List of Abstracts

To cite this article: 2016 IOP Conf. Ser.: Mater. Sci. Eng. 118 011002

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Characterisation of solidification processes during transient liquid phase bonding with rapidly solidified brazing ribbons from the melt spinning process

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Abstract. In technical joining processes, such as brazing, locally molten phases are generated in the workpiece, forming a metallurgical bond between filler metal and base material. Heat input, melting and solidification processes can thereby lead to shrinkage, mismatch and warpage. Furthermore, different process parameters, such as heating rate and holding time, influence the formation of the joining zone and especially the development of the microstructure. Due to the limited possibilities to influence these factors directly and by additional mutual interactions of these factors, the precision and reproducibility of the joints is reduced. As a consequence, rejects arise or post-production steps become necessary to remove defects, such as shrinkage, mismatch and warpage. Therefore, the aim of an interdisciplinary research group at the RWTH Aachen University is to achieve high precision in joined components by controlling and manipulating the factors determining the precision during the joining process. To reach this goal, in a first step the factors that influence precision are analysed.

The Transient Liquid Phase (TLP) bonding is a brazing method based on diffusion of braze metal constituents into the base material and of base metal constituents into the braze metal leading to isothermal solidification. The aim of this study is to analyse the timescale of the solidification and the diffusion processes of the constituents. For this purpose rapidly solidified Sn based braze ribbons from the melt spinning process were brazed at high vacuum with aluminium casting alloy for highly dynamically stressed components for automobile and engineering industry. Prior to the brazing experiments the microstructure of the braze ribbons was analysed by electron microscopy. The melting ranges were examined by differential scanning calorimetry (DSC). The braze seam was analysed by scanning electron microscopy with respect to the phase fractions in dependence of the composition of the ribbons.
Flux-free brazing in a temperature range of 650 to 850 °C under SiH4-doped nitrogen

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Abstract. Results of the public funded project “Development of processes for flux-free protective gas brazing in the temperature range of 650°C to 850°C by means of silane doped process gases” are presented.

In this project the material-based preconditions and the optimal process conditions for brazing relevant parent material combinations made from copper and steel alloys using conventional Cu- and Ag-based braze metals were determined, whereupon the doping of the process gas nitrogen with monosilane as extremely reducing agent enables the brazing without any flux. Brazing processes with silane-doped nitrogen in a conveyor belt furnace as well as in induction brazing under shielding gas were performed and assessed. Especially the latter is a promising alternative to flame brazing processes using flux, which are currently standard processes for industrial brazing in the named temperature range.
Brazing of coated thin steel sheets under a metal inert protective gas with the use of Al based filler metal

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Abstract. On the base of chemical-metallurgical studies and technological development an aluminium-based filler metal was designed with the objective of using it for construction of steel-steel connections. The adverse to conventional CU-based filler metal, considerably lower joining temperature and the resulting advantages considering construction element geometry and distortion are presented. Additionally, a marked lower mass in the joining zone, whereby the ambitions in lightweight construction is supported, results. The brittle phases in the joining zone which are to be expected due to contact of liquid Al-filler metal with steel, are to be limited by regulated short arc processes in combination with alternating current technology. Metallographic examinations confirm that. Brazing parameters are determined for common sheet thicknesses up to 1,5 mm and common coating variants. Results on bridging and misalignment are presented. Brazing speed is dependent on the desired characteristics of the joint and is in the range of 0,30 to 1,2 m/min. A partially mechanized establishment of a junction is recommended. Investigations of employment of the developed filler metal are completed by construction of Aluminium-Aluminum-Joints and mixed joints Aluminium-Steel. Assessment of the newly developed alloy for the production of Aluminium-Aluminium-welded connections is performed in comparison to conventionally commercial off-the-shelf qualities like AlSi5(A) and AlMg5Cr(A). As assessment criteria, besides process stability, serve mechanically adjustable joint characteristics. Special attention is drawn to abrupt stress on the joints.

Applicability of the developed Al-basis-alloy for production of mixed joints Aluminium-Steel was tested and assessed. Technological parameters for their implementation are presented. Shear tensile strength up to ca. 200 MPa is registered.
Brazed joints analyzed by an electrical resistance measurement as an alternative non-destructive testing method

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Abstract. Brazing offers the possibility to connect materials such as cemented carbides and steel with fatigue strength of more than 300 MP. In this regard, this technology is used in a wide range of different applications to produce tools with a high performance for the cutting industry as for example sawblades or hammer drillers. It is necessary to use filler alloys containing a high amount of silver or copper to braze such materials.

If defective brazed joints occur, this can lead to a significant decrease of the quality, which may cause financial damage to the producing companies. A non-destructive quality control with approved methods such as ultrasonic or x-ray testing is very extensive and would increase the costs for the tools. In this regard, many companies do not perform such a precise quality control and rather risk producing failing products.

This paper presents the results of the research project “Qualification of the electrical resistance measurement for a non-destructive testing of brazed joints”, which is supported by the German Federation of Industrial Research Associations (AiF, No. 18469 N/1). Electrical resistance measurement is a promising alternative to conventional non-destructive methods to analyze brazed joints. The 4-wire-technique enables a precise measurement of very low electrical resistances. Defects such as cracks and pores improve the resistance of the joint and as intermetallic phases have a lower electrical conductivity, they could be detected using this method. Finally, the limits and possibilities of this innovative method are discussed and some industrial applications presented.
Arc brazing with thermo-mechanically pretreated Al-base weld deposits

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Abstract. The process of arc brazing with Al-base weld deposits has a strong presence in the manufacturing industry. Despite all this, the short life of the Al-base weld deposits by oxidation constitutes a strong problem. In addition, the forming oxide layer represents a very good storage for hydrogen, which in turn causes the pores in brazing. Purpose of the carried out development was to reduce the porosity of the compounds by a reduction and equalization of the oxide layer, to increase the lifetime and improve the reproducibility of the compounds.

To reach these objectives a compact wire cleaning and activation unit located next to the welding machine has been developed. The wire cleaning uses a thermo-mechanically transferred plasma jet, using the effect of the discharge of gas and metal ions. The surface of the wire becomes activated and the oxide layer as well as the hydrogen content is reduced. Particles formed meanwhile plasma cleaning on the wires surface are removed using a mechanical component.

The critical parameters of the wire cleaning are the current, the distance between the wire and tungsten electrode, the flow of shielding gas (argon) and the wire velocity. The current and wire velocity take influence on the energy transferred per track segment. The distance of the electrode has an influence on the shape and transmission of the energy of the plasma.

Due to wire cleaning and activation a significant reduction of number and size of pores in the compounds could be observed, resulting in an increased stability. Forming of smoulder by welding of Al-Mg-based wires got suppressed. The clogging of the welding nozzle got reduced, increasing its durability and decreasing the number of process interruptions. All that enables the process reliability.
High speed soldering with flat wires – process development

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Abstract. Flat wires are often used in welding technique to increase the joining velocity. In contrast there is a considerable effort for the haulage of such wires. Goal of the realized development of brazing technology is to earn the benefit of the high velocity and correcting the haulage problems.

Using 2-dimensional high-speed-video-footages and high-resolution U-I-t-measurements significant changes in the arcs structure have been detected meanwhile the shift from round to flat wires. They are interpreted to be casual for the high joining velocity (about 3 m/min) adjustable using flat wires. These data is completed by parameter studies on soldering using Al-flat wires. Checkpoints for the definition of the machines characteristics are represented. The soldered connections have been evaluated metallographical and their mechanical properties have been ascertained. One focus of the investigations described here has been the usability of flat wire for forming flanged seams with preferably small opening angle and big connection area. As an edge condition concave seam geometry has been defined for reduced rework.

Specifications for tolerances and the appearance of spatter are developed. Results for the forming of steel-steel-connections are available.

Process stability has been achieved using round wires which have been transformed into flat wires next to the arc and adapting the transfer of energy - the power contact cone. A new wire feeder unit is presented.
Reactive air brazing (RAB) as joining technology for SOFC-applications

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Abstract. High efficient energy conversion systems like solid oxide fuel cells (SOFC) have seen a growing demand during the last decades, because of the increasing energy consumption of the world and the shortening of fossil fuels. The centerpiece of a SOFC stack is the ceramic cell (MEA - Membrane Electrode Assembly) with its three functional layers: cathode, electrolyte, and anode. To prevent a direct reaction of the working gases, the gas compartments of the electrodes must be separated gastight from each other. The working temperature of the SOFC is normally 750° – 850°C, since the ceramic cell components show significant ion conductivity only from this temperature on upwards.

A new SOFC concept based on repeating units with two electrically parallel connected cells is presented. Two alternatives were developed: an all ceramic concept with a 3YSZ cell housing and a metallic housing made of Crofer 22 APU. Reactive air brazing (RAB) was used to join the MEAs in the frames. RAB-brazes are typically made of a silver based matrix and a reactive component, usually CuO, which improves the wetting of the ceramic. Reactive air brazing as a relatively novel brazing technique was specifically developed for application in high temperature electrochemical devices. Unlike the previous sealing techniques, based primarily on high-temperature glasses, the RAB joints exhibit excellent thermal cycling performance and long-term stability in both high-temperature oxidizing and reducing atmospheres.

Test units were produced and gas tightness of the joints could be confirmed. Tests with a two cell unit show good overall performance with a fuel utilization above 75 %. The assembly has been operated for 1,200 hours, including full redox and thermal cycles. The results of the RAB-joining confirm the feasibility of the approach with potential benefits concerning durability and production cost.
Strength and leak testing of ceramic-steel-bonds (3YSZ-Crofer22APU) produced by means of diffusion brazing

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Abstract. The production of highly efficient ceramic-metal-bonds for high temperature applications is still a challenge. Especially due to the steadily increasing demand for energy, combined with an increasing ecological consciousness, completely new applications are developed, for which ceramic-metal composites are needed. Such a noteworthy application is the Solid Ox-ide Fuel Cell (SOFC). For the mass production of SOFC, a suitable bonding technique and material system is required in order to bond the metallic interconnector (Crofer22APU) to the high temperature electrolyte (YSZ). This challenge is still subject to research. Operating tem-peratures of approximately 800 °C, a corrosive environment, as well as thermal cycling must be considered when selecting suitable joining techniques and materials. Currently, glass sol-ders are widely used for this application. However, glass brazes show a high brittleness; be-cause of this fact the service strength is low. Reactive partial diffusion brazing is an interesting alternative to glass brazes. Especially the ductile character of the metallic brazing zone offers distinct advantages compared to glass brazes. In the present study, 3YSZ was brazed to Crofer22APU by using zirconium and titanium as active elements, combined with nickel inter-layers. The active elements were deposited by means of physical vapor deposition (PVD). Different brazing process parameters were tested to achieve a bond between the materials. After brazing, the morphology was investigated with metallographic methods and ultrasonic testing. The shear strength was measured and correlated with the brazing parameters. Since the leak tightness of the brazing plays a significant role, leak tests were conducted with a vacuum test stand. The results of the experiments showed that the shear strength is clearly dependent on the temperature, the holding time, and the used active element. With zirconium as an active element, an average shear strength of 78 MPa was measured. In addition, it could be proved that the brazing zones are vacuum-tight if the connection between both sam-ples is uniform.
Thermal spraying of oxide coatings using solution precursor thermal spraying

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Abstract. The presentation reviews the techniques of film and coatings deposition using solution as a feedstock. After a short description of the processes of: (i) spray pyrolysis; (ii) solution precursor plasma spray (SPPS); solution precursor flame spray (SPFS); and, (iv) solution precursor high velocity oxy-fuel (SPHVOF) some properties of solution feedstock are discussed. The properties include the chemical composition of solutions used to synthesize typical coatings and some physical ones, such as viscosity, which determine the flow of solution in a pipeline and its injection to plasma or flame. The chemical and physical phenomena occurring at spraying are described including atomization in gas, heating and vaporization of solution, precipitation of solution and formation of solid and heating of this solid. The molten solid is then splashed onto substrate and the phenomena at its formation are shortly discussed. Two examples of the oxide coatings prepared in our laboratory are presented: hydroxyapatite and Indium and tin oxides alloy known as ITO.
Investigations of wear caused by solid particle impingement under high temperatures on nickel based hard facings reinforced with carbides

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Abstract. The presentation characterizes the tribological behaviour of nickel based alloys reinforced with carbides stressed under solid particle impingement and high temperatures. Influencing variables were the temperature, angle of impact, velocity of the particles and kind of particles. All hard facings were made by PTA-process. The investigations show that the quantity of wear depends on the temperature, the velocity of the particles, the kind of particles, the grain size of the particles and the hardness of the particles. The results of oxidation studies demonstrate that the reinforced nickel alloys already oxidize at low temperatures and therefore they lose the wear resistance. Based on this oxidation the chromium of the nickel based alloys is reduced and the passivation of the materials is lost. Because of the very complex interaction and the understanding of the influence of the parameters it is possible to develop new materials which are able to resist solid particle impingement wear combined with high temperatures under oxidizing atmosphere.
Al enriched metal/ceramic interface under cyclic thermal load with dwell time

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Abstract. Ceramic O-stabilized zirconia (O-SZ) top coats (TC), where O most often stands for oxides of Y, Ca, Mg, La, Gd, Dy, and Ce and metallic M-CrAlX bond coats (BC), where M most often stands for a Co, Ni or CoNi base alloy and “X” represents alloying elements like Y, Hf, Si or Re have been investigated as metal/ceramic coating system for high temperature applications. During their service under combined heat and oxygen load, a reaction zone forms at the interface between the TC and the metallic BC. The reaction zone reveals formation of different thermally grown metal oxides (TGO) like (Cr,Al)2O3, (Ni,Co)(Cr,Al)2O4 and NiO. The physical characteristics and volume growth of TGOs lead to system failure. For the prepared M-CrAlY/N-SZ by atmospheric plasma spraying technique, it is proved that HQULFKLQJ WKH LQWHUIDFH ZLWK Į is beneficial to an extended operational time by prolonging the steady-state growth stage of the TGO. The corresponding behavior in M-CrAlY/N-SZ systems with heightened Al activity at the BC/TC interface, however, is under study.

In the present study, thin Al layers were deposited by DC-magnetron sputtering on the raw surface of APS sprayed M-CrAlY bond coats. Afterwards, YSZ was sprayed on top. Cyclic load with 30 min dwell time at 1150 °C was conducted. The TGOs formation was investigated by laser scanning microscope, SEM and Raman spectroscopy after 80 cycles. The laser scanning microscopic and SEM analysis were made to choose right place and size of an interesting area of sample for energy dispersive spectroscopy (EDS) and Raman investigations. The designed metal/ceramic systems with Al interlayer (Al-TBC) were compared to reference metal/ceramic systems (R-TBC) concerning their interface characteristics and the oxides formation behavior. The interface enrichment with Al results in less formation of mixed oxides like Al2O3 within the formed TGO and hence allows a higher service time of the Al-TBC systems in comparison to the R-TBC systems for the applied thermal load.
Development of a new production method for manufacturing of hybrid parts from metal and plastics

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Abstract. Increasing requirements for energy and resource efficiency promote the usage of lightweight materials. Moreover, hybrid parts made of different materials can provide a wider range of properties than parts from a single material. One of today’s challenges in production technology is the development of efficient manufacturing methods. Within the scope of the Cluster of Excellence “Integrative Production Technology for High-Wage Countries”, the so-called In-Mould–Metal–Spraying (IMMS) is being developed for manufacturing of metal/plastics hybrid parts. It is based upon the transfer of thermally sprayed coatings from the mold insert to the plastic coating carrier during injection molding. A key factor of the IMMS process is the adjustment of the coating bond strength to the mold insert for a residue-free transfer. The surface topography and therefore the surface pretreatment of the mold insert are important for the IMMS process. In the preliminary study, a surface topography fabricated by glass bead blasting has enabled the transfer of wire arc sprayed Zn-coatings. However, further investigations indicated limitations regarding the mold insert material and local coating residuals on the mold insert surface after coating transfer. For the close investigation of this effect, laser structuring is chosen as surface pretreatment method because of its capability of fabricating freely selectable, defined surface topographies. Surface structures in micron range overlaid by LIPSS (Laser Induced Periodic Surface Structures) in submicron range can be prepared using ultrashort pulse lasers. Different surface structures produced by regularly drilling on the surface and variation of the drilling diameter, depth and distance, which lead to the variation of the coating bond strength, are investigated. The aim of this investigation is to identify a suitable surface topography and to understand the bonding mechanism regarding the IMMS process.
Impact of the substrate topography on the tensile bond strength of thermal sprayed coatings

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Abstract. The tensile bond strength of a coating is one of the limiting factors of thermally sprayed coatings. To improve the bond strength and for cleaning the surfaces prior to the coating, the substrates are pretreated. Many scientific publications in the field of thermal spraying focus on the spraying process and on developing new coating parameters. The pretreatment process, on the other hand, is not often investigated scientifically, rather defined by empirical values. A well-established pretreatment method is grit blasting the surface with corundum. With this method the surface can be cleaned and roughened to support the mechanical clamping between the coating and the substrate. Besides the roughened surface the mechanical clamping is supported by undercuts. Especially the created surface topography depends on the blasting parameters such as grain fraction of the grit, particle velocity and grit blasting time. In this publication the different surface topographies are analysed using confocal laser scanning microscopy and described using standardized surface parameters. By varying the above mentioned grit-blasting parameters different surface topographies are produced. After roughening the surfaces the substrates are coated and the bond strength is measured. One goal of this project is finding a surface parameter, which correlates with the bond strength. For an easy illustration a first attempt is to use a linear presentation. The goal of this correlation is to adjust the surface topography and to minimize the grit blasting time and the usage of grit. It can be shown that the surface parameter Ra shows only minor correlation in terms of coatings bond strength.
Wear protection made by welding for components of railroad wagons

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Abstract. The railroad wagons of the Kirghiz railroad company were made in soviet times in Russia. These wagons are in many cases age-related damaged by wear. A new acquisition of wagons is due to financial reasons not possible. For these reasons important components like the saddle of axis made by cast steel, which are damaged by dry adhesive oscillating wear, should be regenerated by welding. The presentation includes collaborative investigations of the University of Technology Clausthal, the Kirghiz State University of Technology and the new Kirghiz-German Competence Centre of Welding which is supported by the organisation CIM, Germany, for rebuilding those components by welding processes like gas metal arc welding and gas metal arc welding with controlled short arc. These claddings, made by conventional welding wires and flux cored wires, were characterized by metallographical and tribological investigations. The aims of these investigations are reliable and cost-effective repair weldings with improved wear resistance against dry adhesive oscillating wear.
Suspension plasma spraying of zirconia coatings using different plasma torches

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Abstract. The aim of the present work was to test the commercially available plasma torches for a Suspension Plasma Spraying in view of potential application of SPS technology to the industry i.e. for Thermal Barrier Coatings or Solid Oxide Fuel Cells production. Four different set-ups equipped with plasma torches namely: (i) SG-100, (ii) Triplex, (iii) Axial III and (iv) h-WSP were used. The spray process parameters were optimized for each torch separately. The zirconia coatings were produced using three different precursors based on: (i) YSZ – yttria partially-stabilized zirconia, (ii) Tosoh-YSZ – yttria fully-stabilized zirconia and (iii) YCeSZ – both yttria and ceria stabilized zirconia powders. Moreover three different concentrations of suspensions were tested for each plasma torch in order to observe their influence on the coating morphology and plasma spray process efficiency. The coatings’ microstructure was observed using light microscopy, scanning electron microscopy (SEM) as well as electron backscatter diffraction (EBSD). Afterwards the phase composition of coatings was analyzed using X-ray diffraction method. The studies showed that the spray process conditions highly influence coatings microstructure and coatings build-up mechanism.
Inner hydrophobizing of thermal sprayed coatings

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Abstract. The applicability of thermal sprayed coatings is strongly limited by corrosion-initiating atmospheres. One central issue is presented with the open, porous structure of the coat, which leads towards functional damage and shortened service life. Currently, thermal sprayed coatings are protected against infiltrating, corrosive substances by an additional sealing. Even with this method being accepted by the industry, the process stability during production as well as the quality of sealed coatings remain subject to research. Especially the strongly heterogeneous build-up of coats poses a fundamental problem in most use cases. A reliable protection requires a homogeneous, deeply effective and complete inclusion of the sealer into the coat, which cannot be sufficiently guaranteed by conventional sealing methods. Subsequent mechanical post-treatments like finishing can already negatively influence the protective effect.

Coming from the known problems of conventional sealing methods, relocating the seal into the coating system offers a reasonable alternative. It is currently impossible to make a reliable statement about the functional depth of a conventional sealing. With the overlying coating however it is possible to reach an extensive protection of the sealed area. Many sources of defect, which are connected to the insufficient penetration of the sealer, are excluded this way. While conventional methods sometimes require to modify the coating structure to accomplish a deeper penetration, the inner sealing method will get rid of this requirement altogether. Using individually scalable functional layer thickness, it is possible to make life span predictions for the first time, which means an increase in production- and quality safety. Thereby it is possible to strengthen the reliability and market acceptance of these products and furthermore develop new application possibilities.
Corrosion investigations by using gel-type electrolytes

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Abstract. Limitations are encountered regarding the electrolyte when studying atmospheric corrosion reactions on materials that form protective layers on their surface or tend to passivate. For example, the reconstruction of a thin wet film, as well as the interpretation of electrochemical measurements in so-called bulk solutions (a "mass" of electrolyte), often proves to be difficult in view of corrosion behavior under atmospheric conditions. A new approach to this problem in corrosion research includes the use of gel-type electrolytes as an alternative to bulk electrolytes. Gel-type electrolytes form a thin wet film on the surface of the material, whereby the naturally formed protective layer is affected similar to atmospheric conditions and can be examined in an almost non-destructive way. Through electrochemical instrumentation specific values such as polarization resistances and corrosion currents can be determined providing information on kinetics of surface layer formation and stability of surface layers formed under the influence of a thin wet film. Thus, new test methods can be developed that supply a better understanding of corrosion processes in specific atmospheres.

In this article different zinc coatings and aluminium alloys were investigated, their naturally formed protective layers were electrochemically characterized and corrosion relevant values were determined by using a gel pad based on polysaccharide. Corrosion relevant values allowed the differentiation of various coating systems and could describe the current protective effect provided by the coating. It is shown that gel-type electrolytes influence protective layers and coatings considerably less than corresponding bulk electrolytes and that an atmospheric wet film is approached by these test conditions. From the results it is evident that gel-type electrolytes represent a viable and promising field in corrosion research.
Experimental and numerical investigation of the strength behavior of corroded aluminum alloy EN AW-2024-T3 under uniaxial loading

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Abstract. High-strength aluminum alloys are used in a variety of components, such as aeronautical and automotive engineering due to their high strength and good corrosion resistance. However, the corrosion resistance will fail if the passive layer is damaged, e.g. by chloride ions. Local corrosion phenomena (henceforth referred to as defects) and pitting corrosion occur as the damage is proceeding. These defects are the reference of the crack initiation induced by the stress concentration or the functional fatigue, which leads to a strength reduction in the material.

It is well known that the pitting corrosion will decrease the fatigue life time of aluminum alloys under cyclic loading. Additionally, under quasi static uniaxial loading, a decrease of strength and ductility of corroded specimens is noticeable.

This study will present some findings on the influence of pitting corrosion regarding the strength behavior of aluminum alloy EN AW-2024-T3. To generate various defect shapes immersion bath tests using NaCl and “FeCl2” solutions as well as galvanostatic tests were carried out. To analyze the pitting corrosion of the specimens a methodology starting from micro-optical 3D pattern surface measurements was developed, which can be easily transferred to other corrosion tests. Subsequently, uniaxial tensile tests of the corroded specimens were carried out. In addition, numerical investigations using Finite Element Method will be presented showing correlations between the shape of the defects and the strength of the aluminum alloy EN AW-2024-T3.
Influence of nitrogen on the corrosion resistance of martensitic stainless steels

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Abstract. The corrosion resistance of martensitic stainless steels (MSS) depends strongly on the chemical composition and the applied heat treatment. Both determines the distribution of the alloying elements in the microstructure and the resulting material properties. The addition of nitrogen is known to be beneficial for the pitting corrosion resistance of stainless steels. In case of MSS this effect is not only connected to nitrogen itself because nitrogen can be used to substitute carbon which also influences the result of the heat treatment process. This paper shows the effect of nitrogen on the corrosion resistance in relation to the hardening process of MSS. Therefore the effects of austenitization duration, austenitization temperature and cooling rate on microstructure, hardness and corrosion resistance were studied on the MSS X30CrMoN15 1 and X50CrMoV15. The effect of different cooling rates was studied in the range of > 100 K/s down to 1 K/s using the jominy end quench test. The changes in corrosion resistance were detected with electrochemical potentiodynamic reactivation (EPR) and by the determination of critical pitting potentials. Besides this experimental approach thermodynamic calculations with the software thermocalc will be presented and used for the interpretation of the effect of nitrogen on the corrosion resistance of MSS.
Methodology for the development of electrolytes for electrodeposition of alloys

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Abstract. Over 500 binary alloys can be deposited from aqueous solution. But only a small amount of them has been used industrially so far. The problem lies mainly in the strong dependence of the alloy composition from electrolyte composition and the working conditions. The empirical approach in the development of new electrolytes depends extremely on the experimenter. The upscaling from laboratory to industrial scale is also very little implemented because of the local optimization of electrolyte properties.

In order to standardize the electrolyte design, new mathematical optimization algorithms are required. They allow a prediction of the alloy composition as a function of essential process parameters.

The presentation defines the bonding between the metal ion and complexing agent with thermodynamic and kinetic parameters. These parameters allow a prediction of the expected type of alloy and the alloy composition. The methodology for the research of basic electrolytes is resulting from it.
Determination of the die geometry influence in gradation extrusion using numerical simulation and analytical calculation

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Abstract. The forming process Gradation Extrusion enables a severe plastic deformation with a large gradient of microstructure. Materials with tailored properties can thus be provided. Controlling the gradation of the microstructure requires knowledge of the interaction of the forming process and the special die geometry. Based on an analytical calculation approach different geometry variants are characterized. Additionally, selected variants are studied more comprehensively by numerical simulation. The mechanisms of the interaction and possibilities of influencing the deformation process by die design and process parameter optimization are presented and analysed.
Microstructure and mechanical properties of AA6060 after low-temperature extrusion

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Abstract. The various processes of severe plastic deformation often provide ultrafine-grained materials with high strength and ductility, which are, due to their low thermal stability, commonly processed to near net shape by costly and time-consuming cutting processes. In this study a shaping process operating below recrystallization temperature is investigated. Cast billets of the age hardening aluminum alloy AA6060 were solid solution annealed and extruded at room temperature (RT) with an extrusion ratio (ratio of billet vs. shape area) of 6. Additionally, some billets were processed at the aging temperature (AT, 170°C) of the material. Subsequently, the microstructural features and mechanical properties of the extruded materials were analyzed. EBSD-measurements in the center of the profiles show a coarse-grained microstructure with a pronounced fiber texture for both extrusion temperatures. In the surrounding areas fine-grained, pancake-microstructures were found, whose textures differ from the center. As expected, hardness measurements of the rods show that RT-extrusion leads to a lower hardness in the inner center area (103 HV1) compared to the rim area (108 HV1). This gradient can be compensated by a suitable subsequent heat treatment. Compared to commercially available products the RT-extruded material aged to a maximum of hardness achieves a higher tensile strength of about 350 MPa without significant loss of ductility (elongation to failure: 16%). Applying the same extrusion parameters (extrusion ratio and speed) for AT-extrusion results in comparable material properties without additional subsequent aging. Besides artificial aging during the process this approach benefits from a lower pressing force and therefore offers a high potential for integration in industrial process chains.
Unstable plastic flow during combined extrusion-ECAP-processing – Analysis of local mechanical properties and microstructures

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Abstract. In this study, we report on the observation of heterogeneous microstructures after processing of the aluminum alloy 6060 by extrusion and subsequent equal-channel angular pressing (ECAP) at room temperature. A macroscopic, alternating structure of two types of bands is observed: shear bands carrying large amounts of deformation are located next to matrix bands that contain significantly less deformation. Scanning (SEM) and transmission (TEM) electron microscopy reveal an ultrafine-grained microstructure in the shear bands, while the microstructure of the matrix bands is characterized by a high fraction of low angle grain boundaries and dislocation cells. These characteristic microstructural features affect the local mechanical properties, which are found to be distinctly different for the two types of bands. Micro-hardness measurements and nanoindentation jump-tests are performed to explore the characteristics of the deformation bands. In addition to different hardness values, caused by the different deformation induced strain hardening, the ultrafine-grained shear bands exhibit a considerably increased strain rate sensitivity (by a factor of more than 2) compared to the matrix bands. A comparison of the initial extruded microstructure with the ECAP-processed material reveals that simple shear deformation exclusively takes place within the shear bands while the matrix bands pass through the ECAP-die without getting sheared. This observation contradicts the simple theory of homogeneous simple shear during ECAP-processing; we propose a simple mechanical model describing the evolution of the band-structure, based on an alternating interplay of elastic and plastic deformation inside the shear zone driven by local microstructure-dependent softening of the material.
Unstable plastic flow during combined extrusion-ECAP-processing – Investigation of engineering factors using FE-simulations

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Abstract. Equal-channel angular pressing (ECAP) is a method of severe plastic deformation that typically leads to a homogeneous simple shear deformation and that is used to produce ultrafine-grained microstructures. In some special cases, however, single ECAP passes result in the formation of heterogeneous microstructures; this was, for example, observed in a companion study where the formation of alternating types of shear and matrix bands were observed after ECAP of an aluminum alloy 6060. Both microstructural features and mechanical properties (determined by micro- and nanoindentation) demonstrate that the ECAP shear deformation is concentrated in shear bands, whereas the adjacent matrix band regions are hardly deformed. In this contribution, we investigate the influence of different engineering factors on the morphology of the band structure. We use a simple mechanical model to rationalize how a discrete material volume can pass the shear zone of the ECAP die without accumulating significant amounts of plastic shear deformation, and how this process results in the alternating formation of matrix and shear band regions. 2D finite element (FE) simulations with an elasto-plastic material model, contribute to a better understanding how engineering factors directly influence the local deformation behavior. Different engineering factors like inner channel radius, cross sectional area of the ECAP billet, backpressure and pressing speed are investigated. Our results show that the largest equivalent stresses arise at the inner-channel corner, where consequently the formation of shear bands is triggered. Increasing the inner-channel radius or scaling up the cross sectional area of the billet leads to wider matrix bands. The predictions gained from the FE-simulations on band morphologies and dimensions are in good agreement with our experimental observations. These results contribute to a more detailed understanding of the locally heterogeneous deformation of pre-extruded or heavily work hardened materials during ECAP.
Tailor-made grain sizes for aluminum alloys by recrystallization after ECAP

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Abstract. Severe plastic deformation is characterized by microstructures with high dislocation density, a large number of vacancies, and the formation of subgrains. These defects can act as nucleation sites for new grains during recrystallization. In this contribution, we study the influence of recrystallization temperature and time on the grain size development after one pass of ECAP of pure aluminum and different aluminum alloys. The materials are deformed in one pass in a 90° ECAP die at room temperature and then subjected to different annealing heat treatments. For all samples, we determine grain size distributions by electro-polishing and employing the line-intercept method. The resulting data-sets (grain size distributions as a function of annealing time and temperature) allow tailoring homogeneous grain sizes in aluminum alloys after ECAP, which can be useful for further studies such as the scientific corrosion test.
Investigations in turn milling of SiC particle reinforced aluminium matrix composites using monocrystalline diamond tipped milling cutters

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Abstract. Concerning a steady demand for increased performance and efficiency, in many cases requirements cannot be met using unreinforced, microscopically homogeneous materials. A promising alternative represent metal matrix composites, typically using aluminium alloys for light weight applications and ceramic particles as reinforcement. High potential of these materials is seen for example in aerospace applications, especially requiring a high fatigue strength. Additionally to the material characteristics the surface properties significantly influence the fatigue strength. Reduced surface roughness values and surface imperfections as well as compressive residual stresses are beneficial in this regard. However, in machining of aluminium based composites, processes with geometrically defined cutting edges proved advantageous. Recently turn milling has increasingly become subject to scientific investigations and industrial applications.

Using a fractional factorial design and MCD tipped milling cutters the influence of different machining parameters (e. g. axial feed, tangential feed, cutting speed) and tool geometries (e. g. clearance angle) is investigated, aiming for low roughness values, minimised surface imperfections and highly compressive residual stresses. The specimens required are manufactured from an aluminium matrix composite, consisting of the alloy AA2124 and 25 % volume proportion SiC particles, in the heat treated condition T4.

The investigations provide fundamental results concerning the relationships between the cutting parameters and the properties of the surfaces generated in orthogonal turn milling of aluminium matrix composites. It can be concluded that turn milling is suitable for the generation of surfaces without significant voids. Furthermore, small surface roughness values can be obtained, primarily influenced by the axial feed. As turn milling is capable of non-circular machining the results can be transferred to the machining of rotationally asymmetric workpieces as well.
Mechanical performance of short and endless fiber reinforced polypropylene

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Abstract. Glass fiber reinforced polypropylene (PP) is one of the most important thermoplastic, fiber reinforced materials for technical applications. The injection molding process is the thereby the most efficient and flexible technique for producing fiber reinforced thermoplastic structural parts. To meet the required mechanical performance, either highly filled fiber reinforced compounds or textile reinforced thermoplastic prepregs are used. Due to the process technology, the fiber length is limited to a few millimeters in the compound. High shear stress during plastification and injection leads to fiber breakage, which additionally reduces significantly the resulting fiber length in the part. Numerous research and development efforts have therefore dealt with the integration of textile reinforcements in injection molded parts and the provision of appropriate technologies.

In comparative studies, the material performance of short fiber reinforced PP and textile reinforced PP-glass fiber prepregs was compared and considered in relation to the achievable performance in injection molded composites. The achievable strength, stiffness and impact strength run partly contrary to increasing fiber content and fiber length and must be considered in the context of the processing. Increasing fiber contents lead to an increase in the melt viscosity and thus to a higher mechanical load on the fibers during processing, which has a disadvantageous effect on the resulting fiber length. Therefore, the flow properties of the neat polymer have to be matched to the fiber content.

Already at low fiber contents of a view weight-percent a strong change in the mechanical characteristics can be seen. The elongation at break and impact strength decrease sharply, the tensile modulus already increases for 50%. The tensile modulus increases almost linearly to the technological maximum of achievable fiber contents, while tensile strength and impact strength reach the maximum at about 40% fiber content in mass. With increasing fiber length improvements are obtained especially in the strength and toughness. Improving the fiber-matrix adhesion, polymer modifications or electron beam cross-linking lead additionally to an increase in the mechanical properties.
Influencing the creep behavior of particle-reinforced aluminium matrix composites (AMCs)

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Abstract. The presentation focuses on the creep behaviour of an age-hardenable particle-reinforced aluminium alloy. The difference in the creep behaviour compared to unreinforced alloys is documented by means of creep rupture tests. The mechanisms affecting the materials are discussed further. Due to the nature of the powder metallurgical production the AMCs are characterised by a very fine-grained structure, a high concentration of grain boundaries, phase interfaces, as well as a large number of dislocations. All these properties are conducive conditions for diffusion processes to take place, which in turn leads to increased precipitation kinetics of the matrix alloy. Therefore it was examined whether an influence on these effects and thus of the creep behaviour is possible by means of the powder metallurgy. The goal is to lower the possible diffusion of the composite material by adding specific alloying elements. The results showcase the positive impact small quantities of Bor have on the creep behaviour.
Identification of Process Parameters for the Anodization of Al-Cu-Alloys Using Design of Experiments

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Abstract. Precipitation hardenable aluminum-copper alloys exhibit high specific strength levels. Therefore, they are used e.g. in the aircraft industry for safety-related components in lightweight constructions. The application of these alloys is limited by their sensitivity to selective corrosion. In order to effectively protect the components against corrosion, conversion coatings are produced by means of electrolytic anodization. These layers are characterized by very good adhesion, a uniform film thickness distribution and economic producibility. However, the layer quality (thickness, porosity) is negatively affected by the transformation behavior of copper in high-strength aluminum alloys. Thus, an adjustment of the anodizing parameters is required in order to improve the layer properties. As part of the SFB 692 B2, the influence of the process parameters on the anodization of precipitation hardenable copper-containing aluminum alloys is examined on the basis of the alloy EN AW-2024 T4 using methods of the statistical experimental design. This approach minimizes the testing effort and identifies to which extent the interactions of the process parameters have an influence on the thickness and hardness of the conversion layers. Varied parameters are the electrolyte temperature, electric current density, time (at a constant amount of charge) and the electrolyte composition regarding the concentration of sulfuric and oxalic acid. Energetic aspects are considered in order to optimize the anodization process in terms of cost-efficiency. The results indicate that the layer characteristics are particularly affected by the electrolyte temperature and to a lesser extent by the anodic current density and the oxalic acid concentration. The influence of the sulfuric acid concentration is the lowest (within the defined test setup). According to the results, an improvement of the layer thickness and hardness generally demands a much higher amount of electrical energy. Recommendations for industrial anodizing processes are derived and further opportunities for property improvements and reduced energy consumption are discussed. The results of the investigations will be presented in a poster.
High-strength aluminum materials with customized damping features for sled in high-performance sports.

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Abstract. Till now there is little technical application of ultra-fine grained (UFG) aluminum materials. Because of cost-intensive production of these materials just small quantities and dimensions are manufactured. Especially in the field of high-performance sports new high-performance materials could get applied easily because big numbers are not necessary. Smallest batch series with customized performance specification are central in the field of sports equipment and technology. It is the object of this transfer project to apply ultra-fine grained aluminum materials in sports equipment technology for the first time. At the end of the funding period one will have the state of knowledge to build a dynamically loaded component which is operationally reliable. As well as the present light-weight potential will completely be tapped and implemented into a prototype. The focus of the materials science is the investigation of the damping behavior depending on the microstructure of the used UFG materials. Concrete object of investigations in this transfer project are the so-called “bridges” of a sled. The front and back bridges connect as a crossbeam the right and left runner with the seats and the side shell. Normally this connection is an all-steel welded construction. During usage these components get high dynamic loads. Permanent and random vibrations between rail and ice surface bring the whole system sled-rider to vibrate. These vibrations worsen the ride comfort (tractability, acceleration power) of the sled, cause a decreased performance and furthermore affect the reliability of the sled. At the moment there is no systematical and appropriate development of the bridges regarding the requirements on damping, mass reduction and operational stability. In this research program the traditional steel material will be substituted by UFG materials. This will cause a reduction of component mass and an improvement of vibration damping while the operational stability is ensured. Together with the applying partner Thüringer Schlitten- und Bobsportverband e.V. there will get acquired objective methods - beside the measuring of the achieved runtime - to evaluate the functionality of the sports equipment for efficient component development.
Electrochemical development of aqueous iridium and iridium alloy electrolyte and characterization of the deposits for electrical contacts

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Abstract. To optimize the tribological behavior of sliding contacts, electrical industry is looking for surface solutions which can decrease abrasive wear by maintaining a low electrical contact. Additionally there is a great interest to replace the expensive gold coatings. Iridium is a conceivably good alternative, because it combines a high hardness with good contact resistance and conductivity. For this project the University of Applied Science Mittweida is concerned with the development of a stable water-based Iridium electrolyte for electrochemical deposits. The investigations are focused on the impact of different additives and parameter changes. The effects on the properties of the Iridium surface and the deposition rates are studied. Another approach is the specific deposition of some alloying elements to the Iridium matrix to create an Iridium alloy with improved properties to be used in electrical applications.
Influence of natural weathering and the VDA alternating climate test on the mechanical properties of thermoplastic fibre-metal-laminates

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Abstract. Semi-finished products with thermoset and thermoplastic matrix as well as aluminum alloys and titanium alloys are indispensable for the lightweight, because of their specific characteristics. They contribute significantly to the performance of economic, technical and environmentally conscious requirements. Especially the combination of the components for so-called thermoplastic fiber-metal laminates involve a significant potential for lightweight. Thermoplastic hybrid laminates are characterized a comparatively low weight, excellent impact behaviour and very good fatigue crack propagation under cycling loading. Additionally thermoplastics materials exhibit against thermosets essential advantages such as formability, recyclability, cycle time and large-scale process.

The focus of the current paper is based on the investigation of mechanical properties of thermoplastic fibre-metal-laminates, depending on the natural weathering and the VDA alternating climate test. For the laminate manufacturing an aluminum alloy EN AW-6082 is used, which grouted with different fibre-reinforced semi-finished products.
New hybrid materials by use of epoxy components in twin polymerization

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Abstract. Lightweight constructions play an important role in many fields of mechanical engineering due to weight reduction and energy efficiency. Partial substitution of metal with plastic components combines the advantages of both materials and leads to improved material properties. A well-known method for the construction of metal-plastic-composites is mechanical clamping (riveting, pin welding, forming). In addition, chemical modification of the metal compound through a proper adhesion promoter is used. To obtain a high adhesive strength, it is necessary to adjust the adhesive promoter towards both joining partners.

The twin polymerization is a new approach for the synthesis of suitable adhesive promoters. Based on one monomer, with an organic and inorganic fragment, two polymers are built within one procedure. By reasons of the spatial restriction, nano structured, interpenetrating networks with domain sizes of 2–4 nm were generated. This organic-inorganic hybrid materials are synthesized thermally without a catalyst. The combination of the well-established chemistry of epoxy resin and twin polymerization is crucial for synergistic effects in view of the junction between metal and thermoplastic resin. An amino functionalized twin monomer provides the ability of interactions with both joining partners as well as possible cross linking agent with epoxides.

By use of a selected epoxy resin in the two-component system an additional cross linking in the polymer is observed. The combination of twin monomer and resin enables the variation of monomer structure, ratio, temperature and reaction time to adapt properties towards the fields of application e.g. hot pressing or injection molding. Solid state NMR, REM/EDX as well as nanoindentation were used for investigation of chemical structure and mechanical properties of the obtained hybrid materials.
Chemical modification of reinforcing materials to improve adhesion in natural fiber composites

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Abstract. Environmental and economic reasons play an important role in the lightweight construction especially in mechanical engineering and building and construction industry. Natural fiber reinforced thermoplastics have gained great attention, because they have excellent specific properties, which are used inter alia in automobile body construction. The aim in this work is the development of novel biocomposite materials based on thermoplastic biopolymers (bio-polyethylene, bio-polyamide) and renewable reinforcing materials (flax fibers, wood veneer).

The combination of materials with different surface polarities is still a challenging task in the material science. A common approach is the use of adhesion promoters. They can adapt the different surface energies of the single components, which enables an adhesion. A chemical modification or blending of the biopolymers is not allowed due to producer policies. Thus, only the reinforcing materials can be modified, which basically consist of cellulose, hemicellulose and lignin. Therefore, the surface shows a polar character due to the accessible hydroxyl and carbonyl groups. Besides the improved adhesion the scattering of the mechanical properties should be reduced, which is caused by the natural character of the materials.

First attempts to process a veneer-polymer-veneer- (VPV) material with bio-polyethylene (bio-PE) failed without adhesion promoter. An adhesion promoter is necessary to combine the polar veneer with the nonpolar bio-PE. One approach is the hydrophobization of wood veneer surface with polyvinylamine (PVAm, Lupamin®). We present a strategy to hydrophobize wood veneer with PVAm to obtain compatible materials, which can be processed to VPV-materials. The adsorption behavior and the degree of hydrophobization depends on the pH value, the degree of hydrolysis, molar mass and the mass concentration of the PVAm solution. The coated veneers were characterized by contact angle, SEM, EDX and XPS measurements. Furthermore, the tensile properties of the produced VPV-materials were investigated.
Wear behavior of high-entropy alloys

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Abstract. Due to their outstanding properties, high-entropy alloys have gained much scientific interest recently. These properties include high strength and hardness, comparable to bulk metallic glasses. Nevertheless high-entropy alloys also show distinct ductility. Furthermore wear resistance has been investigated briefly showing promising results. The focus of this contribution is on further investigating the potential of high-entropy alloys for wear resistant applications.

For these investigations three alloy systems have been chosen: AlCrCuFeMnNi, CoCrFeNiTi and AlCoCrFeNiTi. Bulk samples with equimolar composition were produced by inert gas arc melting of elemental raw material. Subsequently Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDX) were carried out to investigate the microstructure and chemical composition. Furthermore a phase analysis was carried out by XRD (X-ray diffraction). Mechanical properties were investigated by measuring Vickers hardness (HV). The wear resistance against different wear regimes was tested. Therefor ball on disk wear test, oscillating wear test and scratch test were conducted. Results were correlated with microstructure and hardness. To evaluate wear test results a conventional hard chrome reference plating was characterized as well. Comparing wear test results with the reference coating shows that, especially for the AlCoCrFeNiTi alloy, higher wear resistance can be achieved with the new alloying concept of high-entropy alloys.
FEM-simulation of hybrid metal/plastic-composites

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Abstract. The development of hybrid composite structures for lightweight construction requires an intelligent combination of plastic and metal in variable composition with a defined, process-suitable interface design connecting the joining partners. FEM-simulations are suitable to evaluate the compound in real constructions. To evaluate the interface between the joining partners in terms of adhesive strength and resistance to crack propagation, multiple material tests must be carried out beforehand. The aim of the investigation is to determine the appropriate characteristics, in order to be able to construct the most realistic FEM models possible.
Adhesive strength of wood-veneer-biopolymers

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Abstract. Thermoplastic laminates are usually consisting of oriented fibres in thermoplastic matrices. These thin layers are stack in press processes to certain multilayer-composites according to their applications.

In order to produce bio-based laminates wood-veneer is jointed with polymer films in a continuous process. Veneer itself is a naturally grown composite with an obvious anisotropy. The use of veneer as natural fibre reinforcement for polymers requires a strong adhesion between both components.

Different kind of wood-veneers (European Beech, Fagus sylvatica L. and Spruce, Picea abies) and biopolymers were processed to laminates. European Beech as a hardwood and spruce as a softwood differs in their structure, density and mechanical properties. The impregnation of the veneers is influenced by the melt flow index of the polymer films and the cellular structure of the wood. The adhesive properties of produced laminates were evaluated by pull-off test and tensile test.
Preliminary study on possibility of application of solution precursor plasma spraying process to obtain indium tin oxide coating

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Abstract. To obtain the indium tin oxide (ITO) coatings in the process of solution precursor plasma spraying (SPPS) tin (II) acetate and indium (III) acetate were used as precursors. They were prepared as a liquid solution in dissolved water in two ratios of In:Sn 90:10 and 90:5 by weight. To allow verification of received ITO solution, the liquid was dried at the temperatures of 120°C, 250°C, 500°C and 750°C. The X-ray diffraction (XRD) results of as dried ITO solution showed the big difference in the received structure. With the increase of the drying temperature the structure changed from amorphous to the crystalline cubic structure. After drying the solution above the temperature of 500°C the received structure matched the structure of stoichiometric indium tin oxide crystalline cubic structure. This confirmed the assumptions of the differential thermal analysis (DTA) that the temperature of crystallization the indium tin oxide structure is around 400°C-600°C. The liquid precursors were injected to plasma torch for single scan spraying process onto stainless steel substrates. In the process of single scan spraying the parameters such as power, spray distance and In:Sn ratio were changed. On the surface of sprayed substrates, observed using scanning electron microscope (SEM), were visible areas with fully melted particles of ITO and characteristic depositions for the solution precursor plasma spraying method called “cracked shells”. It was observed that too short distance between the nozzle and the surface can prevent the transformation of solution from droplet to melted solid and its impact on the substrate.
Resistance spot welding of aluminum to steel with the use of cold-sprayed interlayers

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Abstract. The role of dissimilar material combinations is more and more popular in many industrial applications. Usually the main attention is paid on the joining of steel to light metals in order to reduce the weight of elements. However the selected joining processes can still cause many difficulties, what arise from the significant differences in their thermophysical properties.

In this work the preliminary study on the Resistance Spot Welding (RSW) of aluminum alloy 5754 to DP600 steel with use of interlayers were performed. Based on equilibrium phase diagrams two types of materials were selected for interlayers: (i) nickel and (ii) zinc. The steel substrates were coated with Ni and Zn with the use of Low-Pressure Cold Spray method prior to RSW. The welding parameters were selected experimentally based on authors own experience. Afterwards the microstructure of coatings was observed by light microscopy and scanning electron microscopy (SEM). Finally the micro hardness and shear strength were investigated also to have basic knowledge about the mechanical properties of RSW welds.

The studies showed that the appropriate selecting and preparation of interlayer allow to join aluminum alloy 5754 to DP600 steel by the means of Resistance Spot Welding with very satisfactory results. Both interlayers allowed to decrease hardness in welding zone and increase shear strength. The greatest increase in mechanical properties was observed when RSW process was conducted using nickel interlayers for which the failure in shear test occurred outside the weld (on the aluminum side).
Production and characterisation of a thermoformed complexly curved component from thermoplastic FRP/metal laminate

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Abstract. Hybrid laminates comprised of thin light metal sheets and fibre-reinforced plastics (FRP) combine the advantages of the individual material groups. These laminates offer the great potential to substitute complexly curved and bent thin-walled sheet structures in areas relevant for light weight construction. Compared to thermoset-based fibre-reinforced plastic the utilisation of thermoplastic matrices enables the thermal moulding, reshaping and deformation of the laminates. Part of this contribution is the examination of properties not depending on a direction of hybrid laminates comprised of a multi-directional combination of the aluminium alloy EN AW-6082 T4 and the unidirectional, fibre-reinforced polyamide 6. The orthotropic and mechanical properties of planar laminates with a multi-directional construction are determined by means of tensile and bending tests. The results of these tests are subsequently compared by utilising the classical laminate theory (CLT). A hybrid laminate construction designed for bending and torsion is thermally reshaped to create a complexly curved structural component. Subsequent microstructural examinations showcase the effect the deformation has on the structure of the laminate and on the quality of the consolidation. The hybrid component structure is tested additionally with bending and torsion tests and compared to steel 1.4301. Due to the hybrid laminate the weight was reduced by 40%.