Symposium 3

Injection Molding & Molds

S03-645

Application of Ultrasonic Wave to Injection Molding

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We have developed the ultrasonic injection molding (UIM) system as a precision injection molding technology, in which the ultrasonic wave has been applied to injection molding. As a result of molding of optical lens, the weight of the lens increased when the ultrasonic wave is oscillated immediately after the resin filled in a cavity. It is found that the reason why the increase of the lens weight generates the resin flow by oscillating the ultrasonic wave. On the other hand, the surface replication with spherical micro-structure of the lens was improved in UIM compared with the conventional molding. It is considered that the flow resin in the cavity provided because of suppression for shrinkage by the ultrasonic flow during the packing-holding process. Due to the absorption of ultrasonic wave, the local heating of resin was generated to be mechanism of the ultrasonic flow during the packing-holding process. The local heating, which is especially in the region between molten- and solidified-layers, would result in reduction of deformation resistance of the solidified layer, and thus the replication during packing-holding process would be helped by the UIM. Moreover, as a result of evaluating the residual optical strain of concave lens, the strain decreased drastically in UIM compared with the conventional molding. It is considered that the reason why the decrease in the strain is caused by the local heating due to ultrasonic wave.

S03-657

Determination of diameter, length and three-dimensional distribution of fibres in short glass-fibre reinforced injection moulded parts using µ-X-ray computed tomography

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Short glass-fibre reinforced polymer matrix composites exhibit superior properties compared to traditional materials. Thus, they have found a broad variety of applications in modern industry. For process development and quality control sophisticated methods for non-destructive characterisation are needed. X-ray computed tomography(CT) is a powerful radiographic non-destructive-testing method to locate and size volumetric details in three dimensions. The main advantages of µ-CT systems based on a matrix detector and a micro-focus tube are the reasonable high scanning speed and the high resolution. This paper comprises the characterisation of short glass-fibre reinforced injection moulded parts by µ-CT to measure diameter, length and the three-dimensional orientation of the contained fibres. For this respect µ-CT-measurements with resolutions between 15 µm and 5 µm were done on fibre reinforced polybutylene terephthalate and polypropylene with fibre diameters of about 13 µm. Samples were prepared with fibre loadings between 10 and 30 volume percent and injection flow rates between 5 and 140 cm3/s. For comparison and verification one sample was studied at the European Synchrotron Radiation Facility (ESRF) in Grenoble with a resolution of 0.7 µm. In addition the experimental results were compared to simulation results of the injection moulding process using Moldflow. It is shown that µ-CT is a very powerful method for the characterisation of glass-fibre reinforced polymers. The diameter can be determined by µ-CT if the resolution is at least a factor 2 better than the diameter itself. Length and three-dimensional distribution of glass fibres can be determined even at a limited resolution that equals the fibre diameter. The experimental CT-results correspond to the calculated fibre orientation in the injection moulded part quite well. However, the strength of the orientation of the fibres is overestimated by Moldflow as compared to the CT-results.

S03-1180

Multi-component injection moulding - Heat transfer, thermal extension and bonding strength

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Defined moulding conditions and the mutual compatibility of the materials must be ensured in order to produce adhered joints via multi-component injection moulding. The two or more components are injected one after another, i. e. each component absolves the complete cycle of injection, holding pressure and cooling phase. Therefore, each component experiences its own history until it combines with another. A multiple change of cooling and reheating occurs by a local shrinkage and expansion in the polymer-polymer interface. It is well known that those geometrical changes can lead to internal stresses and finally to a weak interfacial bonding strength. Furthermore, it is known that a considerable diffusion requires not only a sufficient thermodynamic miscibility but also a sufficient wetting and melting of the preformed part by the over-moulded component. According to this the polymer-polymer bonding strength depends not only on the material combination and processing conditions (pressure, temperature, breaking time) but also on the flow and cooling conditions inside the mould as well as on the part design.As a consequence of the above mentioned aspects, it is important to pay attention on each processing step regarding to the thermal history of each component and their geometrical changes to reach an optimized bonding strength. In this study both experiments on two component bars or plates and a simulation of the single process steps concerning the change of heat transfer during shrinkage are shown. During the production of the specimens the cavity pressure by sensors and the temperature by an integrated IR-system were measured close to the interface zone. In conclusion, a correlation between e. g. the temperature development of the varied process conditions and the bonding strength is found.

S03-184

Behaviour of a suspension crystallization model in tube flow

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Various formulations describing the rheology of crystallizing polymers are discussed. For some semi-crystalline polymers-for example polypropylene-where spherulites are present in the crystallization process, the use of a suspension-type model is appropriate. Whilst it is possible to describe simple shearing and elongational rheology during on-going crystallization with such models, the flow through a capillary tube is much more complex. Here we present some computational results for this flow and compare them with experiments.

S03-319

Mold surface roughness and cavity filling of micro-injection molding

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Surface roughness is generally not an important consideration for plastic injection molding of macro-parts. However, for a micro-part, micro-scale factors, such as those related to mold surface roughness, become increasingly important as the dimensions of the cavity decreases. We investigate here the effect of surface roughness on the filling of cavity of micro-thickness. To highlight the effect of surface roughness, a disk insert, which has two halves with different surface roughness, was used in the investigations. This allows the comparison of flow patterns on these two different halves under identical processing conditions. Experimental results indicate that mold surface roughness has an effect on the filling of the cavity, and its effects decrease with increase of mold temperature, and increase with increase of melt temperature. Key words: Injection molding, surface roughness.

S03-484

INTEGRATED NUMERICAL SIMULATIONS TO PREDICT BIREFRINGENCE OF INJECTION MOLDED PARTS

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Plastic optical components have been widely used in various industrial applications, such as optical disks, lenses, and waveguides. However, birefringence inside the injection-molded parts greatly affects optical properties and has been regarded as a crucial factor in optical product development. Birefringence is generally considered being mainly affected by flow kinematics and temperature during the whole process including filling, packing and cooling stages. In this study, we successfully predict birefringence of common optical products in each injection molding stage using an integrated simulation based on fluid flow, heat transfer, viscoelasticity, stress-optical law and photoelasticity. Simulation results obtained from this study are in agreement with experimental data, which demonstrates both the reliability and the capability of the presented approach.

S03-572

Water Assisted Injection Moulding: Simulations and experimental results from an instrumented process.

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The water assisted injection moulding process offers a number of advantages compared to gas injection, such as improved cooling efficiency and improved internal bore surface finish. Understanding of the process is, however, limited, and outcomes are often uncertain. To address this, computer simulation is being used as a virtual experimental tool to investigate aspects of the flow and heat transfer, with a view to identifying the relevant fundamental dimensionless parameters and phenomena. In parallel, physical experiments on a highly instrumented tool are providing practical data. Key product features such as residual wall thickness, and process measurements, such as in-mould pressure and temperature profiles, are examined over a range of processing conditions. A number of materials (PS, PBT, PA6, PP, HDPE) with differing rheological and thermal properties are compared. Some materials (e.g. PP, PS, HDPE) exhibit significant voids in the residual wall at low water injection pressures and short water injection delay times; however, with longer delay times and higher water pressures the residual wall is more consistent. The range of materials examined provides useful data on the varying suitability of polymer melts for water core out leading to smooth residual wall deposition. The intention is to bring together computed and experimental results to provide insights into the processing conditions and material properties governing outcomes, and to develop validated computer simulation methods for product and process design.

S03-598

Development of efficient composite systems for the production of resin cast moulding blocks

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The epoxy tooling technology was developed to produce moulding blocks for short run injection moulds. The aim of using rapid tooling techniques like the epoxy tooling is to reduce costs and time-to-market in the development stage of new products. Epoxy tooling is limited to small batch production since the mechanical resistance is far lower than conventional injection moulds. Nevertheless it allows producing small series of plastic parts with satisfactory quality. The main problem of using epoxy moulding blocks, besides its low mechanical resistance, is its low thermal conductivity. There is a need of investigating and developing composite epoxy systems with improved thermal and wear characteristics, and adequate mechanical and physical properties. In this study compositions were made with various amounts of graphite and aluminium fillers in a standard epoxy resin. The influence of the filler amounts in the thermal and mechanical properties was analysed.The various compositions were cast into a silicone mould for obtaining the test bars used in the thermal and mechanical analyses. A commercial epoxy resin composite was used to assess the effectiveness of the developed composite systems.

S03-682

On the Relations between the Surface Topography and Tactile Perception of Injection-Moulded Textured Polymers

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Functionality and usability of a product, e. g. a car or a phone, are for natural reasons of primary importance for the customer. However, this may not be enough to satisfy the customer who also may look for a sensorial experience. The product should transmit an impression of high quality. The perceived quality is obviously to a large extent influenced by the visual appearance of the article, but other sensorial aspects are also important and should not be neglected. Vision and touch are considered to be the most important modalities with regard to the perception of a product. The relation between the engineering properties of the surface and the tactile perception is however not understood in sufficient detail today. The present work constitutes an initial and limited attempt to explore this relation. For this purpose, a number of polymeric plaques, with different surface textures, were injection moulded and evaluated with regard to their surface roughness and friction properties. These engineering properties were then contrasted to the tactile perception of the different textile surfaces. The tactile perception was evaluated by means of a consumer panel who described the surfaces in terms of ten sensory descriptors, e. g. roughness, slipperiness, depth and stickiness.

S03-825

Modeling flow-induced crystallization in injection molding

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Injection molding of semi-crystalline alpha-olefin polymers takes place in the production of most of the plastic commodities. The control of product final properties, e.g. mechanical and optical, is only possible with an accurate prediction of the resultant microstructure upon processing. During injection, the molten material is submitted to a complex thermo-mechanical environment in which the material undergoes phase-changes in conditions far beyond equilibrium. This complex problem is coupled, since not only the processing conditions, e.g. velocity and temperature field, determine the resultant morphology as the developed microstructure (nuclei) also affects the rheology. Flow enhances nucleation and depending on its strength different crystalline structures can be formed, e.g. spherulites and shiskebabs. To address this problem we have modeled the injection molding process with the use of finite elements. The flow kinematics is used to solve a viscoelastic model from which a deformation invariant is computed. This invariant describes the conformation of the molecular chains, i.e. orientation and chain stretch. The magnitude of this invariant is used as the driving force for flow-induced crystallization and serves as input for a kinetic model. From this model information concerning the number of flow-generated structures and their shape is computed. Also quiescent crystallization is taken into account by solving the Schneider rate equations. The volume of crystallized material is used to compute a new viscosity value. A decoupled approach is followed in which the flow simulation, the viscoelastic and crystallization equations are solved in a staggered fashion. Computational results are compared with experiments that were carried out in prototype flows, generated by special experimental setups, in terms of the microstructure developed.

S03-832

Numerical and experimental investigation of long glass fiber breakage in hot runner systems

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Long glass fiber-reinforced polypropylene composites are widely used in industry because of their low cost and high performance. However the strength of the parts depends on the average fiber length, and the fibers are subjected to break during the whole process, in the plasticating phase as well as during the flow through the nozzle and in the cavity of the mold. The aim of this paper is to determine how hot runner systems (HRS) influence the fiber breakage. The type of HRS (open or tip nozzle) and its main geometrical characteristics (e.g. the manifold length and the diameter of the nozzle) could strongly induce a breakage of the fibers during the injection molding process. Experimental tests were conducted with a modular HRS. A polypropylene reinforced with long glass fibers was injected through different configuration of the HRS, maintaining the same process parameters. The flow in the modular HRS channels was also numerically simulated and the fiber breakage was predicted by a coupled fracture model. Eventually, the numerical simulation, calibrated by the experimental results, was used to optimize the geometry of the HRS, thus determining the configuration that retains the optimal fiber length throughout the injection molding process.

S03-859

Effect of Cooling Time on In-Mold Constrained Shrinkage of Injection molded Plastic parts in Consideration of Residual Stresses

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Shrinkage, in molded plastic parts, can be affected by process parameters, part shape, and mold design. Prediction of shrinkage is of great importance in design stage, and hence, understanding this inter-relationship assists molders to design a mold with less correction. It is well known that processing parameters such as holding pressure, holding time, melt temperature, mold temperature, and part thickness have effects of certain degree on final shrinkage. Besides, part design could have noticeable effect on shrinkage where constraints are involved. Existence of molds constraints exerts noticeable effect on the final dimensions of molded parts due to the viscoelastic characteristics of polymeric materials. Variation of in-mold cooling time introduces variations in final part dimensions in relation with the constraints. Although this inter-relationship is well applied, few investigations have been reported to analyze the effect.In this paper, a numerical analysis of in-mold constrained shrinkage of injection molded parts is presented, considering the residual stresses produced during the packing and cooling stages. The numerical analysis experimentally examined for constrained shrinkage with different in-mold cooling times using a case study; a plate consisting of holes (as constraints). A mold was constructed to produce the plate featured by holes and injected to produce experimental data. The results indicated a good agreement between the numerical prediction and the experimental data.

S03-919

Visualization Analysis of Generation Process of Irregular Gloss Patterns Appeared on Hinge-Molded Sample

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Of the various molding defects experienced in injection molding,irregular gloss patterns are serious problem at the production site together with flow marks. In order to clarify the generation mechanism of irregular gloss patterns, it is necessary to investigate how they are generated because they are caused by transcription defects according to various factors. In this study, the generation process of irregular gloss patterns appearing on a hinge-molded sample is investigated by observing the contact conditions between the molded sample and cavity surface using a frosted glass-inserted mold. From the results, the generation mechanism was assumed to be as follows.Transcription has changed with the elongation of the flow front.Transcription was high at areas where elongation was low. A generation model of the irregular gloss patterns was proposed based on this assumption. Moreover, we investigated the relationship between the generation of high transcription areas and flow front behavior by observing the flow front behavior along the thickness direction.

S03-1015

Two component injection moulding: Influence of process parameters and material properties on the adhesive strength of plastic/rubber composites

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The production of two component composites of a hard plastic and a soft rubber is usually realized in an expensive multistage process. First of all, the plastic component is prefabricated by injection moulding. Afterwards, either bonding agents or activation treatments are applied to the surface in order to achieve a high adhesive strength between the plastic and the rubber components. Finally, the rubber component is added by a second injection moulding step. To reduce the high production costs caused by these different steps, a new single-stage process of two component injection moulding has been developed. During this process, plastic/rubber composites are produced without using bonding agents or activation treatments. For the high adhesive strength between the two components, diffusion of polymer chains or chemical reactions in the interface have to take place. Therefore, a system of corresponding plastic and rubber types with specific material properties is required. In addition to this material combination, process parameters like cylinder and cavity temperatures, injection and holding pressures, cooling and vulcanisation times affect the adhesive strength of the plastic/rubber composite. In this study the influence of the process parameters and the material properties on the adhesive strength is investigated. A new two component injection moulding machine is used for the experimental setup, which allows the variation of the process parameters. Different types of plastics and rubbers are used to determine the influence of specific material properties on the adhesion. The adhesive strength is measured by using a peeling test on a standard tensile test machine. The results of this investigation will be used for the development of appropriate plastic and rubber materials and the optimization of this specific injection moulding process.

S03-1024

Some Insights into the Fundamentals of Water Assisted Injection Moulding

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Water assisted injection moulding offers important new capabilities, but much of its potential remains as yet unexploited as a result of limited fundamental understanding of the process and lack of simulation methods. In parallel with experimental work reported elsewhere, computer simulation is being used to gain insights into fundamentals of the flow and heat transfer involved in the process. It is shown how cooling of the polymer melt to the internal water during core-out reduces the thickness of the residual plastic wall layer. Inertial effects in the water are also shown to influence the residual layer thickness. These effects are quantified in terms of relevant dimensionless groups. It is shown how, as the residual layer thickness falls below a critical value, a switch in the flow patter ahead of the water bubble occurs, with consequences for heat transfer and development lengths. The results may indicate favourable and less favourable processing conditions.

S03-1310

Multiple Benefits from Rapid Temperature Cycle Injection Moulding

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Pre-heating the mould tool before injection provides multiple benefits including: high gloss, weld line-free surfaces which avoid the need for paint finishing; resin-rich surfaces on fibre- and particulate-filled resins; improved transcription of micro-features; reduction of moulded-in stress; reduction of birefringence in optical components; extended flow paths and thin wall moulding without high injection pressures; reduction of part wall thickness with material economies and shorter cooling times; and reduction in clamp force tonnage with the possibility of reducing capital and running costs of moulding machines. The key to achieving these is the construction of a tool with low thermal mass, where heating and cooling is confined to a region close to the cavity. Technology to implement this will be described, and experimental results presented showing how rapid heating with steam followed by intensified cooling can be accomplished without extending cycle time as compared with conventional moulding. Considerations for tool design and operation are underpinned by computer simulation and optimization studies.

S03-163

Two component injection moulding: An interface quality and bond strength dilemma

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Two component injection moulding is a special branch of injection moulding where two different polymers are combined in to a single part to exploit the different material properties in the final product. Considering the technical and economical importance of the process, this paper investigates on quality parameters of the two component parts. Most engineering applications of two component injection moulding calls for high bond strength between the two polymers, on the other hand a sharp and well-defined interface between the two polymers are required for applications like selective metallization of polymers, parts for micro applications and also for the aesthetic purpose of the final product. The investigation presented in this paper indicates a huge dilemma between obtaining reasonably good bond strength and at the same time keeping the interface quality suitable for applications. The required process conditions for a sharp and well-defined interface are exactly the opposite of that are congenial for higher bond strength. So in the production of two component injection moulded parts, there is a compromise to make between the interface quality and the bond strength of two polymers. Also the injection moulding process conditions, material shot sequence and part geometry should be chosen based on the priority of bond strength and interface quality.

S03-196

Study on the molding of nanostructure using injection molding

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It is possible to fabricate nanostructures using injection molding. In this study, a silicon calibration grating was used as a mold insert to replicate high quality nanostructures using a simple custom-made injection machine. Nanofeatures made with polypropylene (PP), polystyrene (PS), polycarbonate (PC), and polymethylmethacrylate (PMMA) were tested because of differing viscosities and shrinkages in polymers. The results show that the surface configuration of the polymeric nanofeatures with low melt viscosity could be moulded well, while nanofeatures with high melt viscosity exhibited higher tolerance in depth. However, the moulding depth of nanofeatures could be effectively improved when mould temperature and forming pressure were higher. It was found that the reproducibility of the nanofeatures in large numbers could be replicated well after melt and mould temperatures became stable during moulding.

S03-251

Improvement of Part Surface Quality in Microcellular Injection Moulding Process Using Variable Mould Temperature Control

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A variable mould temperature applied prior to melt injection via induction heating was used to improve surface quality of microcellular foaming parts. Surface roughness can be significantly reduced when mould surface temperature increases from 100°C to 160°C. The flow marks induced by gas bubbles on the part surface can be eliminated completely as well.

S03-296

Properties of Precision Injection Moulded Parts from a Multicavity Mould

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The morphology and properties of parts from 16-cavity injection mould with geometrically balanced runners were examined. Despite such configuration of runners the cavities were filled not simultaneously and, as the result, the mass of the parts coming from different cavities was influenced by the filling sequence. Except for the different mass, morphology of the parts from particular cavities is different as well as dynamic mechanical properties.Even if the filling balance would be achieved by correction of gates dimensions in the mould, this would not solve the problem, because the gate cross-section influence the shear rate of polymer and then parts properties. The analysis of mechanical properties of injection moulded parts in a shape of tensile bars, injected at different gate height, showed the influence of the gate cross-section on tensile strength, Young modulus, Charpy impact strength and hardness.This work shows the need of achieving the simultaneous filling of injection mould cavities which should not be made by gate correction. This is important when high repeatability of parts properties is required, which is considered usually in case of precision injection moulded parts.

S03-405

Improving lifetime of BeCu injection mold insert by depositing with Ni-P-PTFE layer on mold surface

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The beryllium-copper (BeCu) alloy has the potential of being used as mold insert due to its machinability, strength, and high thermal conductivity. However, the oxidation of BeCu mold insert will aggravate the surface quality with increasing the injection shots. Preventing the surface oxidation of mold insert for improving the lifetime of BeCu mold insert is an urgent demand. In this study, the BeCu mold insert machined by single-point-diamond-turning (SPDT) were used for the injection molding of aspheric lens. The plastic material of COC were used. To reduce the oxidation, a Ni-P-PTFE layer deposited onto the surface of BeCu mold insert by electroless plating were employed as a protecting layer. The main compositions of Ni-P-PTFE layer are electroless nickel, phosphorous, and polytetrafluoroethylene. The oxidation degree and surface roughness of the Be-Cu mold inserts as function of injection counts are measured and analyzed by energy dispersive spectrometers (EDS) and surface profiler, respectively.The EDS analysis results confirmed that on the surface of BeCu mold inserts there are elements such as nickel, phosphorous, carbon, and fluorine. No oxygen element has been detected after 1000 injection shots. It proves that the Ni-P-PTFE layer can completely isolate the surface of BeCu mold insert from the air to avoid the oxidation. Furthermore, even after 1000 injection shots, the surface roughness of BeCu mold insert is closed to the value of original BeCu mold insert. It shows the great benefit of Ni-P-PTFE deposition in preventing the surface oxidation of BeCu mold insert.

S03-437

EXPERIMENTAL ANALYSIS OF MATERIALS FOR RAPID PROTOTYPING

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Rapid prototyping (RP) can substantially shorten the time and reduce the cost of developing a new product from the initial idea to production. Rapid prototyping can help in recognizing the basic defects whose subsequent correction may prove very expensive, especially if they are made already when the product is ready for production. There are also many restrictions of RP procedures primarily in the number of available materials and their properties, which may differ significantly from the properties of end product materials. In the work, based on the stipulated standards on the machines for hybrid Polyjet technique (Objet Eden 330), adequate test specimens, with material VeroBlack, were made and with adequate equipment, the analysis of the dimensions, roughness of surfaces, and mechanical properties of prototype test specimens was carried out. Then, based on the data obtained by testing of properties, a critical commentary has been provided regarding the data stipulated by their producer.

S03-454

Pressure Distribution and Flow analysis of Stereolithography Mold in Injection Molding

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Direct tooling using Stereolithography(SL) resins as mold insert has been studied for short-run injection molding. However, the tool strength, thermal conductivity and erosion resistance of the SL mold are lower than that of the traditional metal mold. The lower injection pressure is 20 MPa and the longer cycle time is about 240~360 seconds. In this study, the SL epoxy plate with the dimension of 90.0 mm*30.0 mm*3.0 mm is fixed for the mold insert and a thin wall cavity is designed as flow path of SL mold. Mold cavity sensors are embedded along with the flow direction to measure the injection pressure and temperature inside the mold. The Experiments were performed with various process parameters such as injection speed, injection pressure, melt temperature and mold temperature to investigate flow behaviors of the injection molded parts. Finally, the CAE mold flow analysis is employed to compare with the pressure distribution measurement results to analyze shear stress effect.

S03-475

An Importance of Input Data for Polymer Flow Simulations in Injection Molds

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Polymer flow simulations for injection molds have been verified experimentally. Moldflow Plastics Insight software has been used for calculations. The filling of the mold as well as the pressure development have been evaluated. An importance of input data for simulations is demonstrated. A consistence of simulation parameters and machine operating parameters, ram speed vs. time and hydraulic pressure vs. time, is of high importance. A development of a composite injection molding model is considered for simulation of the polymer flow in plasticating unit as well as in the mold.

S03-476

Simulations of Filling Imbalance in Geometrically Balanced Runner Systems

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The filling imbalance in geometrically balanced feed systems of multi-cavity molding has been simulated using Moldflow Platics Insight software. The degree of imbalance depends on the molding parameters, e.g. injection flow rates, and changes as filling progresses. The simulations provide understanding of the problem. Using of the MeltFlipper overturn apparatus has been also simulated. The simulations are helpful for proper design of the apparatus.

S03-500

VALIDATING 3D NUMERICAL SIMULATION OF CORE DEFLECTION

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In the manufacturing of long hollow plastic parts with one closed end, the melt front advances unevenly around a cantilevered slender core, causing core deflection. This deflection not only causes uneven wall thickness, but also itself accelerates melt flow behind the deflection. Flow simulation is thus especially challenging when injection molding thin-walled parts with such cores. In this study, an effective 3D numerical approach is developed to provide a convenient tool for predicting core deflection, and a single dimensionless group called core deflectability is introduced in the following discussion. To validate our simulation, we compare our core deflection predictions with a recent analytical solution (Giacomin and Hade, 2005).

S03-628

NUMERICAL SIMULATION AND EXPERIMENTAL STUDY ON THE TEMPERATURE BEHAVIOR OF PULSED COOLING

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In order to improve the quality of parts, increasing mold temperature can greatly improve the surface appearance of products. Pulsed cooling is one of the mold temperature control technology to increase mold temperature without significant change in cycle time. In this study, pulsed cooling was applied in the injection and packing process for about 0.3 seconds and mold temperature can be higher than that conventional injection molding by about 5°C. The mold temperature can also be lowered down efficiently in the cooling process. A true 3D fully transient approach is also proposed to simulate the temperature behavior of pulsed cooling. The simulation shows similar trend in mold temperature rise with the experimental results.

S03-729

Development of alternative process technology for the multi-component injection moulding

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The multi-component injection moulding technology is developing more and more as a key-technology in the polymer processing. Further operating ranges are developing by hard-/soft-combinations (thermoplast/thermoplastical elastomer). The advantages of multi-component injection moulding are the features of the several materials and the production of the parts in one process. Particularly with the material TPE as the second component there are new multiplex ranges of application coming, such as soft-touch surfaces or moulded on seals. A common problem of the Overmoulding process is that the aspired bond strength could not be achieved. In many cases the reason for that is located in the process itself and not in the material properties. Therefore the level of temperature in the interface between the two materials is much lower as necessary for a good mergence. Based on consolidated findings in the field of welding and refining of plastic parts several approaches will be investigated particularly with regard to an improvement of the process. The first step is compared to the standard process a much higher level of temperature. The contact temperature is very important for the bond. According to the diffusion and adhesion theories a higher temperature should improve the diffusion or wetting. Experimental investigations with different hard-/soft material combinations and a core back mould with an included cartridge heater in the core show first results concerning a better bond strength. Several process parameters like melt temperature, mould temperature, back pressure, etc. have been systematically varied. Compared with a "cold" core the results of the heated core experiments show an improvement up to 200%. Most notably with lower melt temperatures of the TPE the increase is significant for all material combination which is an additional energetic benefit.

S03-731

Structure of Injection Moulded Parts from Multicavity Mould

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The structure of injection moulded parts from a multicavity injection mould was investigated. The 16-cavity mould with small-sized cavities was used for this investigation. The runners were geometrically balanced. However, as it was confirmed by short shots technique, the cavities were not filled simultaneously but in a repeatable sequence.The size of spherulites and degree of crystallinity was measured for parts made from polypropylene and polyoxymethylene. It was found that there is a difference in these properties for parts coming from the different mould cavities. The parts filled as first and exposed to higher mould temperature have bigger spherulites and higher degree of crystallinity.The conclusions from this work are especially important for precision injection moulded parts. For such parts high repeatability of parts properties is required, so it is extremely important to assure filling balance and the mould temperature with small tolerance for such injection moulds.

S03-816

Co-injection moulding: effects of process parameters on the skin/core distribution in a model mould

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In co-injection moulding two polymers are injected sequentially into a mould, forming a skin/core structure which can be interesting for mechanical, aesthetic or economic reasons. In order to fully exploit this technology the materials' distribution should be optimized, and the breakthrough, i.e. the possibility that core breaks the skin and reaches the mould surface, must be avoided.In this work the effect of processing parameters on core breakthrough and material distribution in a simple mould has been studied. PMMA was used for the skin and ABS for the core. In order to maximize the amount of core material while avoiding breakthrough, a series of computer simulations and experimental tests were performed according to the statistical approach of design of experiment (DOE), which allows to identify the influences of several parameters by means of a minimum number of experiments. The moulding parameters considered were the core volumetric fraction, its injection rate and temperature and the skin injection temperature. The comparison of experimental results and simulations shows that the latter overestimate the ABS content at which the breakthrough takes place. However, the statistical analysis shows good agreement between experiments and simulations. In detail, the core material content and injection rate showed a significant influence both in simulation and experiments: an increase in core content is more likely to cause the breakthrough, whereas a higher core material injection rate seems to have a beneficial effect. The core injection temperature seems to have a limited effect in the simulations, while showed no effect in the experiments – this is probably due to an inadequate temperature control during the long moulding cycle. The skin temperature showed no effect both in simulation and experiments. Work is in progress to assess the effects of other parameters.

S03-941

A Study on the Surface Characteristics of Injection Mold and Injection Molded Part depending on LGP-Mold Fabrication Methods

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LGP (Light Guiding Plate) of LCD-BLU (Liquid Crystal Display - Back Light Unit) is one of the major components that affect the product quality of LCD. The optical patterns of LGP(2.2”) molds are fabricated by three different methods,namely, (1) laser ablation, (2) chemical etching and (3) LiGA – reflow, respectively. The characteristics of surface patterns and roughnesses of molds and injection molded parts were compared to evaluate the optical characteristics. The optical patterns of injection molded LGP with mold fabricated by LiGA – reflow method showed the best geometric structure.The surface roughness (Ra) of LGP’s with molds fabricated by (1) laser ablation: Ra=~31 nm, (2) chemical etching: Ra=~22 nm, and (3) LiGA –reflow: Ra=~4 nm.

S03-972

Transcription of negative and positive microlens arrays of light guide plate in injection molding

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A back light unit (BLU) is a key light source module of TFT-LCD, utilized in various mobile displays. A positive microlens array (MLA) has been widely applied as an optical pattern of a light guide plate (LGP) in the BLU to realize a surface light source with point light sources provided by light-emitting diodes (LEDs). Recently, we have suggested a negative MLA as an optical pattern of the LGP, showing the higher luminance than the positive MLAs. In this study, we present the experimental results of transcription properties of negative and positive MLAs of the LGP fabricated by the injection molding. The MLA pattern (35um in diameter and 8um in height) in the mold insert was achieved by the reflow of photoresist microstructures patterned by UV-photolithography. A nickel mold insert was obtained by electroforming on the fabricated MLA. The injection molding process was applied to the replication of the positive and negative MLAs with polycarbonate. The transcription properties of the replicated negative and positive MLAs were investigated with the help of a 3D surface profiler. Experimental results showed that it was hard to obtain the perfectly replicated microlens due to the rapid cooling of the molten polymer through very small and thin microcavities in the mold insert. For the case of positive microlens, the height of replicated microlens was less than that of mold insert while maintaining almost the same diameter of microlens with the mold insert, thereby resulting in the lower luminance of the LGP. In contrast, it was found that the diameter of replicated microlens was larger than that of mold insert for the negative microlens while showing almost the same height of microlens with the mold insert, and therefore, the higher luminance of the LGP was achieved due to more utilization of light provided by the LEDs.

S03-1029

Influence of injection moulding parameters on the electrical resistivity of polycarbonate filled with multi-walled carbon nanotubes

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Two polycarbonate composites with 2 and 5 wt% multi-walled carbon nanotube content were injection-moulded to plates with a sample geometry of 80x80x2 mm3 using a two-level, four-factor factorial design to evaluate the influence of holding pressure, injection velocity, mold temperature, and melt temperature on the electrical surface and volume resistivity. The level of influence of these parameters was evaluated using the regression analysis method. For both composites, variations in resistivity of the injection-moulded plates up to six orders of magnitude were found. The highest impact on the resistivity was determined for the injection velocity followed by the melt temperature. Besides commonly used integral resistivity measurements, a new and promising local resolution measurement method was performed to get a precise insight in the inhomogeneous and anisotropic character of the injection moulded MWNT/PC composites. These measurements have shown that the resistivity varied also locally within the plates showing differences up to five orders of magnitude for 2 wt% and up to two orders for 5 wt% MWNT content. Thereby, areas of equal resistivity are formed in a semicircular shape with values increasing with the flow path. The reason for the differences in electrical resistivity has to be assigned to changes in the network structure of the MWNT within the PC matrix during the injection moulding process. TEM investigations have shown that a high injection velocity combined with a low melt temperature leads to a highly oriented skin layer with well-separated MWNT, which acts electrically insulating due to the absence of tube-tube contacts. Furthermore, it could be observed that injection-molded MWNT/PC composites exhibit a skin-core morphology with a decreasing MWNT orientation towards the core region. Plates injection-moulded with low injection velocity and high melt temperature showed a network-like MWNT structure even in the skin layer.

S03-1035

Thermo-reversible DMDBS phase separation in iPP applied in injection molding

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Sorbitol-based nucleating agents like DMDBS are often added to isotactic polypropylene (iPP) to accelerate processing, altering the morphology and the properties of the product. The advantage of DMDBS over other nucleating agents is a good dispersion through the mechanism of dissolution in the polymer melt at high temperatures. The phase diagram of the iPP-DMDBS system for low concentrations (up to 1wt%) consists of three temperature regions. In region I, iPP and DMDBS form a homogeneous solution. In region II, upon cooling, DMDBS phase separates into fibrillar crystals. Further cooling, into region III, leads to crystallization of iPP. The final morphology strongly depends on the thermo-mechanical history. Flow in region I creates isotropic structures, where flow in region II leads to orientation of the DMDBS fibrils. The orientation is transferred to the crystals that will grow laterally from the fibrils, resulting in highly oriented morphologies. Upon heating, the transition temperatures between the different regions shift towards higher temperatures (thermo-reversibility), giving rise to a temperature window in Region I, in which DMDBS crystals survive.In our study we investigate the effect of the presence of DMDBS on the final morphology of injection molded samples. For that purpose, a capillary rheometer was adjusted to use as injection unit. The final morphology was studied using optical microscopy (OM) and combined Small and Wide Angle X-ray Scattering (SAXS / WAXD). Standard injection molded samples show the commonly observed oriented skin – isotropic core morphology with no change in the skin layer thickness compared to the pure iPP. It has been shown that by applying a thermal treatment to the melt before injection, based on the thermo-reversibility of the system, samples with oriented structures over the complete thickness could be produced.