Cavity prediction in sand mould production applying the DISAMATIC process
The sand shot in the DISAMATIC process is simulated by the discrete element method (DEM) taking into account the influence and coupling of the airflow with computational fluid dynamics (CFD). The DEM model is calibrated by a ring shear test, a sand pile experiment and a slump test. Subsequently, the DEM model is used to model the propagation of the green sand inside the mold chamber and the results are compared to experimental video footage. The chamber contains two cavities designed to quantify the deposited mass of green sand. The deposition of green sand in these two cavities is investigated with three cases of different air vent settings which control the ventilation of the chamber. These settings resulted in different air- and particle-velocities as well as different accumulated masses in the cavities, which were successfully simulated by the model.

General information
State: Published
Organisations: Department of Mechanical Engineering, Manufacturing Engineering, Fluid Mechanics, Coastal and Maritime Engineering, DISA Industries A/S
Authors: Hovad, E. (Intern), Larsen, P. (Ekstern), Spangenberg, J. (Intern), Walther, J. H. (Intern), Thorborg, J. (Intern), Hattel, J. H. (Intern)
Pages: 204-217
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Powder Technology
Volume: 321
ISSN (Print): 0032-5910
Ratings:
Numerical simulation of flow and compression of green sand

The focus of the industrial PhD project was concentrated on the production of the sand mold (green sand) which gives the cast component its final geometrical shape. In order to ensure a high quality of the cast component, it is important to
The flowability of the green sand is important when the sand flows down through the hopper filling the chamber with sand during the sand shot. The flowability of green sand is mostly governed by the amount of water and bentonite which both decrease it. The flowability and the internal forces thus control how well you can fill a complex mold geometry in which shadowing from ribs and other geometric obstacles may be present. If the flow stops prematurely it might hinder the mold from being completely filled or result in too high variation in the material density which could influence the final surface of the cast part. The wet bridges created by the bentonite makes the sand grains stick together where the bentonite and water make the green sand very cohesive and by squeezing the mixture it obtains mechanical properties that stabilizes the mold to acquire a strong mold for the casting process. Therefore the green sand flowability is important during the sand shot for a proper filling of the chamber, and subsequently the solid mechanical proper-ties during the squeezing process are important for the final strength of the mold. This is problematic since these mechanical behaviours have an inverse relationship, e.g. if the green sand is too dry then the green sand flowability will be very high and the strength of the mold will be low and vice versa at least for the wet green sand up to a certain water content level. Therefore, obtaining the correct green sand condition and improving the filling of the mold during the sand shot are of great importance.

The project dealt with the flow of the sand particles and the deposition of sand during the production of sand molds using the sand shot in the DISAMATIC process. The deposition of the green sand in the chamber was investigated with a special cavity design where air vents were placed inside the cavities. The air vents are used to transport the green sand with an airflow during the sand shot. By changing the air vents settings in the chamber and in the cavities it was possible to improve the filling in the narrow passages in the cavity design, thereby improving the final sand mold as well. The sand shot with the cavity design was simulated by the discrete element method (DEM) modelling the flow of the green sand combined with classical computational fluid dynamics (CFD) for modelling the airflow in the chamber and the airflow through the air vents. These experiments and simulations gave beneficial insights to the DISAMATIC process and how to improve it. Additionally fluidization properties of green sand were investigated with a fluidized bed and the newly developed Anton Paar Powder Cell was used to obtain the fluidized viscosity.

Knowledge was acquired about the filling of the mold chamber with green sand in a special designed cavity geometry. The settings of the air vents together with the air pressure initially applied in the air tank gave valuable ideas for improving the filling in the cavities thereby improving the final mold. Furthermore, it was possible to apply the commercial software of STAR-CCM+ using the combined CFD-DEM model to simulate the process with a 3-D slice representation of the geometry successfully. This makes it more feasible to develop a stand-alone code in the future for simulating the DISAMATIC process. The sand shot in the DISAMATIC process might also be modelled with a continuum model where the ring shear tester could give indications of the solid mechanical behaviour of green sand and the Anton Paar DISAMATIC process. The sand shot in the DISAMATIC process might also be modelled with a continuum model where the Discrete Element Method (DEM) was chosen as the numerical model since the discrete nature of the method simulates the granular structure of the green sand with good agreement. The DEM model uses a rolling resistance model to emulate the non-spherical quartz sand particles’ resistance to rolling as well as a cohesive model to emulate the binding of the quartz sand particles from the bentonite.

General information
State: Published
Organisations: Department of Mechanical Engineering, Manufacturing Engineering
Authors: Hovad, E. (Intern), Hattel, J. H. (Intern), Larsen, P. L. (Intern), Thorborg, J. (Intern)
Number of pages: 290
Publication date: 2017

Numerical simulation of flow and compression of green sand
Publication: Research › Ph.D. thesis – Annual report year: 2017
An analytical solution describing the shape of a yield stress material subjected to an overpressure

Many fluids and granular materials are able to withstand a limited shear stress without flowing. These materials are known as yield stress materials. Previously, an analytical solution was presented to quantify the yield stress for such materials. The yield stress is obtained based on the density as well as the spread length and height of the material when deformed in a box due to gravity. In the present work, the analytical solution is extended with the addition of an overpressure that acts over the entire body of the material. This extension enables finding the shape of a yield stress material with known density and yield stress when for instance deformed under water or subjected to a forced air pressure.

General information
State: Published
Organisations: Department of Mechanical Engineering, Manufacturing Engineering, DISA Industries A/S, Magma Gießereitechnologie GmbH
Authors: Hovad, E. (Intern), Spangenberg, J. (Intern), Larsen, P. (Ekstern), Thorborg, J. (Ekstern), Hattel, J. H. (Intern)
Number of pages: 5
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: A I P Conference Proceedings Series
Volume: 1738
Article number: 030049
ISSN (Print): 0094-243X
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.21 SJR 0.163 SNIP 0.236
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.179 SNIP 0.217 CiteScore 0.18
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.165 SNIP 0.191 CiteScore 0.17
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.16 SNIP 0.173 CiteScore 0.16
ISI indexed (2013): ISI indexed no
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.17 SNIP 0.176 CiteScore 0.14
ISI indexed (2012): ISI indexed no
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.153 SNIP 0.141 CiteScore 0.12
ISI indexed (2011): ISI indexed no
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.16 SNIP 0.144
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.157 SNIP 0.137
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.162 SNIP 0.112
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.157 SNIP 0.125
Scopus rating (2006): SJR 0.157 SNIP 0.121
Scopus rating (2005): SJR 0.157 SNIP 0.187
Scopus rating (2004): SJR 0.122 SNIP 0
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 0.416 SNIP 0.765
Rheological Characterization of Green Sand Flow

The main aim of this paper is to characterize experimentally the flow behaviour of the green sand that is used for casting of sand moulds. After the sand casting process is performed, the sand moulds are used for metal castings. The rheological properties of the green sand is important to quantify as they can be used to evaluate whether the casting process will be successful. In addition, the properties can potentially be implemented in a computational fluid dynamics model which can be used as a tool to optimize the process. The rheological experiments are carried out on a MCR 502 rheometer with a new module for characterizing granular materials. The new module enables viscosity measurements of the green sand as function of the shear rate at different flow rates, i.e. 0, 2, 4, 6, 8, 10, 12 and 15 L/min. The results show generally that the viscosity decreases with both the shear- and flow rate. In addition, the measurements show that the green sand flow follows a shear-thinning behaviour even after the full fluidization point.

Shape Effect of Crushed Sand Filler on Rheology: A Preliminary Experimental and Numerical Study

Two types of filler from crushed sand were mixed with cement paste with constant superplasticizer dosage per mass of cement to investigate how their shape affects the rheology. The fillers were mylonitic quartz diorite and limestone produced using Vertical Shaft Impact (VSI) crusher and air classification, and had length/thickness (L/T) aspect ratios of 2.00 and 1.82, respectively. The particles were characterized with X-ray micro-computed tomography, coupled with spherical harmonic analysis to mathematically describe the full 3-D shape of the particles, while the rheological performance was quantified with the slump flow test (i.e. mini cone). The shape effect was isolated in the experiments by the use of non overlapping bimodal particle distributions of cement particles with a number average diameter of approximately to 0.01 mm and filler particles with a number average diameter of approximate to 0.1 mm. The two filler types were tested with a range of chi-values (volume of cement divided by total volume of solids). The flowability of the matrix increased with decreasing aspect ratios of the filler. However, the chi-value at which the maximum volume fraction threshold was obtained varied for the two filler types. Subsequently, a discrete element model was utilized to simulate the experimental data, thereby providing an initial step toward a numerical tool that can assist when proportioning self-compacting concrete with high volumes of crushed sand fines.
Simulating the DISAMATIC process using the discrete element method — a dynamical study of granular flow

The discrete element method (DEM) is applied to simulate the dynamics of the flow of green sand while filling a mould using the DISAMATIC process. The focus is to identify relevant physical experiments that can be used to characterize the material properties of green sand in the numerical model. The DEM parameters describing the static friction coefficients are obtained using a ring shear tester and the rolling resistance and cohesion value is subsequently calibrated with a sand pile experiment. The calibrated DEM model is used to model the sand shot in the DISAMATIC process for three different sand particle flow rates as captured on the corresponding video footage of the interior of the chamber. A mould chamber with three ribs mounted on the fixed pattern plate forming four cavities is chosen as a reference geometry to investigate the conditions found in the real moulding process. The geometry of the cast part and the casting system can make the moulding process complicated due to obstacles such as ribs that deflect the sand flow causing “shadows effects” around the cavities of the mould. These dynamic effects are investigated by the qualitative flow dynamics and quantitative mould filling times captured in the video footage and simulated by the calibrated DEM model. Both two- and three-dimensional DEM models are considered and found to produce results in good agreements with the video footage of the DISAMATIC process.

General information
State: Published
Organisations: Department of Mechanical Engineering, Manufacturing Engineering, Fluid Mechanics, Coastal and Maritime Engineering, DIASA Industries A/S
Authors: Hovad, E. (Intern), Spangenberg, J. (Intern), Larsen, P. (Ekstern), Walther, J. H. (Intern), Thorborg, J. (Intern), Hattel, J. H. (Intern)
Pages: 228-240
Publication date: 2016
Main Research Area: Technical/natural sciences
Flow Dynamics of green sand in the DISAMATIC moulding process using Discrete element method (DEM)

The DISAMATIC casting process production of sand moulds is simulated with DEM (discrete element method). The main purpose is to simulate the dynamics of the flow of green sand, during the production of the sand mould with DEM. The sand shot is simulated, which is the first stage of the DISAMATIC casting process. Depending on the actual casting geometry the mould can be geometrically quite complex involving e.g. shadowing effects and this is directly reflected in the sand flow during the moulding process. In the present work a mould chamber with "ribs" at the walls is chosen as a baseline geometry to emulate some of these important conditions found in the real moulding process. The sand flow is simulated with the DEM and compared with corresponding video footages from the interior of the chamber during the moulding process. The effect of the rolling resistance and the static friction coefficient is analysed and discussed in relation to the experimental findings.
Authors: Hovad, E. (Intern), Larsen, P. (Ekstern), Walther, J. H. (Intern), Thorborg, J. (Intern), Hattel, J. H. (Intern)
Number of pages: 9
Publication date: 2015
Conference: 14th International Conference on Modelling of Casting, Welding and Advanced Solidification Processes, Awaji island, Hyogo, Japan, 21/06/2015 - 21/06/2015
Main Research Area: Technical/natural sciences

Publication information
Journal: I O P Conference Series: Materials Science and Engineering
Volume: 84
Article number: 012023
ISSN (Print): 1757-8981
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.39 SJR 0.187 SNIP 0.499
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.172 SNIP 0.281 CiteScore 0.22
Scopus rating (2014): SJR 0.186 SNIP 0.306 CiteScore 0.18
Scopus rating (2013): SJR 0.183 SNIP 0.256 CiteScore 0.16
ISI indexed (2013): ISI indexed no
Scopus rating (2012): SJR 0.161 SNIP 0.203 CiteScore 0.14
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.155 SNIP 0.149 CiteScore 0.1
ISI indexed (2011): ISI indexed no
Scopus rating (2010): SJR 0.151 SNIP 0.112
Original language: English
Electronic versions:
1757_899X_84_1_012023.pdf
DOIs:
10.1088/1757-899X/84/1/012023

Bibliographical note
Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Publication: Research - peer-review › Conference article – Annual report year: 2015

Time-dependent Taylor–Aris dispersion of an initial point concentration
Based on the method of moments, we derive a general theoretical expression for the time-dependent dispersion of an initial point concentration in steady and unsteady laminar flows through long straight channels of any constant cross-section. We retrieve and generalize previous case-specific theoretical results, and furthermore predict new phenomena. In particular, for the transient phase before the well-described steady Taylor–Aris limit is reached, we find anomalous diffusion with a dependence of the temporal scaling exponent on the initial release point, generalizing this finding in specific cases. During this transient we furthermore identify maxima in the values of the dispersion coefficient which exceed the Taylor–Aris value by amounts that depend on channel geometry, initial point release position, velocity profile and Péclet number. We show that these effects are caused by a difference in relaxation time of the first and second moments of the solute distribution and may be explained by advection-dominated dispersion powered by transverse diffusion in flows with local velocity gradients.

General information
State: Published
Organisations: Department of Micro- and Nanotechnology, Department of Physics
Authors: Vedel, S. (Intern), Hovad, E. (Intern), Bruus, H. (Intern)
Pages: 107-122
Publication date: 2014
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Fluid Mechanics
Volume: 752
ISSN (Print): 0022-1120
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 2.82 SJR 1.671 SNIP 1.636
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.912 SNIP 1.676 CiteScore 2.57
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.865 SNIP 1.808 CiteScore 2.66
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.894 SNIP 1.915 CiteScore 2.71
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.731 SNIP 1.88 CiteScore 2.47
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.165 SNIP 2.023 CiteScore 2.72
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.29 SNIP 2.163
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.563 SNIP 1.891
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.691 SNIP 2.073
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.417 SNIP 1.975
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.641 SNIP 2.181
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.836 SNIP 2.107
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.411 SNIP 2.196
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.896 SNIP 2.059
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 3.042 SNIP 2.205
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 3.783 SNIP 2.518
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 3.66 SNIP 2.242
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.928 SNIP 1.95
Projects:

Intelligent Quality Assessment of Railway Switches and Crossings
This project aims at significantly improving the safety, reliability and operational lifetime of the 3500 switches and crossings (S&Cs) in the Danish railway network. The project is a close cooperation between the Technical University of Denmark (DTU), the Danish rail infrastructure provider Rail Net Denmark and four affiliated European partners with significant expertise within this field. An inter-disciplinary scientific effort is employed to obtain enhanced rail transport reliability and regularity simultaneously with significant savings in S&Cs maintenance costs. The project results will make maintenance based on intelligent fault prediction tools, instead of the presently used regular planned inspections, and it will provide sophisticated tools to prevent hidden faults from developing to failure in the future. In a novel approach, the project will install state-of the-art sensor technology in selected S&Cs and correlate dynamic parameters during train passage with static geometry data from conventional measurement vehicles. Monitoring of the dynamic responses will provide diagnosis of patterns that indicate when components or ballast begin to deviate from fully functional conditions. Modelling of dynamics will identify root causes to signs of degradation. Damage assessment of components identified by anomalous readings will be done by metallurgical examinations. Data and results will be processed by a holistic model that can produce Maintenance Performance Indicators (MPI) for the S&C condition. The correlation of sensor data to measuring vehicle data will allow existing data to be used reliably as input for the MPI model. It is expected that this project will enable optimisation of maintenance procedures, by which appropriate maintenance can be predicted in advance, thus avoiding unscheduled repairs and delays in the railway traffic.

Department of Wind Energy
Materials science and characterization
Department of Electrical Engineering
Automation and Control
Department of Mechanical Engineering
Solid Mechanics
Department of Applied Mathematics and Computer Science
Statistics and Data Analysis
Banedanmark
Period: 01/03/2015 → 28/02/2019
Number of participants: 14
Acronym: INTELLISWITCH
Number of related Ph.D. students: 1
Project participant:
Galeazzi, Roberto (Intern)
Blanke, Mogens (Intern)
Hansen, Søren (Intern)
Barkhordari, Pegah (Intern)
Asadzadeh, Seyed Mohammad (Intern)
Santos, Ilmar (Intern)
Tejada, Alejandro de Miguel (Intern)
Danielsen, Hilmar Kjartansson (Intern)
Dhar, Somrita (Intern)
Ersbøll, Bjarne Kjær (Intern)
Kulahci, Murat (Intern)
Thyregod, Camilla (Intern)
Hovad, Emil (Intern)
Project Manager, academic:
Juul Jensen, Dorte (Intern)
Numerical Simulation of Flow and Compression of Green Sand
Department of Mechanical Engineering
Period: 15/08/2013 → 07/09/2017
Number of participants: 7
Phd Student:
Hovad, Emil (Intern)
Supervisor:
Larsen, Per Leif (Intern)
Thorborg, Jesper (Intern)
Main Supervisor:
Hattel, Jesper Henri (Intern)
Examiner:
Szabo, Peter (Intern)
Rasmussen, Niels Winther (Intern)
Schumacher, Peter (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Industrial PhD
Project: PhD

Relations
Publications:
Numerical simulation of flow and compression of green sand
Documents:
Numerical simulation of flow and compression of green sand
Project: PhD