent overlaying of colours. MULTICOLOR offers not only a great decoration effect, it is also the best solution in production lines where only limited space is available.

Decorating using dry engobe powders

Based on 40 years knowledge in this field, SMAC has developed a new model of dry powder-application machines called STABLIDRY and DECOBRICK which allow powder decoration on all three visible sides of the facing brick.
These machines have three dosing devices: an upper one for the horizontal side of the brick, and two lateral for the vertical sides. The final effect will be of "random" type, a so-called casual effect on the brick. For more colours, there has to be used a plant with independent collecting tanks and conveyors, which are interrupted on purpose in order to avoid contamination of the various colours.
With this method, it's possible to obtain, for example, effects that vary from concentrat-

Fig. 5 Compact module composed of the MULTICOLOR system for application of four colours and an electric dryer

Fig. 6 Compact module based on the MULTICOLOR system for four colours application and the STABLIDRY system for one colour application using dry engobe powder

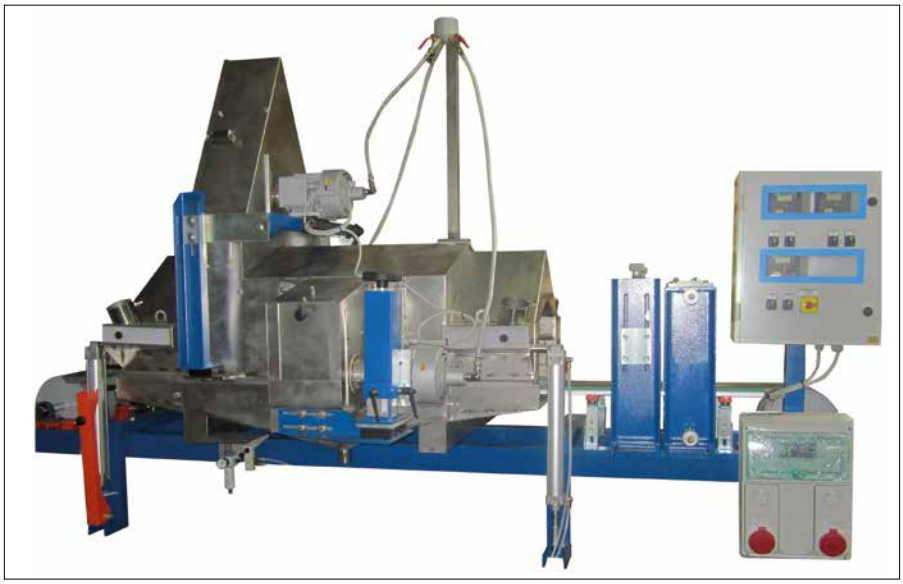

Fig. 7 Compact module based on the SIT model for uniform coating and 3D-texturing rollers

Fig. 8 **Compact module composed of a sandblasting machine model MAS and 3D-texturing rollers**

ed points and diffused splashes over uniform cover effects. A common feature of this type of machines is their extreme compactness that allows installation in small spaces.

Dry decorating using sand

One possibility of dry decorating is high-pressure application of sands on unfired bricks just after the extruder. In this case, a sandblasting machine model MAS is used. The machine is equipped with special applicator nozzles which allow to apply granules with a diameter up to 5–6 mm. The possible decorating combinations depend on the nozzle diameter, the applicators oscillating movement as well as the conveyor speed. After sand application, pressure rollers for the correct adherence of the granular material can be eventually used.

Furthermore, facing bricks with rustic effect and desired texture can be obtained by applying a module equipped with 3D-engraved shaping rollers at the exit of the sandblasting machine.

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MEETINGS & EXHIBITIONS

2019

04.-06.12.2019 Tokyo (JP)	Ceramics Expo Tokyo www.ceramics-japan.jp/en
11.-12.12.2019 Dresden (DE)	2nd HyMaPro Workshop – Hybrid Materials and Additive Manufacturing Processes www.iws.fraunhofer.de/en/events/hymapro.html

2020

03.-07.02.2020 Valencia (ES)	Cevisama hiips://cevisama.feriavalencia.com/
10.-11.02.2020 Castellón (ES)	Qualicer www.qualicer.org/en/
15.–18.03.2020 Jülich (DE)	KERAMIK / CERAMIC 2020 – 95. DKG-Jahrestagung www.dkg.de/veranstaltungen/jahrestagungen/event/209
31.03.-03.04.2020 Munich (DE)	analytica www.analytica.de/index.html
28.-29.04.2020 Karlsruhe (DE)	4th International Conference Hybrid 2020 Materials and Structures https://hybrid2020.inventum.de
08.-09.07.2020 Coventry (GB)	Ceramics UK hiips://ceramics-uk.com/
24.-27.08.2020 Darmstadt (DE)	Electroceramics XVII Conference www.electroceramicsXVII.org
28.09.-02.10.2020 Rimini (IT)	Tecnargilla https://en.tecnargilla.it
28.09-02.10.2020 Bologna (IT)	Cersaie www.cersaie.it
04.-07.10.2020 Lisbon (PT)	Euro PM2020 Congress and Exhibition www.europm2020.com

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