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MANUFACTURING TECHNOLOGY ABSTRACTS

FORMING

112600 In-situ measurement of higher-order strain derivatives for advanced analysis of forming processes using spatio-temporal optical flow

Christoph Hartmann; Philipp Lechner; Wolfram Volk ***[CIRP Annals, v 70, n 1, 2021, Starting Page 251, Pages 4]*** In-situ full-field measurements became one of the drivers for process understanding, model creation, validation and inverse analysis. Therefore, a novel spatio-temporal optical flow method for the robust measurement of higher-order strain derivatives is proposed. This computer vision approach overcomes inherent restrictions of established DIC methods. For advanced process analysis of shear cutting processes, the deformation curvature (2nd-order displacement derivative) and the respective rate (3rd-order displacement derivative) are of high interest. For the first time, it is possible to quantify experimentally these higher-order derivatives in sufficient quality with the proposed spatio-temporal optical flow approach. In addition, interesting correlations between the microstructure of the material and macroscopic process results are determined. This demonstrates the potential of the novel in-situ measurement approach for the advanced process analysis of metal forming processes in general.

112601 Large strain flow curves of sheet metals by sheet extrusion

Felix Kolpak; Heinrich Traphöner; Oliver Hering; A. Erman Tekkaya ***[CIRP Annals, v 70, n 1, 2021, Starting Page 247, Pages 4]*** Metal sheets are forward extruded at large plastic strains up to 1.6. The sheet specimens are placed between two half-cylindrical billets and cold-extruded collectively. While extruding the sheets, their central zone is plastically deformed nearly homogeneously under a deviatoric stress state equivalent to simple tension. Tensile test specimens are extracted from the extruded sheets at various extrusion strains delivering flow stresses at discrete large plastic strains of the flow curve. Sheet thicknesses as thin as 0.2 mm could be tested successfully. Steel and aluminum alloys with different strengths were investigated. Results were compared with in-plane torsion test measurements.

112602 Criterion for microcrack resistance of multi-phase steels based on property gradient maps

Lukasz Madej; Yuling Chang; Danuta Szeliga; Wolfgang Bleck; Maciej Pietrzyk ***[CIRP Annals, v 70, n 1, 2021, Starting Page 243, Pages 4]*** A novel criterion for microcrack resistance of multi-phase steels based on property gradient maps is proposed. Two industrial sheets of steel were processed to obtain dual-phase and complex-phase microstructures with exactly the same chemical composition. Experimental investigations showed characteristic differences for the tensile tests, hole expansion and the local plastic behavior during deformation. An innovative full-field modeling approach that explicitly predicts mechanical property gradients as a function of microstructural gradients during forming was developed and validated. This allowed to form a new criterion for evaluation of structure–property relationship in nano-structured multi-phase steels and can reveal the formability limitations.

112603 Cognitive clamping geometries for monitoring elastic deformation in forming machines and processes

Robin Kurth; Markus Bergmann; Robert Tehel; Martin Dix; Matthias Putz ***[CIRP Annals, v 70, n 1, 2021, Starting Page 235, Pages 4]*** In the context of inline monitoring and controlling of forming processes, the distribution of acting forces on tool and forming machine causing elastic deformation of the clamping surfaces provides fundamental information on the resulting part quality whereas the inline detection is still challenging. This paper presents a novel method using the T-slot geometry as a cognitive area for inline analyzing of the elastic deformation of the tool-clamping surfaces. Using a newly developed sensor device, the elastic deformation state of the T-slot geometry under process forces is detected by strain measuring of a deformation body mounted inside the T-slot. The functionality principle of the sensor device and measuring method for process monitoring are demonstrated by simulation and experiments, demonstrating the potential for process control.

112604 Residual stress evolution in partial and full axisymmetric forming processes

Peter Groche; Alessandro Franceschi ***[CIRP Annals, v 70, n 1, 2021, Starting Page 227,***

Pages 4] Expedient residual stress distributions offer extensive opportunities for improved product properties. Metal forming process chains provide an excellent opportunity for the targeted manipulation of residual stresses. The required purposeful process design has to take into account the possible inheritance of residual stress states along the process chain. The paper at hand reveals new insights into the evolution of residual stresses by a distinction between partial and full forming and an analytical model derived for axisymmetric forming. Presented results show the relevance of initial residual stress distributions especially for partial forming processes.

112605 Plastic deformation of workpiece during unloading in plate compression
Z. G. Wang; T. Hakoyama; Y. Yoshikawa ***[CIRP Annals, v 70, n 1, 2021, Starting Page 223, Pages 4]*** Deformation behaviour during loading and unloading is studied in compression of an aluminium plate with a high ratio between the diameter and the thickness by a DLC coated die. A compressed plate becomes thinner during unloading after the plate is compressed to a larger reduction in thickness in loading. The plastic deformation of a compressed plate during unloading is confirmed by measuring the increase of the plate diameter during unloading. The optimum profile of a die crown approaches to the reverse shape of the elastic deflection of a flat die at the loading stroke end with increasing reduction in thickness.

112606 Characterization of a novel aerostatic lubrication system for deep drawing processes
Mathias Liewald; Christoph Wörz; Kim Rouven; Riedmüller ***[CIRP Annals, v 70, n 1, 2021, Starting Page 239, Pages 4]*** For economic and ecological aspects, use of lubricants containing mineral oil in sheet metal forming is sought to be reduced or avoided. Here, the application of gaseous N2 or liquid CO2 as volatile media acting as an aerostatic lubrication system represents a new approach for dry metal forming processes. In this paper, friction mechanisms occurring in this lubrication system and main factors influencing friction conditions had been identified by extended research work. An empirical friction model is presented, allowing the prediction of resulting friction coefficients as a function of the contact normal stresses acting between sheet metal and tool surface.

MACHINES

112607 Influence of bearing ball recirculation on error motions of linear axes
Gregory W.Vogl; Kyle F. Shreve; M. Alkan Donmez ***[CIRP Annals, v 70, n 1, 2021, Starting Page 345, Pages 4]*** For positioning systems utilizing linear guides and trucks with recirculating balls, a method is presented that uses the measured total error motions and the measured phase of ball loops within trucks to determine the influence of each ball loop on the error motions. The influence of ball recirculation on the error motions is estimated a priori via a least-squares solution based on data collected from a multitude of motion tests in which varying phases were measured by sensors integrated into the trucks. This method enables real-time estimation of performance degradations and identification of their sources.

112608 Effect of quasi-static motion on the dynamics and stability of robotic milling
Lutfi Taner Tunc; Bora Gonul ***[CIRP Annals, v 70, n 1, 2021, Starting Page 305, Pages 4]*** Robotic milling exhibits low frequency chatter, which is highly affected by the robot configuration and milling position. There has been significant effort to investigate the effect of robot structures on milling stability, most of which rely on the modal parameters which are measured under static conditions, i.e. robot is not moving. This study shows that the vibration response of industrial robots under quasi-static motion conditions differs from that of static conditions, which in return affects the stability limits at low frequency chatter conditions. Conclusions are derived from the experimental results to lead the requirement of on-the-fly identification of modal parameters.

112609 Active control of high frequency chatter with machine tool feed drives in turning
Alper Dumanli; Burak Sencer ***[CIRP Annals, v 70, n 1, 2021, Starting Page 309, Pages 4]*** This paper presents a new active vibration control strategy to mitigate high frequency regenerative chatter vibrations using machine tool feed drives. Rather than modal damping, proposed approach aims to control regenerative process dynamics to shape the Stability Lobe diagram (SLD) and attain higher material removal rates. The controller is designed as a feedback filter whose parameters are optimized to compensate regeneration. The proposed strategy is applied to actively control orthogonal (plunge) turning dynamics where

>2.5 [kHz] chatter vibrations are suppressed by a fast tool servo (FTS) drive system. Stability lobes are shaped locally to reach up to 4x higher material removal rates.

112610 Automatically tuned boring bar system
Yusuf Altintas; Derry Lappin; David van Zyl; Dan Östling ***[CIRP Annals, v 70, n 1, 2021, Starting Page 313, Pages 4]*** This paper introduces a boring bar system which includes an automatically tuned internal vibration absorber, called a tuned mass damper (TMD). The TMD head can be attached to boring bars with a wide range of lengths. An electromagnetic impulse force actuator is developed to measure the frequency response function (FRF) of the boring bar with an integrated power screw. A portable servo motor is attached to the power screw for adaptive tuning of the vibration damper's stiffness. The measurement and tuning cycle is automated until the negative real part of the FRF is optimized to maximize the chatter-free depth of cut. The system is experimentally validated on boring bars with a wide range of length to diameter ratios.

112611 Vibration analysis and cutting simulation of structural nonlinearity for machine tool
Naruhiro Irino; Yasuhiro Imabeppu; Yosuke Higuchi; Yuta Shinba; Kengo Kawai; Norikazu Suzuki; Junichi Kaneko; Yasuhiro Kakinuma; Masahiko Mori ***[CIRP Annals, v 70, n 1, 2021, Starting Page 317, Pages 4]*** The dynamic behavior of a machine tool is affected by the forces applied to the structure. However, cutting processes have been analyzed considering the linear systems in most of the studies so far. In this study, a machine tool structure was excited by using an electromagnetic shaker and the force-dependant frequency response characteristics were measured. Based on the measured result, the nonlinear characteristics of the machine tool structure was identified, and a machine tool with the nonlinear characteristics was mathematically reproduced, which enabled to analyse the nonlinear frequency response characteristics and simulate cutting processes.

112612 Fabrication of textured surface with ultrasonic vibration-assisted indentation
Hirofumi Suzuki; Tsunehiro Nakagawa; Akihiro Suzuki; Mutsumi Okada' Seiji Hamada ***[CIRP Annals, v 70, n 1, 2021, Starting Page 321, Pages 4]*** An ultrasonic vibration-assisted indentation system/method is proposed and developed to fabricate structured or textured surfaces more precisely and efficiently than the conventional micro-cutting process. Indenters made of single crystalline diamond (SCD) were fabricated by laser fabrication and polishing with diamond abrasives on a cast iron plate. In the experiments, the microarray molds of four-corner cone and semi-sphere shapes were generated precisely on the electroless Ni-P substrate with ultrasonic vibration-assisted indentation using the SCD indenters. From the indentation experiments, it is clear that the microtextured patterns were formed precisely and effectively by using the developed indentation system.

112613 Robust and accurate prediction of thermal error of machining centers under operations with cutting fluid supply
Toru Kizaki; Shinji Tsujimura; Yuya Marukawa; Shigeo Morimoto; Hisashi Kobayashi ***[CIRP Annals, v 70, n 1, 2021, Starting Page 325, Pages 4]*** A novel temperature measuring system named LATSIS was proposed to realize a robust and accurate prediction of the thermal deformation of machining centers, even under external disturbances such as cutting fluid supply. LATSIS enables a drastic increase in the number of sensors employed for measuring the temperature of the machine tool. Thus, the entire temperature distribution can be obtained by interpolating the measured temperature 3-dimensionally without calculating the heat conduction. A set of experiments was conducted in which the LATSIS was employed to predict the TCP error. A total of 284 sensors were placed on the machining center, and the TCP error was predicted based on the measured temperature for the situation with/without the cutting fluid supply. The results of the prediction showed good agreement with the measured TCP error even during the initial transient temperature change as well as in the cooling phase after the machine halt. The TCP error with the cutting fluid supply is accurately predicted. LATSIS was proven to be a robust and accurate method for predicting the thermal deformation of machine tools, and is a promising technology for future manufacturing systems.

112614 Why is it hard to identify the onset of chatter? A stochastic resonance perspective
Daniel Bachrathy; Henrik T. Sykora; David Hajdu; Bence Beri; Gabor Stepan ***[CIRP Annals, v 70, n 1, 2021, Starting Page 329, Pages 4]*** A stochastic dynamical model is presented to identify the difficulties in chatter detection during cutting processes. The theoretical implications are based on measurements related to the stochastic

character of the cutting force. The stochastic model is validated in a Hardware-In-the-Loop (HIL) environment where the multiplicative component of the stochastic cutting force is varied parametrically. In case of an industrial machine tool, the stochastic resonance effect is also demonstrated quantitatively by means of high resolution vibration measurements for various spindle speeds in full immersion milling. The proposed method predicts the noise induced peaks in the spectrum of the vibration signals, which occur already within the chatter-free parameter domains and might be misjudged as chatter.

112615 Direct measurement of thermo-elastic errors of a machine tool

Christian Brecher; Robert Spierling; Marcel Fey; Stephan Neus ***[CIRP Annals, v 70, n 1, 2021, Starting Page 333, Pages 4]*** The knowledge of thermo-elastic tool center point (TCP) errors offers significant potential to increase the achievable product quality in manufacturing. This paper presents a novel, cost-effective, machine integrated measurement method for small and medium sized machine tools to detect thermally induced errors utilizing a position sensing detector (PSD) and a thermo-stable laser frame. Based on the measured output of the developed system, 13 of 21 errors of a three axis kinematic can be derived. Furthermore, the error-specific uncertainties are evaluated by means of Monte Carlo method. Experimental results are presented and give an impression of the capability of the measurement method.

112616 Online adaption of milling parameters for a stable and productive process

Benjamin Bergmann; Svenja Reimer ***[CIRP Annals, v 70, n 1, 2021, Starting Page 341, Pages 4]***On the way to fully autonomous machine tools it is essential to independently select suitable process parameters and adapt them on-the-fly to the appropriate process conditions in a self controlled manner. Such systems require complex physical process models and are usually limited to feed and spindle speed adaption during the milling process. This paper introduces a new approach enabling machines during the milling process to learn which parameters lead to a stable process with maximum productivity and to adjust them autonomously. It is shown that this approach enables the machine tool to independently find stable process parameters with maximum productivity.

112617 A linear hybrid model for enhanced servo error pre-compensation of feed drives with unmodeled nonlinear dynamics

Cheng-Hao Chou; Molong Duan; Chinedum E. Okwudire ***[CIRP Annals, v 70, n 1, 2021, Starting Page 301, Pages 4]*** Servo error pre-compensation (SEP) is commonly used to improve the accuracy of feed drives. Existing SEP approaches often involve the use of physics-based linear models (e.g., transfer functions) to predict servo errors, but suffer from inaccuracies due to unmodeled nonlinear dynamics in feed drives. This paper proposes a linear hybrid model for SEP that combines physics-based and data-driven linear models. The proposed model is shown to approximate nonlinearities unmodeled in physics-based linear models. In experiments on a precision feed drive, the proposed hybrid model improves the accuracy of servo error prediction by up to 38% compared to a physics-based model.

112618 Active damping of chatter in the boring process via variable gain sliding mode control of a magnetorheological damper

Mostafa K. A. Saleh; Abasin Ulasyar; Ismail Lazoglu ***[CIRP Annals, v 70, n 1, 2021, Starting Page 337, Pages 4]*** In this article, a sliding mode control of a magnetorheological fluid damper is presented for active damping of chatter in the boring process for the first time. A boring bar is integrated with an in-house developed magnetorheological fluid damper system. The variable gain super twisting sliding mode control algorithm is designed and implemented for suppressing the chatter in the boring process. Simulations of the controller show its fast response and robustness against disturbances and parametric uncertainties. Validation cutting tests performed under various machining conditions showed that the stability limit can be increased significantly with the sliding mode control of the magnetorheological fluid damper.

PRECISION ENGINEERING AND METROLOGY

112619 CNC table based compensation of inter-axis and linear axis scale gain errors for a five-axis machine tool from symbolic variational kinematics

Sareh M. Esmaeili; J.R.R. Mayer ***[CIRP Annals, v 70, n 1, 2021, Starting Page 439, Pages 4]*** A compensation lookup tables (LUTs) scheme is

programmed using a CNC's indigenous LUTs capability to virtually correct geometric error parameters of a five-axis machine tool. Using variational kinematics, the geometric errors are forward propagated to the tool tip and the required axis command corrections are obtained in closed form by inverse kinematics. 40 lookup tables and multiplication and summation functionalities compensate ten inter-axis errors and three linear positioning gain errors. Validation tests on a wCAYFXZt topology machine with a 45° angle between the C- and A-axis show significant reductions in dominant geometric errors and a 79% improvement in volumetric errors.

112620 Novel six-axis robot kinematic model with axis-to-axis crosstalk
S. Ibaraki; K. Fukuda; M. M. Alam; S. Morita; H. Usuki; N. Otsuki; H. Yoshioka ***[CIRP Annals, v 70, n 1, 2021, Starting Page 411, Pages 4]*** Conventionally, the volumetric error compensation of six-axis robots is mostly based on a kinematic model with position and orientation errors of the rotary axis average lines, known as Denavit–Hartenberg (D–H) parameters. This study proposes a novel kinematic model with angular positioning deviation of each rotary axis, modeled as a function of the command angle and rotation direction. The error motions of one rotary axis can be dependent on the angular position of other axes owing to changes in the moment of inertia or center of gravity. The prediction accuracy of the proposed model was experimentally evaluated. Compensation experiments showed a significant reduction in the static volumetric error over the entire workspace.

112621 A novel direct drive electromagnetic XY nanopositioning stage
Zhiwei Zhu; Li Chen; SuetTo ***[CIRP Annals, v 70, n 1, 2021, Starting Page 415, Pages 4]*** To overcome the inherent limitation of existing nanopositioning stages running in hundreds of micrometres, a novel normal-stressed electromagnetic actuator is developed to construct a direct drive XY nanopositioning stage, which features a contactless dual-axial actuation with a relatively high force density, a loosely-constrained stroke, and a monolithic magnetic circuit. Assisted by the established model, the mechanical-electromagnetic parameters for the stage are determined with a further verification through both finite element analyses and experimental tests. By combining a PID-based and a parallel resonant controller, the control system for the stage is constructed, which is then demonstrated by ultra-precisely tracking a Lissajous trajectory.

112622 Position sensor for active magnetic bearing with commercial linear optical encoders
MathiasTantau; Paul Morantz; Paul Shore ***[CIRP Annals, v 70, n 1, 2021, Starting Page 419, Pages 4]*** Active magnetic bearings are used in a number of applications but their disadvantage is the high asynchronous error due to sensor noise amplification. In this paper a new radial position sensor for active magnetic bearings (AMB) based on linear optical encoders is presented. A commercial encoder scanning head faces a round scale with concentric, coplanar lines on its face. Because such a scale is not readily available, it is made by high precision micro machining and different options are compared. In experiments a measurement noise of 3.5 nm at 10 kHz bandwidth is achieved. In addition, a magnetic bearing is built to demonstrate the sensor in closed-loop.

112623 Statistics-based decision rules for the ISO 10360 series of standard tests
Stefano Petrò; Giovanni Moroni ***[CIRP Annals, v 70, n 1, 2021, Starting Page 423, Pages 4]*** Verification tests defined in the ISO 10360 series of standards guarantee that coordinate measuring systems (CMS) have consistent performance. The development of these tests is focused on practical industrial applicability. All tests are based on multiple measurements of probing points. This gives the tests a statistical nature. As each measurement is treated separately and must conform to the maximum permissible error, a considerable risk of false acceptance/rejection is present. An approach based on a statistical model of the test is proposed instead. The approach can manage customer and producer risks in a way that is consistent with ISO/IEC GUIDE 98–4.

112624 Tooth flank approximation with root point iteration – potentials and limits in gear metrology
Andreas Fischer; Axel von Freyberg; Dirk Stöbener ***[CIRP Annals, v 70, n 1, 2021, Starting Page 427, Pages 4]*** Gear production demands high-precision metrology, for which a holistic evaluation approach of the geometric data is proposed to overcome current restrictions. The holistic

approximation with integrated partitioning and iterative root point calculation can cope even with modified flanks and is validated for gear parameter estimation with systematic deviations <0.2 µm. Apart from low signal-to-noise-ratio cases, where the approximation suffers from the multidimensionality of the optimization, the accuracy of standard evaluation procedures is achieved. Furthermore, holistic approximation is able to perform the required mathematical separation of the integral geometric elements of a tooth flank automatically when determining unknown gear parameters.

112625 Machine tool integrated inverse multilateration uncertainty assessment for the volumetric characterisation and the environmental thermal error study of large machine tools

F. Egaña; J. A. Yagüe-Fabra; U. Mutilba; S. Vez ***[CIRP Annals, v 70, n 1, 2021, Starting Page 435, Pages 4]*** Thermal effects on an uncontrolled manufacturing environment are the main barrier for accurate large machine tools. Internal and external heat sources combined with different expansion coefficients result in a constant thermal drift of the machine's structural loop. Thus, a characterisation method remains a challenge. This work presents a new methodology for the uncertainty assessment of a Machine Tool Integrated Inverse Multilateration approach where the ambient temperature variation is demonstrated to be a major uncertainty contributor. An "a priori" Monte-Carlo simulation-based research allows developing an appropriate measurement strategy for the use of the proposed approach minimising the influence of thermal issues.

112626 Autonomously triggered model updates for self-learning thermal error

Nico Zimmermann; Mario Breu; Josef Mayr; Konrad Wegener ***[CIRP Annals, v 70, n 1, 2021, Starting Page 431, Pages 4]*** The presented method significantly increases the self-optimization ability of thermal error compensation models by triggering on-machine measurements when unknown thermal conditions occur. These conditions, which are not represented by the training data of the compensation models, are identified by a novelty detection approach based on one-class support vector machines. The results show that the autonomously triggered on-machine measurements applied to a 5-axis machine tool overcome the trade-off between precision and productivity for thermal error compensation. The non-productive time to detect an exceedance of the predefined tolerances is reduced by 78% without significantly reducing the precision of the thermal error compensation.

PRODUCTION SYSTEMS AND ORGANIZATIONS

112627 Platform and direct exchange-based mechanisms for resource sharing in distributed manufacturing: a comparison

Ádám Szaller; Botond Kádár *[CIRP Annals, v 70, n 1, 2021, Starting Page 407, Pages 4]*

The operation of production facilities is shifting from centralized organizations towards decentralized networks. The paper investigates and compares alternative mechanisms for resource sharing in distributed manufacturing. Specifically, with the same underlying assumptions, a platform and a direct exchange-based model are presented and examined. The models have in common that resource assignment decisions are made ultimately by the autonomous facilities, also based on trust they maintain towards each other. Agent-based simulation is used to compare the two mechanisms with respect to utilization rate, service level and communication load. The findings can be applied in the design of crowdsourced manufacturing platforms.

112628 Mobile-agents based hybrid control architecture—implementation of consensus algorithm in hierarchical control mode

Guillaume Demesure; Hind Bril El-Haouzi; Benoit Iung ***[CIRP Annals, v 70, n 1, 2021, Starting Page 384, Pages 4]*** The concept of autonomous mobile robots has already been implemented in some manufacturing fields; however, it is not yet effective in the field of shop floor logistics because issues linked to decision-making control remain. A contribution to this challenge is proposed in this study through an innovative hybrid control architecture in which mobile agents adapt their degree of autonomy by switching between hierarchical and heterarchical operating modes to dynamically face disturbances and absorb them. The focus is on operational manufacturing control and the navigation layer in hierarchical mode, where a consensus control algorithm is

elaborated to reduce the instability with respect to the detailed schedule. Simulation results are provided to demonstrate the effectiveness of the proposed consensus algorithm.

112629 An agile production network enabled by reconfigurable manufacturing systems
Bogdan I Epureanu; Xingyu Li; Aydin Nassehi; Yoram Koren ***[CIRP Annals, v 70, n 1, 2021, Starting Page 403, Pages 4]*** Emergencies, and efforts to address them, create disruptions to local and global supply chains and surges in demand of emergency resources, which substantially affect global production. Reconfigurable manufacturing systems are promising solutions to improve flexibility and to reduce the effort needed to adapt supply chains and production networks to fit a perturbed environment. This paper proposes a method for coordination of reconfigurable manufacturing resources from multiple enterprises to structure ad-hoc production networks for critical products required in emergencies. Network optimization models and interaction algorithms are integrated to evolve the production network through synchronous machine-level and network-level reconfiguration driven by data.

112630 High-accuracy pose estimation method for workpiece exchange automation by a mobile manipulator
Yuta Oba; Kota Weaver; Anand Parwal; Hideki Nagasue; Makoto Fujishima ***[CIRP Annals, v 70, n 1, 2021, Starting Page 357, Pages 4]*** A mobile manipulator that consists of a robot manipulator and an Automated Guided Vehicle (AGV) was developed to automate transporting and exchanging workpieces for machine tools. Despite less accurate positioning of the AGV, positioning accuracy of 1 mm must be realized during attachment and removal of workpieces. To compensate for an error of the AGV, this paper proposes a novel method of high-accuracy pose estimation using a fiducial marker. Experimental results show that workpiece exchange can be automated with high reliability even though a clearance between a chuck and workpieces in diameter is as small as 1 mm.

112631 Design of reconfigurable machining lines: A novel comprehensive optimisation method
Olga Battaïa; Alexandre Dolgui; Nikolai Guschinsky ***[CIRP Annals, v 70, n 1, 2021, Starting Page 393, Pages 6]*** We present a novel comprehensive optimization model for designing reconfigurable machining lines. Due to the proposed fine mathematical modelling, it is possible to optimize simultaneously the whole set of machines and machining modules as well as their cutting parameters, their configuration that will be used for processing of each part and part position at each machine. The experimental results show that the proposed optimization approach substantially outperforms the existing heuristic design method and therefore it can be used by the designers in order to reduce the total system cost and improve the efficiency of reconfigurable machining lines.

112632 A model-based Digital Twin to support responsive manufacturing systems
Maria Chiara Magnanini; Tullio A. M. Tolio ***[CIRP Annals, v 70, n 1, 2021, Starting Page 353, Pages 4]*** Manufacturing systems are subject to continuous changing conditions, which are due both to external reasons (e.g. changing demand) and to the natural system evolution, (e.g. machine degradation, operators' upskilling). At tactical level, production engineers are challenged to continuously improve the system performance. At strategical level, the manufacturing company must monitor the system status and proactively identify reconfiguration actions to ensure system fitness to the evolving competitive scenario. A novel Digital Twin based on an analytical model for performance evaluation of manufacturing system embedding evaluation of joint parameter variations is introduced. In particular this work concentrates on how tactical decision makers can benefit from an integrated system model. The method is proved in a real industrial case in the railway sector.

112633 Auction-based production planning considering operators' skill criterion
Toshiya Kaihara; Daisuke Kokuryo; Nobutada Fujii; Daichil taya ***[CIRP Annals, v 70, n 1, 2021, Starting Page 399, Pages 4]*** With the penetration of the IoT and data science, new manufacturing initiatives are accelerating. However, conventional approaches have emphasized the use of machine-based data. A need exists to realize more productive work styles considering the abilities and physical condition of operators. In this paper, we propose a production planning method to allocate machines and operators with different

skill level optimally. After formulating a combinatorial auction mechanism, developing a schedule that minimizes the total production cost, we verify that the proposed method can realize human-centered production planning by combining the schedules with different evaluation indices.

112634 Multi-scale modelling of manufacturing systems using ontologies and delta-lenses

Walter Terkaj; Qunfen Qi; Marcello Urgo; Paul J. Scott; Xiangqian Jiang ***[CIRP Annals, v 70, n 1, 2021, Starting Page 361, Pages 4]*** The adoption of digital technologies in manufacturing enables intelligent dynamic control approaches, at the cost of increased design complexity. In this paper, ontologies and delta-lenses are exploited to enable multi-scale models of a manufacturing system to map digital models at different scales and let data flow according to the level of fidelity. A workflow is designed to assess the capability of models with a lower level of details to approximate the behaviour of the original system, through the application of a hybrid delta-lens. The approach is illustrated with a user case and applied to an industrial case, aiming at deciding the positions of sensors in an assembly line.

112635 Semi-Double-loop machine learning based CPS approach for predictive maintenance in manufacturing system based on machine status indications

Goran D.Putnik; Vijaya Kumar Manupati; Sai Krishna Pabba; Leonilde Varela; Francisco Ferreira ***[CIRP Annals, v 70, n 1, 2021, Starting Page 365, Pages 4]*** The paper presents two original and innovative contributions: 1) the model of machine learning (ML) based approach for predictive maintenance in manufacturing system based on machine status indications only, and 2) semi-Double-loop machine learning based intelligent Cyber-Physical System (I-CPS) architecture as a higher-level environment for ML based predictive maintenance execution. Considering only the machine status information provides rapid and very low investment-based implementation of an advanced predictive maintenance paradigm, especially important for SMEs. The model is validated in real-life situations, exploring different learning algorithms and strategies for learning maintenance predictive models. The findings show very high level of prediction accuracy.

112636 Incremental discovery of new defects: application to screwing process monitoring

Mahmoud Ferhat; Mathieu Ritou; Philippe Leray; Nicolas Le Du ***[CIRP Annals, v 70, n 1, 2021, Starting Page 369, Pages 4]*** Defect detection by in-process monitoring plays a key role in the traceability and optimization of production. Many fault detection algorithms are trained on known faults. However, industrial data is generally unlabeled and certain faults are unknown or missing in the training dataset. This paper presents an original approach for the incremental discovery of new manufacturing defects, by Bayes rule and distance rejection. Rejects are analyzed periodically to determine the possible appearance of new defect cluster among them. Visualization then supports the cluster interpretation by a manufacturing expert. The approach was successfully applied to a screwing database from automotive industry.

112637 Text mining for AI enhanced failure detection and availability optimization in production systems

Fazel Ansari; Linus Kohl; Jakob Giner; Horst Meier ***[CIRP Annals, v 70, n 1, 2021, Starting Page 373, Pages 4]*** The success of data-driven maintenance is strongly dependant on effective use of AI and multi-structured data sources. Introducing and integrating an AI-enhanced methodology in reliability-centred maintenance study of complex production systems leads to reducing failure rates and optimizing availability. In manufacturing enterprises, information about machine failures and expert knowledge are often stored in digital shift books (DSB). This paper introduces a transferable and scalable AI-enhanced methodology for DSB in automotive industry, which enhances Overall Equipment Efficiency (OEE) by optimizing availability through reducing the Mean Failure Detection Time (MFDT). Experimental investigations in the use-case suggest an OEE increase by over 5%.

112638 Integrated process-system modelling and control through graph neural network and reinforcement learning

Jing Huang; Jianjing Zhang; Qing Chang; Robert X. Gao ***[CIRP Annals, v 70, n 1, 2021, Starting Page 377, Pages 4]*** Modern manufacturing systems are becoming increasingly complex, dynamic, and connected, and their performance is being affected by not only their constituent processes

but also their system-level interactions. This paper presents an integrated modelling method based on a graph neural network (GNN) and multi-agent reinforcement learning (MARL) collaborative control for adjusting individual machining process parameters in response to system- and process-level conditions. The structural and operational dependencies among process machines are captured with a GNN. Iteratively trained with MARL, machines learn to adaptively control local process parameters, e.g., machining speed and depth of cut, while achieving the global goal of improving production yield.

112639 Self-adjusting multi-objective scheduling based on Monte Carlo Tree Search for matrix production assembly systems
Nicole Stricker; Andreas Kuhnle; Constantin Hofmann; Patrick Deininger ***[CIRP Annals, v 70, n 1, 2021, Starting Page 381, Pages 4]*** As a response to the low utilization of production lines in the context of an increasing number of product variants with significant differences in cycle times, line-less modular assembly concepts known as matrix production have evolved. Whilst the many degrees of freedom a matrix production offers provide different ways to react to disturbances and balance utilization, it also increases the complexity for scheduling exponentially. For real-time scheduling high solution quality and high efficiency are needed. This paper contributes a multi-objective scheduling approach based on Monte-Carlo Tree Search that self-adjusts to the scheduling problem to improve solution quality and execution time.

112640 A priori performance assessment of line-less mobile assembly systems
Robert H. Schmitt; Guido Hüttemann; Sören Münker ***[CIRP Annals, v 70, n 1, 2021, Starting Page 389, Pages 4]*** Present assembly systems are often based on rigid, line-based approaches and are hindered in their reconfiguration capability. Line-less Mobile Assembly Systems (LMAS) are a novel approach for assembly organization. They improve flexibility through mobile resources, permitting spatiotemporal freedom in scheduling and resource assignment. This paper presents a method for a priori assessment of LMAS during the early stages of the assembly system design process. The method applies a modified, extended mean value analysis to a closed queuing network representation of LMAS to estimate performance. The method is validated model analysis and comparison on two use cases indicating plausible model behavior.

112641 An intelligent agent-based architecture for resilient digital twins in manufacturing
Rok Vrabič; John Ahmet Erkoyuncu; Maryam Farsi; Dedy Ariansyah ***[CIRP Annals, v 70, n 1, 2021, Starting Page 349, Pages 4]*** Digital twins (DTs) offer the potential for improved understanding of current and future manufacturing processes. This can only be achieved by DTs consistently and accurately representing the real processes. However, the robustness and resilience of the DT itself remain an issue. Accordingly, this paper offers an approach to deal with uncertainty and disruptions, as the DT detects these effectively and self-adapts as needed to maintain representativeness. The paper proposes an intelligent agent-based architecture to improve the robustness (including accuracy of representativeness) and resilience (including timely update) of the DT. The approach is demonstrated on a case of cryogenic secondary manufacturing.

SURFACES

112642 Wood-based flexible graphene thermistor with an ultra-high sensitivity enabled by ultraviolet femtosecond laser pulses
Young-Jin Kim; Truong-Son Dinh Le; Han Ku Nam; Dongwook Yang; Byunggi Kim ***[CIRP Annals, v 70, n 1, 2021, Starting Page 443, Pages 4]*** Real-time monitoring of temperatures over extensive free-form surfaces of precision machines, smart products, and human bodies with a high resolution can provide invaluable information for smart manufacturing, Internet-of-Things, and advanced healthcare. However, traditional rigid thermistors could not be conformally attached on arbitrarily curved surfaces. In this study, a high-resolution flexible graphene thermistor is demonstrated by transforming wood into laser-induced-graphene via ultrafast laser pulses and subsequent transfer to flexible substrates. This thermistor provides a 16-times higher resolution than the state-of-the-art counterparts which was applied to precise temperature monitoring of an electric motor, glass cup, and human hand.

112643 Holistic multi-scale model of contact stiffness considering subsurface deformation
Daisuke Kono; Yuki Jorobata; Hiromi Isobe ***[CIRP Annals, v 70, n 1, 2021, Starting Page 447, Pages 4]*** The stiffness of mechanically fastened joints influences static and dynamic characteristics of machine tools. The conventional contact stiffness model considers only the deformation of roughness asperities based on uncertain topographic parameters. This study presents a holistic contact stiffness model considering the subsurface deformation and avoiding assumptions of topographic characteristics, which tend to introduce uncertainty. Subsurface deformation was also investigated via stress distribution measurements and finite element simulations. Using the proposed model, the stiffness of jointed parts was estimated with an error <15%. Moreover, the subsurface deformation's influence on contact surface design was discussed.

112644 Uncertainty evaluation of small wear measurements on complex technological surfaces by machine vision-aided topographical methods
Gianfranco Genta; Giacomo Maculotti ***[CIRP Annals, v 70, n 1, 2021, Starting Page 451, Pages 4]*** Wear assessment is an essential feature within the Industry 4.0 framework to optimise machining and control durability of components made of innovative materials. Complex topographies often make wear measurement a challenging task. Literature tackles it by comparing the final topography with the unworn state, either by empirical methods or by registration via machine vision algorithms. This paper develops a framework to evaluate the related measurement uncertainty, so far lacking, by exploiting instruments metrological characteristics and statistical modelling. This framework is applied to an industrially relevant case study to compare the performances of accredited methods for wear measurement available in literature.

112645 Closed-loop form error measurement and compensation for FTS freeform machining
Zhen Tong; Wenbin Zhong; Wenhan Zeng; Xiangqian Jiang ***[CIRP Annals, v 70, n 1, 2021, Starting Page 455, Pages 4]*** To improve fast-tool-servo (FTS) freeform machining accuracy, a closed-loop FTS system is developed with functional modules including toolpath generation, on-machine surface measurement, machining error mapping and compensation. A surface characterisation toolkit was identified and integrated into the processing chain to realise in-process inspection and fast quality control. Surface sampling and reconstruction strategies and robust surface filtration algorithms are adapted to regulate the data flow for both freeform surface characterisation and the optimisation of compensation toolpath from machined error maps. The performance of the developed system is demonstrated by successfully generating three typical freeform surfaces with improved form accuracy by 50%.

112646 Surface texturing to enhance sol-gel coating performances for biomedical applications
AndreaGhiotti; Rachele Bertolini; Luca Pezzato; Enrico Savio; Mara Terzini; Stefania Bruschi ***[CIRP Annals, v 70, n 1, 2021, Starting Page 459, Pages 4]*** The paper proposes a novel approach to increase the performances of a sol–gel coating for biomedical applications. In particular, ultrasonic vibration-assisted turning in combination with cryogenic cooling is explored for the first time to generate a complex and isotropic texture more prone to be coated, and, in turn, less corrosion susceptible compared to the corresponding surfaces generated through conventional machining. A comprehensive characterization of the generated surfaces before and after coating gives new insights for understanding the mechanisms of increased performances, which were validated on bones fixation pins.

112647 Surface nanostructuring of bioresorbable implants to induce osteogenic differentiation of human mesenchymal stromal cells
Marco Sorgato; Enrica Guidi; Maria Teresa Conconi; Giovanni Lucchetta ***[CIRP Annals, v 70, n 1, 2021, Starting Page 463, Pages 4]*** Surface nanostructuring of bioresorbable polymers is a promising solution for tissue regeneration therapies, as such nanostructured implants non-toxically degrade after producing localized and prolonged stimuli. In this work, a process chain for the fabrication of bioresorbable polymer implants was developed and validated. The implants present surface arrays of nanopillars whose main design parameters were optimized to induce the osteogenic differentiation of human stem cells. In vitro and in vivo cell experiments provided evidence for the potential application in tissue regeneration and revealed that nanopillars' diameter, height, and spacing need to be independently optimized to effectively promote osteogenic differentiation.

Patent Abstracts on Pump Manufacturing

CN210790270 (U) 19-Jun-20

CYLINDRICAL GRINDING MACHINE FOR WATER PUMP MANUFACTURING

Inventor: LIU YUAN; WANG TONGHAN

Applicant: SHENYANG HUIERXIN PUMP MFG CO LTD

The utility model discloses a cylindrical grinding machine for water pump manufacturing. Including a base, the top end of the base is fixedly connected with a grinding machine body. The bottom end ofthe base is fixedly connected with two supporting bases. A control cavity is formed in the base. A through groove is formed in the inner wall of the top end of the control cavity, the through groove is communicated with the top end of the base, clamping rods are symmetrically arranged in the through groove, the top ends of the clamping rods extend to the upper portion of the base, the bottom endsof the clamping rods are connected with a connecting plate located in the control cavity, and a sliding block is fixedly connected to the bottom end of the connecting plate. The utility model relatesto a cylindrical grinding machine for water pump manufacturing. The clamping device is simple in structure and convenient to operate, the manufacturing cost is reduced, the using effect is better, the friction force between the clamping rods and the machining parts is increased, meanwhile, the two clamping rods are prevented from shaking relatively, and the stability of part machining is guaranteed.

CN209887465 (U) 03-Jan-20

PISTON ROD FIXING DEVICE FOR SLURRY PUMP MANUFACTURING

Inventor: WEI FUZHI; LIU ZHIZHEN; HAN HUALIN; ZHENG JIFENG; XUE JIALIN; LIU YONGMING; WANG YUANYUAN

Applicant: SHANDONG YOUKESI PETROLEUM EQUIPMENT CO LTD

The utility model discloses a piston rod fixing device for slurry pump manufacturing, relates to the technical field of slurry pump manufacturing, and aims at solving the problem that an existing piston rod fixing device cannot clamp and fix piston rods with different lengths and diameters in the using process. A sliding rail is arranged on the upper surface of the operation table. A supporting rod is arranged above the sliding rail; a sliding groove is formed in the lower surface of the supporting rod. The supporting rod is slidably connected with a sliding rail on the upper surface of the operation table through a sliding groove; a fixing mechanism is arranged on the upper surface of the supporting rod; a fixing bin is arranged in the fixing mechanism; two clamping plates are arranged inthe fixing bin, through holes are formed in the outer walls of the two sides of the fixing mechanism, internal threads are arranged on the inner walls of the through holes, the internal threads and the through holes are of an integrated mechanism, an adjusting handle is arranged on one side of each through hole, and a transmission rod is arranged on the outer wall of one side of each adjusting handle.

CN110053065 (A) 26-Jul-19

WORKPIECE TRANSFER MECHANICAL HAND FOR WATER PUMP MANUFACTURING AND ASSEMBLY

Inventor & Applicant: XU JIABIN

The invention provides a workpiece transfer mechanical hand for water pump manufacturing and assembly. The workpiece transfer mechanical hand comprises a rack, a transmission belt transmission mechanism and electric clamping claws, wherein the top end surface of the rack is in sliding connection to one group of beams; the upper end surfaces of the beams are in sliding connection to one group of support plates; the front end surfaces of the support plates are in sliding connection to one group of lifting stand columns; the lower end surfaces of the lifting stand columns are axially connected with one group of working heads; and four surfaces of the outer sides of the working heads are fixedly connected with one group of electric clamping claws and are in sliding connection to one group of electric clamping claws. The electric clamping claws capable of adjusting positions are adopted, and the distance between two electric clamping claws is adjusted to conveniently clamp workpieces of different sizes, so that the range of application of the mechanical hand is increased, use frequency of the mechanical hand is improved, and a vacancy rate is reduced; and while the process or the product model is changed, the mechanical hand still can adapt very well, so that adjustment is convenient, and adaptation of the mechanical hand is improved.

CN109648408 (A) 19-Apr-19

A HIGH-PRACTICABILITY CYLINDRICAL GRINDING MACHINE FOR WATER PUMP MANUFACTURING

Inventor & Applicant: CHEN ZHIPING

The invention discloses a high-practicability cylindrical grinding machine for water pump manufacturing. The device comprises a base. A grinding machine body is welded to the top of the base. A controller is arranged on the left side of the base, two fixing blocks are arranged in an inner cavity of the base, the tops and the bottoms of the front faces of the two fixing blocks are movably connected with first connecting rods and second connecting rods through first rotating shafts correspondingly, and the ends, away from the fixing blocks, of the two first connecting rods and the two second connecting rods are movably connected through second rotating shafts. According to the embodiment, the controller, the fixing blocks, the first connecting rods, the second connecting rods, positive and negative motors, a wheel disc, a sliding mechanism, a limiting device, a supporting device and clamping blocks are matched with one another, thus solving the problem that an existing cylindrical grinding machine is low in practicability; different clamping devices do not need to be replaced when the cylindrical grinding machine is used, and therefore a large amount of time is saved for a user, thewater pump manufacturing speed is increased, and the user can use the cylindrical grinding machine conveniently.

CN107931792 (A) 20-Apr-18

WATER PUMP MANUFACTURING TECHNOLOGY BASED ON ACTIVE WELDING METHOD

Inventor: MO CHENGZHI; LIANG DONGXIAN; LIANG GUANGLIANG; YANG JIYOU; PENG SHAOHUA; PAN MINGXING; MO JIJIAO

Applicant: GUANGDONG WINNING PUMPS IND CO LTD

The invention relates to a water pump manufacturing technology based on an active welding method. The manufacturing technology comprises the following steps of 1) coating the surface of a joint to bewelded with an active welding agent; and 2) carrying out welding by adopting a TIG welding technology. According to the manufacturing technology, the surface of the joint to be welded is firstly coated with a thin layer of the active agent, and then welding is carried out; and aiming at a stainless steel water pump, active TIG welding is adopted, the welding penetration of active TIG welding can reach 2-3 times of the welding penetration of traditional TIG welding, single-surface welding and double-surface forming of a plate butt joint can be realized, the heat affected zone is small, the welding efficiency is high, the welding cost is low, and the productivity can be greatly improved. The water pump manufacturing technology based on the active welding method has the advantages that the welding penetration can be remarkably increased, active welding can be used for all-position welding, complete welding can be guaranteed, and operation is simple; and after the active agent is used, thewelding deformation can be reduced, the welding seam tissue and the performance of active TIG welding are superior to the welding seam tissue and the performance of traditional TIG welding, and the comprehensive performance of the joint can meet the standard requirements.

CN207448058 (U) 05-Jun-18

CYLINDRICAL GRINDER FOR WATER PUMP MANUFACTURING THAT PRACTICALITY IS STRONG

Inventor & Applicant: CHEN ZHIPING

The utility model discloses a cylindrical grinder for water pump manufacturing that practicality is strong, the on-line screen storage device comprises a base, the top welding of base has the grinding machine body, the left side of base is provided with the controller, the inner chamber of base is provided with two fixed blocks, two positive tops of fixed block and bottom through first pivot respectively swing joint have head rod and a second connecting rod, the one end that the fixed block was kept away from to two head rods and two second connecting rods is all through second pivot swing joint. The utility model discloses a current low problem of cylindrical grinder machine practicality has been solved to the mutually supporting of device control ware, fixed block, head rod, second connecting rod, forward and reverse motor, rim plate, slide mechanism, stop device, strutting arrangement and fixture block, the cylindrical grinder different chucking device that does not need to be changed when using to practice thrift a large amount of time of user, accelerated water pump manufacturing's speed, thereby made things convenient for user's use.

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