

International Conference on Progress in Digital and Physical Manufacturing



ProDPM'19

Book of Abstracts

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Editors

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Preface

The “Progress in Digital and Physical Manufacturing” book contains keynotes and papers presented at the first International Conference on Progress in Digital and Physical Manufacturing (ProDPM'19), organized by the School of Technology and Management (ESTG) of the Polytechnic Institute of Leiria (IPLEiria), from the 2nd to the 4th of October 2019.

This international conference aims to provide a major international forum for the scientific exchange of multi-disciplinary and inter-organisational aspects performed by academics, researchers and industrial partners in order to exchange ideas in the field of digital and physical manufacturing and related areas. It represents a significant contribution to the current advances in industrial digital and physical manufacturing issues as it contains topical research in this field.

The ProDPM'19 conference expects to foster networking and collaboration among participants to advance the knowledge and identify major trends in the field. The conference addresses to industrial challenges focused on current market demands and actual technological trends, such as mass customization, new business and industrial models or predictive engineering. Its contribution in science and technology developments leads to more suitable, effective and efficient products, materials and processes, generating added-value for the Industry and promoting the awareness of the role and importance of the digital and physical manufacturing development in the society.

This book is, therefore, an essential reading for all of those working on digital and physical manufacturing, promoting better links between the academia and the industry. The conference papers will cover a wide range of important topics like additive manufacturing, biomanufacturing, advanced and smart manufacturing technologies, rapid tooling, micro-fabrication, virtual environments, simulation and 3D CAD and data acquisition, materials and collaborative design.

We are deeply grateful to the keynote speakers, authors, participants, reviewers, the International Scientific Committee, Session chairs, student helpers and Administrative assistants, for contributing to the success of this conference.

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Invited Lectures

The conference had the privilege of including in the scientific program the following world renown speakers:

Alain Bernard, École Centrale de Nantes, France

Prof. Alain Bernard, 1960, graduated in 1982, PhD in 1989, was Associate-Professor, from 1990 to 1996 in Centrale Paris. In 1996, he got a Full Professor position in University Nancy I, in the “Integrated Design and Manufacturing” team, and moved to Centrale Nantes in 2001 where he was Dean for Research (2007-2012). He is researcher in Digital Sciences Laboratory (LS2N-UMR CNRS 6004) in the “Systems Engineering” (IS3P) team. Recent research topics are KBE applied to computer-aided decision making systems for additive manufacturing. He is Vice-President of the French Additive Manufacturing Association (AFPR), CIRP Fellow and Member of the French National Academy of Technologies.

Bruno Romero, HP Inc.

Bruno Romero is the Iberia 3D Printing Applications Engineer of HP’s 3D Printing Jet Fusion Business. This position includes supporting Spain and Portugal sales team and transferring HP’s 3D Printing knowledge to partners and customers. Main team is based in Barcelona, Spain. Bruno joined HP in 2017 in the 3D Printing Sales organization and Applications Development team. In this position he is connected to Business Development, Sales, Marketing and R&D teams but also to the WW Applications Development team.

Carlos Mougueira, TRUMPF, Portugal

He has been employee at TRUMPF Portugal since 2015 as a sales engineer responsible for Laser Division in Aerospace, Automotive and Metalworking sectors. He graduated in Mechatronic Engineering from Universidade de Évora and has gained experience in Laser Technology and Systems in Portuguese and Spanish industries during more than 10 years.

Eujin Pei, Brunel University, UK

Dr. Eujin Pei is the Director for Postgraduate Research and Programme Director for the BSc Product Design and BSc Product Design Engineering programmes at Brunel University London. He is a Chartered Engineer (CEng) and a Technological Product Designer (CTPD) with the Institution of Engineering Designers. He is the Convenor of the International Organization for Standardization ISO/TC261/WG4 committee that is responsible for Data Transfer and Design Standards for Additive Manufacturing; and Chair for the British Standards Institute BSI/AMT/008 for Additive Manufacturing. His research interest centres on Functionally Graded Additive Manufacturing and 4D Printing.

Igor Drstvensek, University of Maribor, Slovenia

Prof. Dr. Igor Drstvensek is lecturer at University of Maribor, Faculty of Mechanical Engineering, where he is lecturing Production technologies and Maintenance. His research work in last 15 years is dedicated to Additive Manufacturing and especially to Medical Applications of Additive

Manufacturing. He is the Head of the Additive Manufacturing Laboratory at the Faculty of Mechanical Engineering, University of Maribor. In 2006 he has initiated the first implant production by use of layered technologies in Slovenia and in last 10 years conducted 30 projects of cranial and maxillofacial implant production that ended with successful implantation of 27 PMMA and 3 Ti64 implants, owning several patent applications.

Inma Vazquez, Stratasys

Inma Vazquez is Channel Manager France and Iberia for Stratasys. She is one of the European women with more experience in additive manufacturing. Worked 11 years in 3DSystems, 2 years in HP division 3Dprinting and 4 years in Stratasys as Sales Manager. Speaks 6 languages and is an expert in introducing new products in several European markets focusing on applications to improve manufacturing processes in various industries.

Jaume Homs, HP Inc., Spain

Jaume Homs is the Iberia Channel and Sales Manager of HP's 3D Multi Jet Fusion Business. This position includes Spanish and Portugal responsibility of channel recruitment, management and sales of HP's 3D Printing Multi Jet Fusion line of solutions. Main team is based in Barcelona, Spain. Jaume joined HP in 2002 in the R&D organization as a software engineer and project manager. Since then he has held different positions in R&D, Marketing, Sales and Business Management. Prior to his current position, Jaume was the Indigo Commercial Business Manager for Europe Middle East and Africa. Previously, he had a sales position in Iberia in the Indigo business and prior to that in the Designjet business. Jaume has a proven track overachieving all business goals. Jaume holds a Master in Computer Science from Universitat Autònoma de Barcelona, a Master in IT Management and an Executive MBA by la Salle.

Joana de Medina, Stratasys

Joana Mayeur de Medina is a Chemical Engineer with over 20 years' experience in technical sales and key account management. Born in Rio de Janeiro, Joana has moved to France in 2001 and has built a successful career growing businesses at different levels for companies such as ExxonMobil, Xerox, Canon, Experian and HP. In 2016, Joana has embraced the challenge of building up the 3D printing business for HP in France. Since 2018 at Stratasys, she is the Strategic Account Manager for France and Iberia, working actively with the main industries to develop and implement additive manufacturing solutions that will transform the Industry.

Marc Dimter, TRUMPF, Germany

Marc Dimter has been an employee at TRUMPF as an industrial tooling manager for additive manufacturing. He graduated in Mechanical Engineering from the University of Stuttgart and specialised in laser material processing and machine tools. Since 1997 he has gained experience in the application of Laser Technology and Additive Manufacturing, and since 2004, has specialized on conformal cooling of mold inserts.

Omar Fergani, Siemens, Germany

Dr. Fergani is a strategic software technology manager at Siemens digital industries software. His main focus is to deliver cutting edge software technology to industrialize additive manufacturing (AM). Some of his topics of interest are print first time right processes, the closed

loop solution to achieve the autonomous machines as well as the smart factory. Previously, he oversaw developing the first AM process simulation to complete Siemens digital twin offering. He is a holder of a Ph.D. in mechanical engineering and a double master's degree in manufacturing and materials from the Georgia Institute of Technology and the Norwegian University of Science and Technology. He is selected as one of the Outstanding Young Manufacturing Engineer and was previously selected as 30 under 30, future leaders of manufacturing by the Society of Manufacturing Engineers.

Paulo Bártolo, University of Manchester, UK

Paulo Bártolo is Professor of Advanced Manufacturing and Head of the Manufacturing Group at the School of Mechanical, Aerospace and Civil Engineering, University of Manchester. He is the University's Industry 4.0 Academic Lead, team leader of the Industry 4.0 societal challenge at Digital Futures and sits on the Management Board of the EPSRC & MRC Centre for Doctoral Training in Regenerative Medicine. He is Professor at the Advanced Manufacturing Group at the Tecnológico de Monterrey, at Nanyang University, and member of CIAUD (at University of Lisbon). He is a Fellow of CIRP, advisor of the Brazilian Institute of Biofabrication and several UK and International Funding Agencies and received a commendation and public recognition from the Portuguese Government. He is the Founding Editor of Virtual and Physical Prototyping Journal and Editor-in-Chief of Biomanufacturing Reviews.

Terry Wohlers, Wohlers Associates Inc., USA

Terry Wohlers is president of Wohlers Associates, Inc., an independent consulting firm he founded 32 years ago. He has authored more than 421 books, articles, and technical papers on product development and manufacturing and has given 155 keynote presentations on five continents. In 2004, Wohlers received an Honorary Doctoral Degree of Mechanical Engineering from Central University of Technology in Bloemfontein, South Africa. In 2005, he became a Fellow of the Society of Manufacturing Engineers (SME). In 2016, he became an adjunct professor at RMIT University in Melbourne, Australia. For 24 years, Wohlers has been a principal author of the Wohlers Report, an annual worldwide publication focused on additive manufacturing and 3D printing.

Ulric Ljungblad, Freemelt

Dr. Ulric Ljungblad is CEO and co-founder of Freemelt. After his PhD at University of Gothenburg, he worked for 10 years in the semiconductor industry. From 2006 he has been working in additive manufacturing focusing on systems development and innovation. He holds more than 20 patents. He co-founded Freemelt in 2017 aiming to launch an open source electron beam AM system to promote much faster development of processing parameters for new metal materials. He worked as R&D manager at Freemelt during the development of the Freemelt ONE system that was launched in 2018 and he became the CEO of Freemelt in 2019.

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HP 3D Printing: Accuracy and Repeatability in Digital Manufacturing

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Abstract:

HP Multi Jet Fusion is a 3D Printing technology with a high rate of penetration into real manufacturing environments. This aspect is pushing HP to deliver products and solutions more robust, more profitable, with higher productivity, and more precise and accurate. Recently, HP has introduced the new printer Jet Fusion 5200 and the software HP 3D Process Control that will allow to produce high volume of parts at the lowest cost and with tolerances matching ISO 286 IT13 grade and repeatability with Cp CpK over 1.

Keywords: Multi jet fusion, Additive manufacturing, Process capacity, OEE

1 Process Capacity and OEE in Digital Manufacturing

1.1 HP Multi Jet Fusion approach to process capacity and OEE

Nowadays there are many 3D Printing technologies available in the market. Each technology presents advantages for certain applications, namely, prototyping, jigs and fixtures or tooling and in some cases true final parts. However, manufacturing final parts in big volumes with consistency, repeatability, part quality and cost effectiveness it is only available for few technologies.

HP's Multi Jet Fusion (MJF), first introduced in 2016, is a technology ready for manufacturing environments capable to compete with plastic injection molding and CNC machining in terms of material properties and isotropy, cost per part and productivity. The factors that increase the breakeven point of MJF vs. injection molding or CNC machining are part size, part design complexity and expected production volume. For instance, a gear of 30 cm³ up to 100,000 units it would be more economic to be manufactured using MJF than with injection molding (Fig. 1). The first HP 3D Printer, Jet Fusion 4200, has proofed the big penetration in several markets and in many of the cases to produce true final parts.

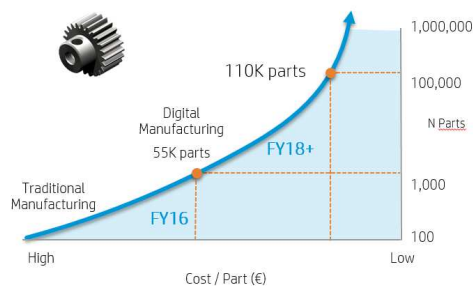


Fig. 1. Cost per Part breakeven point MJF vs. Injection Molding.

Recently HP has introduced a new MJF platform: the HP Jet Fusion 5200. The hardware architecture and several software modules of this 3D Printer have been designed to maximize the accuracy and repeatability of printed parts, while increasing the OEE (overall equipment effectiveness).

In terms of accuracy and repeatability, most of the printers in the market make trade-offs in mechanical properties and achievable dimensional tolerances depending on part orientation, part location on the build

platform resulting in low process capacity (C_p and C_{pK}). Thanks to the software HP 3D Process Control and complex algorithms running from HP's Cloud System, the users are able to create parts with consistent dimensions and tolerances independently of the build location and build after build achieving high process capacity (C_p and C_{pK}).

The OEE is a metric that integrates the tracking and control of the entire end-to-end manufacturing process, enabling the detection of deviations that might appear at any stage of the process. The HP 3D Printers are designed to bring the highest OEE among the printers in the market.

1.2 HP 3D Process Control

HP 3D Process Control it is a cloud-based software developed by HP that will allow to print parts consistently with a tolerance in the range of grade IT13- IT14 according to ISO 286 (Fig. 2).

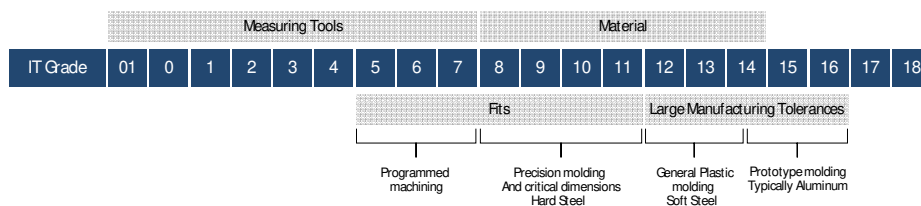


Fig. 2. ISO 286 IT grades description.

Conversationally IT13-IT14 grades are well known tolerance ranges achievable by injection molding with aluminum molds and soft steel molds.

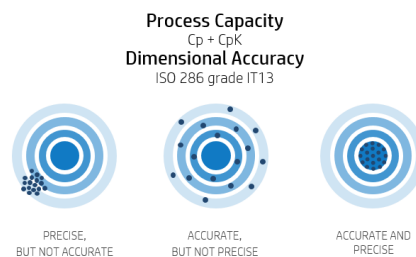


Fig. 3. Visual description of Precision and Accuracy.

Additionally, HP 3D Process Control enables dimensions consistency across the build and build after build by defining a C_p/C_{pK} for a given set of critical dimensions in a given part.

Basically, 3D Process Control operates creating a profile of the build platform compensating the dissimilar material contractions all over the build volume acting at several levels:

- MJF technology singularities and aspects
- Printer by printer deviations
- Part by part geometry singularities

1.3 Overall Equipment Effectiveness

The OEE is calculated by multiplying the manufacturing process availability, quality and performance (Fig. 4).

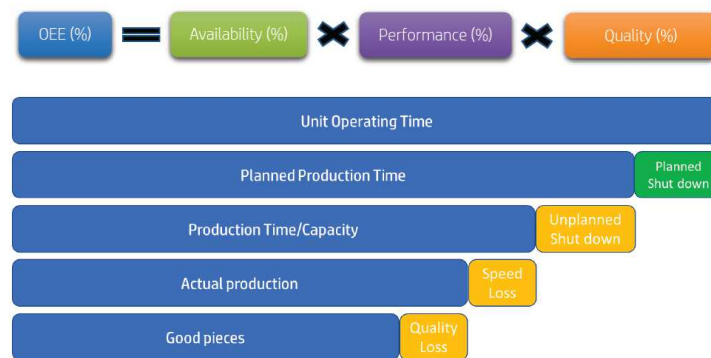


Fig. 4. OEE (overall equipment effectiveness) definition.

Availability factor refers to unexpected waiting times. HP strategy to maximize this factor is:

- 3D Printers are designed modular to maximize the operability and throughput;
- Printer components and systems are tested to determine end of life and to proactively suggest predictive maintenance;
- Components known to fail in a higher rate are redundant to avoid stops during manufacturing process;
- Basic HP Service Support includes remote support and next business day on-site support.

Performance factor refers to deviations to expected process time. HP strategy to maximize this factor is:

- 3D Printers are designed modular to maximize the operability and throughput;
- The printing module does several subsystems pre-checks and calibration before starting the printing process. These operations are most of the parallel to shorten the time. Once the print is finished the build platform can be extracted and the printer immediately ready to print a new build.

Quality refers to parts that are out of specifications, mainly in dimensions. HP strategy to maximize this factor is:

- Define a clear expectation of achievable dimensional tolerances according to ISO 286;
- Provide and adjust repeatability and accuracy thanks to HP Process Control;
- Thanks to HP Service Support react to any deviations to help customers to get back to quality parameters.

The full paper of this abstract is included in the ProDPM'19 Conference Proceedings "Progress on Digital and Physical Manufacturing", published by Springer International Publishing under the book series "Lecture Notes in Mechanical Engineering", Almeida, H.A., Vasco, J. C., et al. (Eds.), Springer Nature Switzerland AG (Hardcover ISBN: 978-3-030-29041-2, eBook ISBN 978-3-030-29041-2), DOI: 10.1007/978-3-030-29041-2

Laser Metal Deposition & Laser Metal Fusion

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Abstract:

Additive Manufacturing: the benefits of the Laser Metal Fusion and Laser Metal deposition in application areas where conventional production reaches its limits.

Keywords: Additive manufacturing, 3D printing, Laser metal fusion.

1 Additive Manufacturing Process

1.1 Laser Metal Fusion

Powder Bed Based laser melting (Laser Metal Fusion, LMF) is often referred to as metallic 3D printing, Powder Bed Fusion or Selective Laser Melting. The laser builds up the workpiece layer by layer from a bed of powder. The blueprint is provided by a CAD model. Tools are not required. The powder is applied to a platform, and the laser beam melts the powder with high precision, according to the CAD data, connecting defined locations with the layer below. The laser then repeats this process until the metallic component is ready. The workpiece now possesses the properties of the material that was used in powder form. A large number of metallic materials in powder form can be used for this method, including steel, aluminum, or titanium.

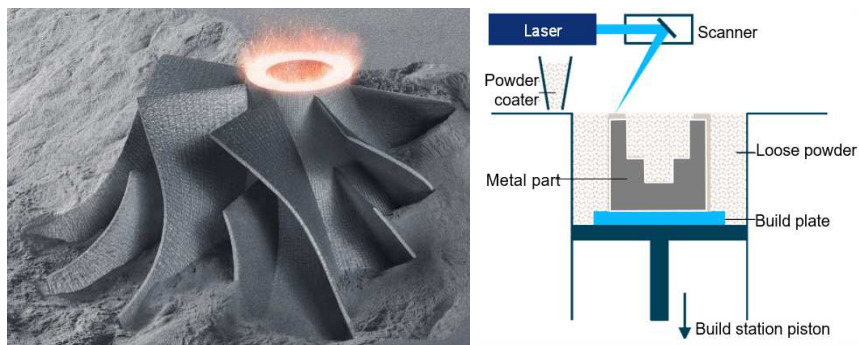


Fig. 5. Powder Bed Based laser melting (Laser Metal Fusion, LMF).

Example: Exhaust Manifold:

- Material: Titanium
- Nº of layers: 2 915 | 60 µm
- Time of processing: 26 h 33 min
- Objective: Design optimization



Fig. 6. Optimization design of a manifold.

1.2 Laser Metal Deposition

Laser Metal Deposition – or LMD for short – is also known as Direct Energy Deposition or Laser Cladding. The process is simple to explain. The laser creates a melt pool on the surface of the component, and metallic powder is automatically

fed in through a nozzle. Interconnected weld beads are thus formed which form structures on existing substrates or even create entire components.

Example: Wishbone

- Material: Aluminum
- Time of processing: aprox. 20s
- Objective: costs and time production reduction

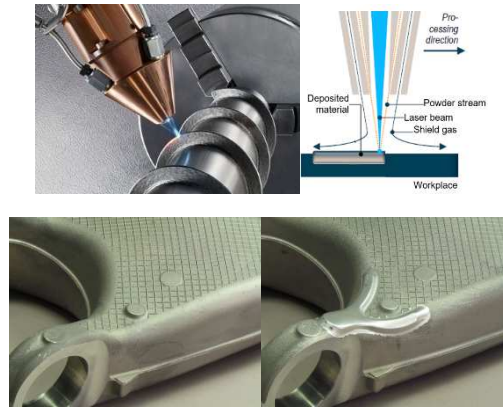


Fig. 7. Laser metal deposition on a wishbone component.

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The full paper of this abstract is included in the ProDPM'19 Conference Proceedings "Progress on Digital and Physical Manufacturing", published by Springer International Publishing under the book series "Lecture Notes in Mechanical Engineering", Almeida, H.A., Vasco, J. C., et al. (Eds.), Springer Nature Switzerland AG (Hardcover ISBN: 978-3-030-29041-2, eBook ISBN 978-3-030-29041-2), DOI: 10.1007/978-3-030-29041-2

Digital Manufacturing is a reality with HP 3D Printing: Introducing the new HP 3D Jet Fusion 5200 Printing Solution

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Abstract:

HP Multi Jet Fusion it is a 3D Printing technology with a high rate of penetration into real manufacturing environments. This aspect is pushing HP to deliver products and solutions more robust, more profitable, with higher productivity, and more precise and accurate. Recently, HP has introduced the new printer Jet Fusion 5200 and the software HP 3D Process Control that will allow to produce high volume of parts at the lowest cost and with tolerances matching ISO 286 IT13 grade and repeatability with Cp Cpk over 1.

Keywords: Product design, Design process, Technology development, Additive manufacturing

1 Unleash new growth and scale production with HP's most advanced plastics 3D printing solution

1.1 Introducing the new HP 3D Jet Fusion 5200 Printing Solution

HP has recently announced the release of its new Jet Fusion 5200 Series 3D printing solution, introduced a new TPU material, launched its Digital Manufacturing Network and expanded on strategic partnerships within various industries. The major announcements broaden the company's AM operations in a big way and enable HP customers to truly exploit digital manufacturing. As Christoph Schell, President of 3D Printing and Digital Manufacturing at HP, explained: "The Fourth Industrial Revolution is one of the most transformative forces in our lifetime. New technology innovations will be required, new partnership models will emerge and new modes of doing business will unfold.

HP is committed to helping customers with diverse manufacturing needs turn change into opportunity by delivering the most innovative solutions portfolio and comprehensive ecosystem of industry-leading partners. The broadening of our portfolio with the new Jet Fusion 5200 Series 3D printing system, coupled with expanded industrial alliances and our new Digital Manufacturing network, are important accelerators of our digital manufacturing journey.

The new Jet Fusion 5200 Series expands upon HP's existing Multi Jet Fusion portfolio, which also includes the Jet Fusion 300/500 Series for functional prototyping applications and the Jet Fusion 4200 Series, for short runs and production. The new 3D printer series adds to the portfolio, offering a solution for volume production.

The hardware comes with a number of improvements and upgrades which enable users to benefit from higher productivity, accuracy, consistency and efficiency. Other advantages of the new series include increased flexibility, improved uptime, streamlined workflows and simplified fleet management.

The new system effectively moves the center of the operation from a two-pass mode to a one-pass mode. This approach is enabled by the presence of a more powerful lamp and allows for a higher degree of productivity compared to HP's other MJF systems. Further, the more powerful lamp also creates opportunities for working with high-temperature materials down the line.

The Jet Fusion 5200 Series also integrates a more sophisticated thermal imaging system (with five times the resolution of the 4200 Series), providing better precision and tighter process control.

The new 3D printing system also comes with a new cooling module, which further streamlines and automates the production process. The low-cost cooling unit essentially sits on top of the build unit and once the printing process is complete, the still hot parts are automatically transferred into the cooling boxes so that the build unit is liberated for the next job. This is highly advantageous for customers requiring high productivity and that operate multiple build units.

The 5200 Series comprises of three 3D printer models: the Jet Fusion 5200, Jet Fusion 5210 and Jet Fusion 5210 Pro. The latter two models offer better economic value than the 5200 for larger volume production. The 5210 models are also more conducive for industrial applications because they enable manufacturers to see the status of the machine from a distance.

1.2 Improved Software and New Materials

To accompany the new hardware, HP has also introduced two new software suites: **3D Process Control** and **HP 3D Center**. The former helps to optimize the dimensional accuracy and consistency of part geometries. HP 3D Center, for its part, gives users the tools to optimize their whole factory. Finally, HP also launched the HP 3D Parts Assessment Service, which helps customers to identify and assess what parts can be 3D printed.

Excitingly, HP has also taken this opportunity to launch a new material for its Jet Fusion 5200 Series technology: **ULTRASINT**, a TPU thermoplastic polyurethane material developed by BASF. The new material is well suited for the automotive, industrial and consumer goods sectors for applications that require good shock absorbance, energy return and flexibility.

A number of companies are already utilizing the new material and HP's Jet Fusion 5200 systems for production applications.



Fig. 8. HP 3D Jet Fusion 3D Printing Solution.

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CONFORMAL COOLING: Opportunities – Applications – Challenges

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Abstract:

The concept of digital twin is at the core of the digital transformation happening in manufacturing industries. The digital twin of the production process is an effective technology that allows the use of data-driven or physics-based model to simulate the process and optimize the process parameters to achieve the best quality product. In the context of additive manufacturing, the scrap rate is high compared to more traditional process. Due to the full digital nature of AM processes, the concept of digital twin of the process, also referred to as the process simulation is used in this presentation as a test bed to demonstrate the usefulness of the digital twin of the production.

One of the first applications of powder bed 3D-metal printing aimed towards tooling industry. Using tool steel grade materials, it's possible to print conformal cooling lines beyond the surfaces of mold inserts used in plastic injection molding and die casting – with big impact regarding reduction of cycle time and part quality.

What looks easy in a first step, must be seen from different points of view.

It's necessary to understand how conformal cooling works in principle, but also what are the main things to think about when doing an additive design of mold inserts. Topics like material properties, design of cooling lines, finish machining and polishing/coating of the inserts have to be considered, but also the challenges in the later on use of those inserts under production conditions.

The presentation will give a short and compact overview on opportunities by 3D-printed conformal cooling, successful applications but also boundary conditions when using this high potential technology.

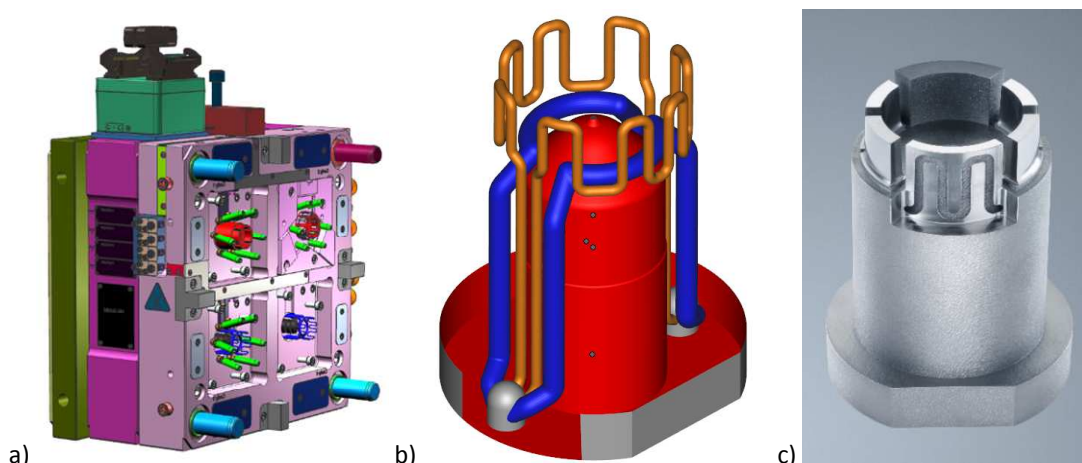


Figure 1: The part shown on the pictures is a so called “gate bushing”, a very common part used in plastic injection molding: a) Shows one half of the mold with 4 cavities – each cavity is equipped with one gate bushing; b) CAD-Model of cooling lines; c) 3D-printed part, partially finished, partially opened for demonstration of the channels inside.

The digital twin of production, the ultimate tool to achieve first-time-right in metal additive manufacturing

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Abstract:

The concept of digital twin is at the core of the digital transformation happening in manufacturing industries. The digital twin of the production process is an effective technology that allows the use of data-driven or physics-based model to simulate the process and optimize the process parameters to achieve the best quality product. In the context of additive manufacturing, the scrap rate is high compared to more traditional process. Due to the full digital nature of AM processes, the concept of digital twin of the process, also referred to as the process simulation is used in this presentation as a test bed to demonstrate the usefulness of the digital twin of the production.

Keywords: Additive manufacturing, digital twin, process simulation

1 Introduction

A digital twin is a virtual representation of a physical product or process, used to understand and predict the physical counterpart's performance characteristics. Digital twins are used throughout the product lifecycle to simulate, predict, and optimize the product and production system before investing in physical prototypes and assets. By incorporating multi-physics simulation, data analytics, and machine learning capabilities, digital twins are able to demonstrate the impact of design changes, usage scenarios, environmental conditions, and other endless variables – eliminating the need for physical prototypes, reducing development time, and improving quality of the finalized product or process. To ensure accurate modelling over the entire lifetime of a product or its production, digital twins use data from sensors installed on physical objects to determine the objects' real-time performance, operating conditions, and changes over time. Using this data, the digital twin evolves and continuously updates to reflect any change to the physical counterpart throughout the product lifecycle, creating a closed-loop of feedback in a virtual environment that enables companies to continuously optimize their products, production, and performance at minimal cost. The potential applications for a digital twin depend on what stage of the product lifecycle it models. Generally speaking, there are three types of digital twin – Product, Production, and Performance, which are explained below. The combination and integration of the three digital twins as they evolve together is known as the digital thread. The term "thread" is used because it is woven into, and brings together data from, all stages of the product and production lifecycles.

In the context of additive manufacturing, Figure.1 demonstrate the capabilities encapsulated in each digital twin in one integrated solution. To support the end user, solve multiple challenges related to the industrialization of additive manufacturing. From a system level, the data integrity and consistency are key to deliver the highest quality product and the end to end platform is an answer to this challenge.

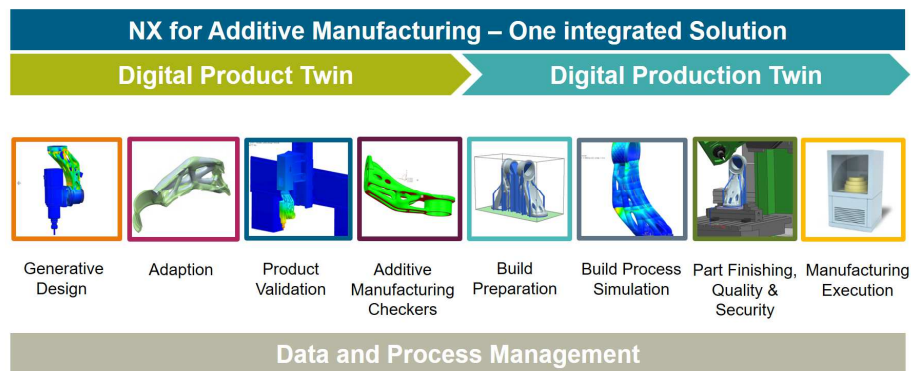


Fig. 9. Concept of the digital twin applied for additive manufacturing.

Moreover, the end to end solution deliver key technologies to solve other manufacturing issues such as the scrap rate. In additive manufacturing, and due to the complex thermos-mechanical process involved, the scrap rate is quite high (estimated at 30%) mainly due to challenges as described in Figure.2.

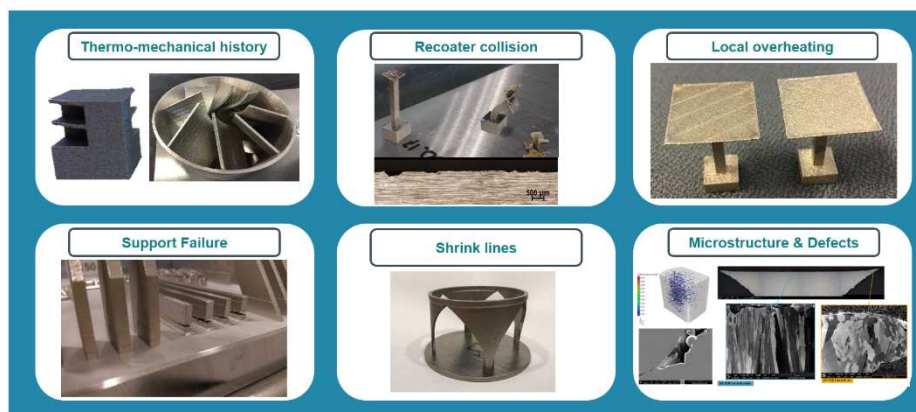


Fig. 10. The different root causes leading to the high scrap rate in metal additive manufacturing.

As discussed previously, the concept of the digital twin provides multiple technologies integrated in one platform to address the most pressing manufacturing problems. In the next section, we will describe how the digital twin of the production process provides a strong physics-based tool to analyses the AM process at multiple level, from macro to micro scale identifying and correcting potential manufacturing challenges upfront in a cost-effective manner.

2 Methodology and approach

The process simulation also digital twin of the manufacturing process provides a guided workflow to the user that allows for the assessment of distortions, the prediction of recoater collisions, prediction of areas of overheating, and other important feedback about the print process. The AM Process Simulation solution offers the ability to iterate on a solution between the design and build tray setup steps of the workflow, and the simulation step. This closed feedback loop is possible due to the tightly integrated nature of the CAD, CAM, CAE and the machine controller. The simulation data created feeds into the digital thread of information which informs each step of the printing process. This digital backbone enables the system to develop pre-compensated models and, more importantly, to feed those seamlessly back into the model design and manufacturing processes without additional data translation. This high level of integration is what customers need today in order to be successful in industrializing additive manufacturing. Figure.3, describes the architecture of the finite element-based solution that was implemented for this purpose.

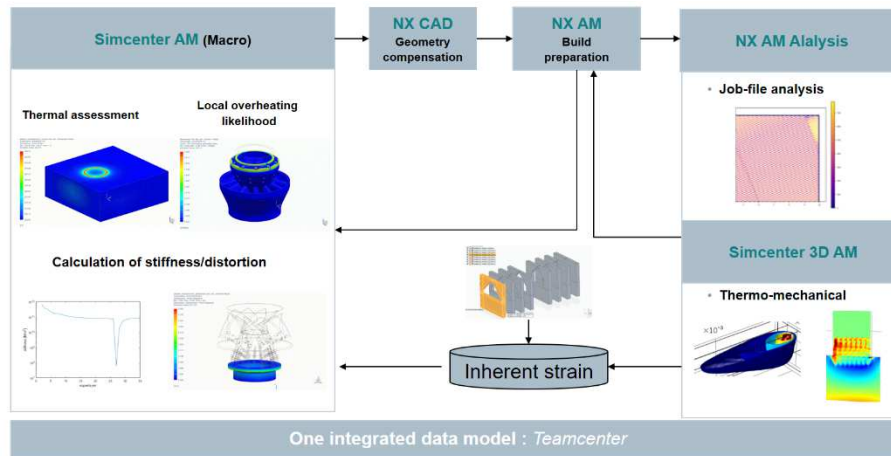


Fig. 11. Architecture of a finite element-based process simulation solution.

3 Results and discussions

This technology was implemented and investigated in multiple use cases. We demonstrate here a complex gas turbine component. This part was designed thanks to additive manufacturing capabilities. The original part was an assembly of 27 parts that were consolidated to one in this case. The complexity of the geometry led to a number of manufacturing challenges. These issues were predicted thanks to the technology described previously and corrected upfront in a cost-effective way. Figure.4 describes the obtained results compared to the 3D scan.

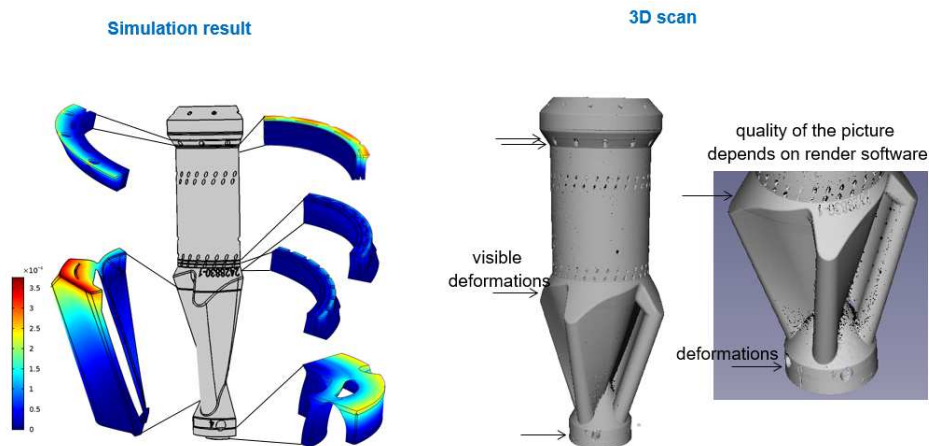


Fig. 12. Simulation results compared to 3D scans.

Multiple simulation demonstrated that the usage of the physics-based simulation to predict overheating, distortion and other challenges like residual stress is beneficial for the designer to make changes at an early stage. Also, it is demonstrated through experiments, that the process simulation is a key step to reduce machine failures, thanks to capabilities like prediction of recoater crash and the optimization of the job file. The ultimate objective of such technology is to achieve a zero scrap rate and deliver the promise of a fully digital manufacturing technology. Although the progress is impressive, efforts are needed to develop more technologies for additive manufacturing where the power of physics is combined with the insight from the data. Most of the future capabilities of Siemens digital twin will be based on this new paradigm.

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Additive Manufacturing State of the Industry

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Abstract. This paper provides a sampling of information published in *Wohlers Report 2019*, a 369-page global study. The publication provides a worldwide view of the technologies and applications of additive manufacturing (AM) and 3D printing—terms used interchangeably throughout the report.

1 Systems Sold by Region

The following chart shows the total number of industrial AM systems sold in 2018 by companies headquartered in each geographic region. For 2018, the U.S. holds the top spot with 36.2% of unit sales, a substantial increase from the 20.9% in 2017. This increase was largely due to the high unit sales by Markforged. In 2012, the U.S. produced nearly 61% of all industrial systems.

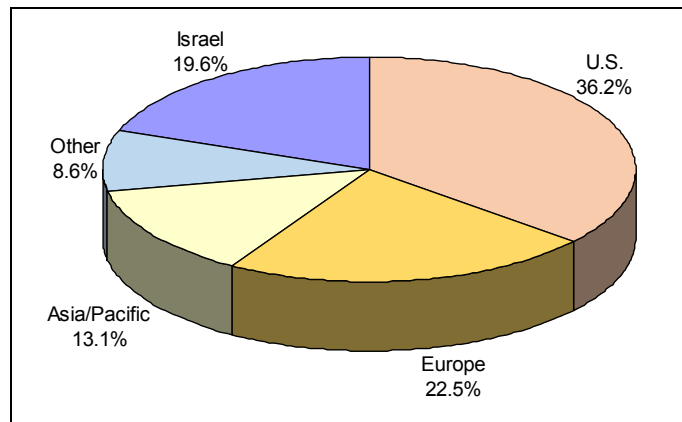


Fig. 1. Total number of industrial AM systems sold in 2018 by companies headquartered in each geographic region. Source: *Wohlers Report 2019*

2 Metals for AM

Revenue from metals for AM grew 41.9% in 2018 to an estimated \$260.2 million, up from \$183.4 million in 2017, \$126.8 million in 2016, and \$88.1 million in 2015. This segment grew 44.6% in 2017, 43.9% in 2016, and 80.9% in 2015. Wohlers Associates began to track the sales and growth of metals for AM in 2009, as shown in the following graph. The estimates are in millions of dollars.

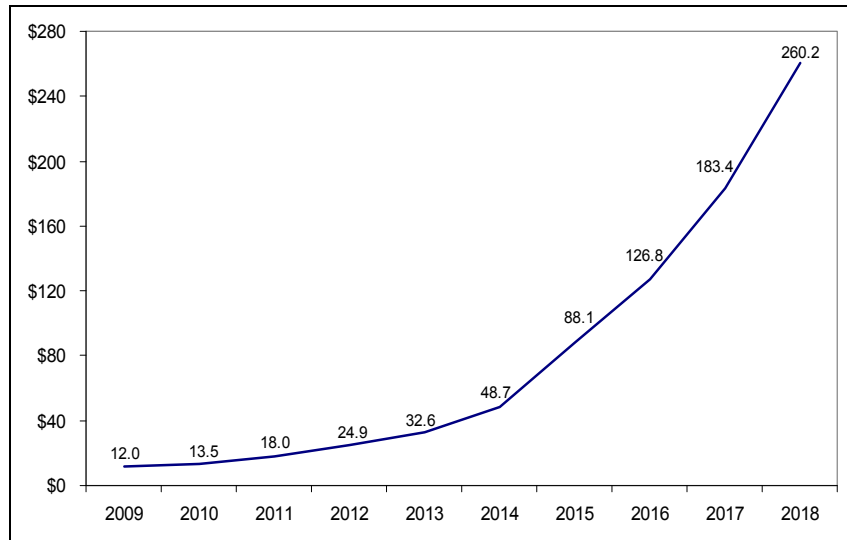


Fig. 2. Revenue from metals for AM grew 41.9% in 2018 to an estimated \$260.2 million. Source: *Wohlers Report 2019*

A major trend in 2018 was increased powder production capacity among AM materials suppliers. Capacity grew across a wide spectrum of alloy systems. Titanium alloy powder may have experienced its highest percentage growth rate yet. Aluminum powder is also attracting increasing interest from the AM community. The industry also saw many supply chain collaborations and acquisitions.

3 Investment in Publicly Traded Companies

Sales results for publicly traded AM companies were mixed in 2018, similar to 2017. 3D Systems and Stratasys continue to account for about 70% of the collective market capitalization of all publicly traded AM-focused companies. 3D Systems' revenue increased 6% in 2018, while Stratasys' revenue declined 1% the same year. For 2018, Stratasys management initially forecast revenue growth of 2.5% (at the midpoint of the guidance range). 3D Systems management did not provide a revenue forecast at the beginning of 2018.

3D Systems' 5% organic revenue growth in 2018 represents an improvement from flat organic revenue in 2017 and a 5% organic decline in both 2016 and 2015. The company's revenue growth rate has decelerated substantially since reporting organic growth of 25% in 2012, 30% in 2013, and 14% in 2014. Stratasys has experienced a similar slowdown, with organic revenue declines of 1% in 2017, 3% in 2016, and 10% in 2015, following organic revenue growth of 27% in 2012, 25% in 2013, and 32% in 2014.

4 Most Desired AM Technologies

Service providers were asked which technology they would most likely purchase if they were going to expand their AM capacity. The most popular response, by a large margin, was HP Multi Jet Fusion technology, as shown in the following chart. The second and third most popular were metal and polymer powder bed fusion (PBF) from EOS. The responses to this question show increasing interest in PBF systems.

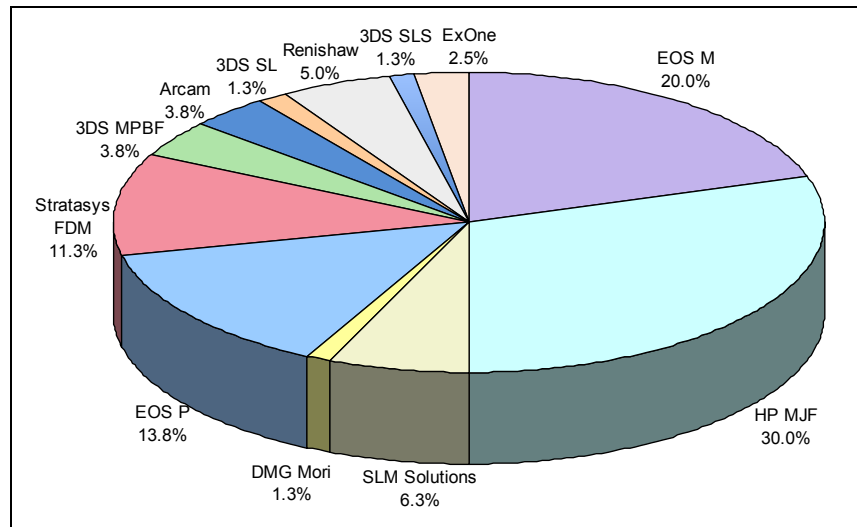


Fig. 3. AM machine technology service providers would most likely purchase. Source: *Wohlers Report 2019*

For many years, service providers have purchased established AM systems from the likes of EOS, Stratasys, 3D Systems, and others. In 2018, service providers added 63 less-established AM systems (22.3%) out of a total of 283 machines purchased. This is down from 40.6% in 2017. As companies grow, some might move from less-established AM machines to more established, and often more expensive, systems.

5 AM Applications in Aerospace

GE Aviation has been a trailblazer in using AM for the production of final parts for the aerospace industry. As a well-known example, the company is producing metal AM fuel nozzles for its LEAP engine. As of October 2018, more than 30,000 fuel nozzles had been manufactured using AM. By 2020, the company expects to manufacture more than 120,000 parts by AM for the LEAP and other aircraft engines.

Airbus has done considerable work with the design and production of polymer and metal AM parts for its aircraft. It has manufactured and is flying more than 100,000 plastic brackets, clips, and other devices for securing cables, wires, and hoses. Many are produced in ULTEM 9085 on fused deposition modeling (FDM) equipment from Stratasys, including 2,700 parts for the A350 XWB aircraft. Materialise is the company's first supplier of serial FDM parts for the A350.



Fig. 4. Redesigned titanium bracket, resulting in a 30% weight reduction, courtesy of Airbus and Toolcraft

6 AM Activity in Africa

When compared to Europe, North America, and Asia, the AM market in Africa is small. However, many believe that the uptake of new technologies on the continent will follow a similar trend to other parts of the world. The potential for growth in AM activities is believed to be high.

AM is in a healthy state in South Africa. The national AM strategy has led to national government support of AM, including the Collaborative Program in Additive Manufacturing (CPAM). CPAM is funded through the Department of Science and Technology. The Rapid Product Development Association of South Africa (RAPDASA) has been in operation for 21 years and continues to provide strong support to industry and academia. As of February 2019, about 50 startup companies had registered on the RAPDASA website. Many will receive some form of support from university partners.

Outside of South Africa, the use of metal AM in Africa is limited. In Morocco, Thales has created an industrial competence center in Casablanca that is specializing in 3D printing.

In Egypt, metal AM is used at the Central Metallurgical Research and Development Institute (CMRDI). CMRDI has the capability to produce 3D-printed parts in stainless steel, titanium alloys, and nickel alloys. The institute has significant experience in processing Ti-6Al-4V for medical prostheses and implants. CMRDI also has polymer AM capabilities. Another Egyptian organization working in AM is Additive Manufacturing Technologies Ltd.

A networking project called Digital Blacksmiths began in 2015. The network includes African Born 3D Printing in Kenya, the STIC Lab in Tanzania, and KLAKE Technologies in Ghana. Within the network, the low-cost Retr3D open-source 3D printer is manufactured using local materials and parts such as recycled scrap from electronic products.

7 The Future of AM

At the nexus of hardware, software, business, and human-centered design, AM is an exciting, multi-disciplinary field. Advances in the technology are not confined to novel processes and materials, but to new and promising use cases and creative applications. Software for build-simulation and manufacturing execution is bolstering reliability and decreasing the guesswork in AM, enabling its use in mission-critical applications. Clever innovators and entrepreneurs are finding their way into the landscape each day by applying or improving AM technology. AM is fertile ground for both prospecting, investing, creating, and dreaming.

Recent effort by system manufacturers has gone into increasing the speed of AM machines and in automating post-processing. This will continue to improve, gradually reducing the cost of making parts. The biggest change over the recent past has been in making companies aware of the need for good DfAM practices. As this trend continues, it will have the greatest effect on the increased industrial adoption of AM for production.

AM has reached a tipping point where the developments in materials, machine speeds and accuracy, and enabling software have combined to create a production-ready process. It is advancing from niche products to mainstream manufacturing. Particularly in the metals domain, AM is being accepted as a cost-effective production process in some of the most demanding applications. In the future, AM will be increasingly integrated into manufacturing systems at a line, cell, and machine level, with hybrid processing used to overcome the limitations of AM.

The exuberance of a youthful industry is giving way to the earnestness of adolescence. As AM comes of age for production applications, it is increasingly about applications and solutions, and less about how materials are cured, melted, jetted, or bonded. Users are rightfully beginning to ask what AM can do for them, and when it makes sense to use it. For its part, a maturing AM industry is addressing regulation, post-process automation, and economics. These concerns are evidence of an industry that, while continuing to innovate, is on a steady march towards adulthood and an equal place at the table of manufacturing processes.

Additive Manufacturing was the answer, but what is the question?

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Abstract:

At its core, this paper forms a discussion around the popular uptake of technologies such as AM, and why technologies such as these are not pursued with equal interest in industry as they have been in popular culture. More specifically, it asks – Why is AM still hard to sell into the manufacturing industry? As an ongoing work this paper is an attempt to construct a vision and roadmap to how AM could be implemented in any businesses dealing with physical, manufactured products. Using design tools and techniques from systemic design, service de-sign and industrial design, this paper argues for a broader and more holistic approach to AM. We see this qualitative emphasis on design through the lenses of client/designer/producer relations that are becoming increasingly complex, in their approach to business models and relations with costumers.

Keywords: Product design, Design process, Technology development, Additive manufacturing

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Expectations of Additive Manufacturing for the Decade 2020-2030

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Abstract:

Additive manufacturing became one of the most important manufacturing technologies in the last three decades. The freeform building capacity plays a relevant role on industrial applications where conventional manufacturing approaches are not technically or even not economically feasible. The development of advanced materials for AM is an ongoing process, providing a new competitive edge to AM technologies. Nowadays, AM plays an important role on the production of complex geometries for products of several domains, such as aerospace, automotive, medical among others, supported by high performance materials and in-creased efficiency AM processes. Distributed manufacturing supply chain also became a reality, enabling new business models and bridging the gap between product designers and end-users. Additionally, high levels of manufacturing automation, incorporating AM equipment as well as smart factories are emerging. At the middle of the 2020s-decade, standardisation for materials, material testing and manufacturing processes started its appearance to establish ground-breaking standards to harmonize the use of additive manufacturing technologies world-wide. Now, on the edge of a new decade, a bright future for AM technologies can be foreseen. This paper presents the AM prospects for the next decade and its prospective impact on business and industrial production models.

Keywords: Additive manufacturing, Technologies, Trends, Business models

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Additive technologies in the medical field for 2030

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Abstract:

Additive technologies are by definition technologies capable of producing products in a layer-by-layer fashion. Due to the specific characteristics of these technologies, the products can be produced in multi-materials and without any geo-metric limitations. By associating the use of biocompatible materials, it has become an excellent technology to develop products and / or devices for the medical field. Additive manufacturing technologies within the medical field have created a specific technological field, namely biomanufacturing which is capable of producing medical devices with the combination of biomaterials, drugs and growth factors and the use of cells for the production of biomedical implants. Additive manufacturing and biomanufacturing technologies have thus shown to be capable of meeting the requirements demanded by the medical sector. However, the significance of these technologies can't be based only on the current context, but also need to be assessed in the future context.

Given the growth and diversity that these technologies have achieved, this study aims to examine the future impact of additive manufacturing technologies in the medical field for the year 2030. To meet this goal, we used the Delphi method which is a technique that involves the application of questionnaires to experts in the field, until reaching the relative consensus of the predictions of these technologies.

Keywords: Additive manufacturing systems, Bio manufacturing systems, Biomedical technologies and medical applications, Delphi method

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Technological and economic comparison of additive manufacturing technologies for fabrication of polymer tools for injection moulding

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Abstract:

This paper investigates the technological and economic potential of 10 different AM materials manufactured with four different AM technologies for the use of tool production for injection moulding in small series applications. Therefore, experimental trials with three different injection moulding materials with increasing manufacturing difficulty in terms of resulting tool loads are conducted. Tool wear, resulting part quality and tool manufacturing cost are taken into account for potential evaluation. A concrete selection of the most suitable materials for further investigation is given.

Keywords: Additive tooling, Injection moulding, Rapid tooling

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Novel Robotic 3D Printing Technology for the Manufacture of Large Parts

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Abstract:

Additive manufacturing technologies are being used more widely to manufacture complex part geometries. Given the existing space limitations and the substantial time required to build up parts (small layer thicknesses), most 3D printing technologies do not operate cost effectively. When they are combined with industrial robotics, however, they become particularly interesting for the manufacture of large parts. This paper reports on the development of the design of a novel high-production system that can build parts weighing as much as 50 kg and measuring more than 1000 mm.

The innovative solution is based on the build platform's six-axis controller to deposit large quantities of material (5-10 dm³/h) with layer thicknesses of 5-10 mm rapidly. The use of three extruders makes it possible to process different thermoplastics such as ABS, PC, PLA or PP in granule form. Both hard-soft materials and different colours can be combined. The VINCENT simulation tool developed by the Fraunhofer IFF is being used to develop the control system for complex manufacturing operations. This this new integrative approach to motion planning and event simulation makes it possible to test geometry and function even before the system starts being built.

Keywords: 3D printing, Large parts, Multi-material, Simulation

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Implementing RAMI4.0 in Production – a multi-case study

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Abstract:

The Industry 4.0 (i4.0) paradigm was conceived bearing smart machines enabling capabilities, mostly through real-time communication both between smart equipment on a shop floor and decision-aiding software at the business level. This interoperability is achieved mostly through a reference architecture specifically designed for i4.0, which is aimed at devising the information architecture with real-time capabilities. From such architectures, the Reference Architectural Model for Industrie 4.0 (RAMI 4.0) is considered the preferred approach for implementation purposes, especially within Small and Medium Enterprises (SMEs). Nevertheless, the implementation of RAMI 4.0 is surrounded with great challenges when considering the current industrial landscape, which requires retrofitting of existing equipment and the various communication needs. Through three different case studies conducted within footwear and cork industries, this research proposes a RAMI 4.0 SME implementation methodology that considers the initial stages of equipment preparation to enable smart communications and capabilities. The result is a methodological route aimed for SMEs' implementation of smart machines, based on RAMI 4.0, which considers both the technological aspects as well as the business requirements.

Keywords: RAMI4.0, SMEs, Technology implementation management

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Integrating nature inspiration into Design for Additive Manufacturing: design challenges and future directions

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Abstract:

The freedom provided by Additive Manufacturing (AM) allows exploring new paths in geometry design. Nature provides a vast range of solutions to solve problems in an optimised way. In recent years, the use of nature as inspiration for the design of optimal structures in AM is attracting much attention. The integration of solutions inspired by nature reveals some challenges in the Design for AM of functional components. This paper reviews this process in various projects using different AM technologies and proposes a strategy to integrate nature solutions in the AM design workflow. The challenges and perspectives for bio-inspired AM design in the future are also addressed.

Keywords: DfAM, Additive manufacturing, Biomimicry, Bioinspiration, Biomimetic

Assessing industry 4.0 readiness of Portuguese companies

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Abstract:

Industry 4.0 (i4.0) has changed the industrial processes. Increasingly, companies have to adapt their processes to follow the technology development which has caused a digital transformation. However, mainly the Small and Medium Enterprises have difficulty to evaluate its i4.0 readiness level and design a strategy that implements the i4.0 concepts. Towards this scenario, we present the SHIFTo4.0 – a self-assessment tool that evaluates the i4.0 readiness level of a company.

SHIFTo4.0 is based on a model which contemplates six different dimensions: (i) strategy and organization; (ii) smart factory; (iii) smart operations; (iv) smart products; (v) data-driven services; and (vi) human resources. Each dimension is classified using a scale between 0 and 5. In addition, it provides a report with a set of recommendations, i.e., a roadmap, to guide the company in the i4.0 implementation to achieve a higher readiness level. As result, we present a case study that shows how a company can improve their current i4.0 readiness level by using SHIFTo4.0.

Keywords: Industry 4.0, Portuguese industry 4.0 readiness, Information systems, Modelling

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Exploring the linkages between the Internet of Things and planning and control systems in industrial applications

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Abstract:

The potential of the Internet of Things (IoT) and other technologies in the realm of Industry 4.0 to generate valuable data for monitoring the performance of the production processes and the whole supply chain is well established. However, these large volumes of data can be used within planning and control systems (PCSs) to enhance real-time planning and decision-making. This paper conducts a literature review to envisage an overall system architecture that combines IoT and PCS for planning, monitoring and control of operations at the level of an industrial production process or at the level of its supply chain. Despite the extensive literature on IoT implementations, few studies explain the interactions between IoT and the components of PCS. It is expected that, with the increasing digitization of business processes, approaches with PCS and IoT become ubiquitous in the near future.

Keywords: Internet of things, Planning and control systems, Information flow, System architecture

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Virtual Workstations Applied to the Mould Industry – A Case Study

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Abstract:

Professional CAD/CAM users in the mould making industry count on these environments to design and engineer moulds for the plastic industry. Conventionally this software is accessible through high-powered workstations shared among professionals in closed facilities. Operating in various countries, the access to data and projects, security and real-time collaboration became imperative.

The look for solutions to provide mobility turned Tecnimoplás to virtualization to deliver VDI environments to their commercial, managers and project users.

However, these kind of VDI environments weren't extensively tested yet in the mould making industry, so the company decided to try this solution on their own.

A proof-of-concept was made, and initial conclusions were taken from there leading the project forward. The final solution was tailored and implemented, and users started working only with VDI systems. Tests were then made to achieve the optimal VDI configuration and file time opening, processing times, update times and power consumption measurements took place.

The continues VDI technology update makes this kind of study only a brief approach to this recent technology.

Keywords: Virtual workstations, Mould industry, CAD/CAM

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To simulate or not to simulate? Challenges in digitally prototyping HMI interactive technologies

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Abstract:

This study of automotive HMI (human-machine interface) design is built around the fact that traditional product modelling and testing tools (i.e. foam-clay mock-ups, working prototypes) are increasingly being replaced by simulation technologies. The development of these technologies creates challenges as well as opportunities for product design teams. This study was carried out as a workshop to understand these challenges. A shortlist of fourteen new in-vehicle interactive technologies was determined through a literature review, followed by recruitment of four experts to evaluate the simulation of these technologies. The evaluation was based on pre-set criteria regarding the suitability, availability of tools and ex-tent of research and development required to simulate the interactive technologies, within a context of new product design and development.

Keywords: Interactive technologies, Simulation tools, Feasibility of simulation

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Study on the On-line Support System for Welder

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Abstract:

In recent years, the shortage of experienced welder has become a problem.

Therefore, we are developing online welder support system so that we can demonstrate the performance of experienced welder by providing information to non-skilled welder during welding. This system can be applied to the actual work of welding as well as training only. In this system, the prediction and optimization for welding condition is provided to the welder as acoustic, visual and haptic information during actual work by analysing the measurement results of welder's behaviour and welding condition with molten pool shape, etc. For data analysis, the prediction of penetration shape and optimization of torch movement can be also carried out using numerical simulation by molten pool model. In this paper, in order to develop the on-line support system for welder, a basic investigation was carried out. As a result of the welder gaze measurement test using the smart glass with the proper filtering, it was confirmed that the eye tracking of the skilled welder was more stable than the non-skilled welder. Also, in the TIG manual welding, based on the measurement results of the torch movement by the camera for skilled welder and beginner, the situation of the backbead by numerical simulation was compared. The simulation results agree with the trend of actual welding. It was shown that the application of numerical simulation based molten pool model to simulation manual welding is effective.

Keywords: On-line support for welder, Welder behaviour, Numerical simulation, Eye tracking, Visual information, Education of welder, TIG welding

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Development of a supporting system of pass design in multi-pass welding based on GMAW weld pool simulation

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Abstract:

The multi-pass welding process is an indispensable to build a large construction. An automated welding system by a welding robot is desired to realize a high-productive process. Normally, so many welding tests are carried out to determine the optimum welding condition. However, there are many disturbances in the manufacturing site, and the welding quality becomes worse even though the optimum condition is used. Therefore, to realize a high-productive automated welding system, a pass design system which can optimize and correct the welding condition depending on disturbances is required. In this study, a supporting system of pass design in multi-pass welding process is constructed by using numerical simulation of the weld pool. In this study, the system is applied to the multi-pass groove welding in horizontal position. Weld pool simulation is carried out to obtain the relationship between the welding condition and shape of the weld bead, and make a database of the system. This system can show the optimum welding condition depending on the gap size between the base metals. In addition, the system can correct the welding condition pass by pass depending on the shape of the previous pass. Finally, this system is applied to the experiment and the weld region shows good quality so the gap can be filled without defect. Therefore, the system developed in this study can support to optimize and correct the welding condition depending on the disturbance.

Keywords: Multi-pass welding, Numerical simulation, Automated welding, Optimization of welding condition, Correction of welding condition

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Integration of BIM and generative design for earthbag projects

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Abstract:

Although earthbag construction is recognizably a low environmental impact solution, existing software tools are limiting factors, since they do not have enough technical data to support its building information model. We propose a visual programming language code to generate earthbag domes inserted in a BIM environment, where these structures can be associated with other design and structural elements, producing the required technical data to inform construction including technical specifications as well as material and task quantification. This re-search adopted an experimental methodology exploring the advantages of the combination of Building Information modelling with parametric generative design in of the design of earthbag buildings or hybrid constructions involving earthbag walls of different geometries. It was validated resorting to a simulation process where it was possible to redesign and 3D print a scaled model of an existing earthbag building that merges different shapes in the same building, including the automated generation of the associated technical data. The developed tool allows designing different types of earthbag buildings providing a typical BIM model including both geometric model and technical specifications.

Keywords: Earthbag, Building information modelling (BIM), Visual programming language

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Potential of Natural Ventilation and Vegetation for achieving low-energy tall buildings in tropical climate: An overview

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Abstract:

Climate change and rise in urban temperatures have further increased the cooling load demands for tall buildings located in hot climatic regions. Cooling loads in tall buildings can be reduced by integrating them with natural ventilation (NV) and building integrated vegetation (BIV) techniques. This study explores the potential of NV and BIV for obtaining low-energy buildings by analysing ten tall buildings as case studies. Buildings are analysed for NV, BIV, architecture design parameters, and energy savings. The results show that mixed-mode ventilation is the most commonly employed, and circular building plans have the highest potential for energy savings. Furthermore, the combination of NV with sky-gardens (BIV type) is the best strategy for achieving low-energy tall buildings in the tropical climate. The outcomes show that the application of well-researched building physics rules is in practice for making energy-efficient tall building. These findings may be helpful for designers and planners to develop further strategies and low-cost methods aiming at the development of more sustainable and healthier tall buildings.

Keywords: Tall buildings, Ventilation, Vegetation

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Improve Engineering Skills in Digital Manufacturing for new Products

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Abstract:

The 3D printing technologies has changed the reality of manufacturing processes and today to prepare future engineers and designers, we need to think which are the best skills and scientific knowledge and also technical know-how capable to promoting and accelerating changes on companies to improve their competitive-ness. How we can develop a consistent method to improve the skills for future engineers to deal with it.

The methodology focus is in the development of an integrative project for a new product. The project aim to prepare students to develop an product from the initial idea to the final prototype and involve diverse competences like 3D modelling, physical models, CNC machining and 3D printing process.

The results of the methodology and tasks established are adequate and possibility to improve the individual and group performance. The evaluation model implemented permit the valorisation of the final work and that preserves the context of the workgroup and individual commitment.

Keywords: 3D printing, Digital Products, Digital Manufacturing, CAD/CAM/CNC

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Room Temperature Extrusion 3D Printing of Polyether Ether Ketone Using a Stimuli-Responsive Binder

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Abstract:

We report 3D printing of polyether ether ketone (PEEK) at room temperature by direct-ink write technology. The room-temperature extrusion printing method was enabled by a unique formulation comprised of commercial PEEK powder, soluble epoxy-functionalized PEEK (ePEEK), and fenchone. This combination formed a Bingham plastic that could be extruded using a readily available direct-write printer. The initial green body specimens were strong enough to be manipulated manually after drying. After printing, thermal processing at 230 °C resulted in crosslinking of the ePEEK components to form a stabilizing network throughout the specimen, which helped to preclude distortion and cracking upon final sintering. A final sintering stage was conducted at 380 °C. The final parts were found to have excellent thermal stability and solvent resistance. The T_g product specimens was found to be 158 °C, which is 13 °C higher than commercial PEEK as measured by DSC. Moreover, the thermal decomposition temperature was found to be 528 °C, which compares well against commercial molded PEEK samples. Chemical resistance in trifluoroacetic acid and 8 common organic solvents including CH_2Cl_2 and toluene were also investigated, and no signs of degradation or weight changes were observed from parts submerged for 1 week in each solvent. Test specimens also displayed desirable mechanical properties, such as a Young's modulus of 2.5 GPa, which corresponds to 63% of that of commercial PEEK (reported to be 4.0 GPa).

Keywords: Additive manufacturing, Polyether ether ketone (PEEK), Direct-ink write, Room-temperature extrusion printing, Epoxy-functionalized PEEK

Geometry-based process adaption to fabricate parts with varying wall thickness by direct metal deposition

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Abstract:

The process of direct metal deposition gains recently high attention in the additive manufacturing community, but its capabilities to fabricate complex geometries is still limited. Especially for thin-walled structures, heat accumulation can disturb the process significantly. An adaption of process parameters, for instance by a semi-empirical model, is able to stabilize the process. Herein, an algorithm is pro-posed that creates a digital twin of the part from a given NC code, analyses the massiveness of the part by calculating a local geometric factor, and alters the laser power accordingly: The heat flux in a thin wall is limited compared to a massive plate due to its smaller cross section and requires therefore less laser power to generate a comparable melt pool, especially if waiting times shall be avoided. The algorithm correlates experimentally determined process parameters to the local geometric factor. Since no physical simulation is performed, it is fast, easy to use, and enables a clearly defined and repeatable process. The buildup of a demonstrator part reveals the potential of the parameter adaption to fabricate arbitrary geometries.

Keywords: Additive manufacturing, Direct metal deposition, CAM programming, Parameter adaption

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A probable next step in Sustainable Product Design

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Abstract:

This abstract is part of the PhD study 'Sustainable Product Design from Seaweed for New Zealand'. The aim of the thesis is to develop ways to solve local challenges/problems with local resources whilst maximizing the added value derived from local resources. Seaweed is a resource widely available around New Zealand but farming is by law restricted. Nevertheless, certain non-native seaweed has become a pest on mainly the South Island of New Zealand and is harvested and used as fertilizer. This seaweed, *Undaria*, has enormous potential. My aim is to develop new products from this seaweed, using an overall sustainable perspective, a multi-disciplinary and multi-sciences approach.

Part of this PhD is to research the different schools of thought dealing with sustainability, and current sustainable initiatives around the globe. Based on these findings and my extensive international work experience on sustainable (economic) development, the most appropriate approach for this research is identified, and a probable next step for sustainable product design in general, is discussed.

Over the last half century, we tried to tackle ecological challenges resulting from the world's economic and population growth, to get to a sustainable prosperous future for our world. It started with the 'The Club of Rome' in 1972 and the report 'The Limits of Growth', followed by agreements like Agenda 21, Kyoto Protocol, the Paris Agreement, the United Nations Millennium Development Goals (MDG's) and more recently the Sustainable Development Goals (SDG's).

As the world population grows and the consumption increases, products and production processes, the use of resources, and the scarcity of resources has become more prominent and even a reason for conflicts and violence. The definition of sustainability had developed over the years and some constancy remains. Victor Papanek wrote in *Design for the Real World* (1971) "integrated design is comprehensive: it attempts to take into consideration all factors and modulations necessary to a decision-making process. Integrated, comprehensive design is anticipatory". And being anticipatory has proven to be a real challenge in our ever-changing world. Recently, amongst others, Circular Economy, Eco-footprint, Blue Economy, Biomimicry, and Natural Capitalism are ideas widely discussed and used. And there are still lessons to be learned around the world, both from 'mistakes' made, as well as from solutions that evolved. Integrating as many schools of thought as appropriate, together with lessons learned over time and around the globe, a comprehensive sustainable design approach should evolve. This approach should shed light on the appropriate path of Sustainable Product Development in our current times and for the near future.

In New Zealand, and in many other parts of the world, there are lessons to be learned about restoring a balance with nature and ensure our (economic) wellbeing, and existence for the eras to come.

Keywords: (Design for) sustainability, (Use of) by-products, Seaweed

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Design and Printing Parameters Effect on PLA Fused Filament Fabrication Scaffolds

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Abstract:

The Fused Filament Fabrication technique was used to build PLA scaffolds for bone tissue replacement. Scaffolds with 100 % interconnectivity were fabricated using different printing parameters and geometry design. Two temperature values and two extrusion speeds were combined with two different layer thicknesses. The influence of these parameters upon produced scaffold morphology and compressive mechanical properties was assessed. Afterwards, two different geometries were fabricated considering only the best performing parameters, to assess the influence of the main and lateral pores dimension on scaffolds mechanical properties. Specimen morphology was analysed by scanning electron microscopy, to assess the geometrical quality of the produced parts. It was verified that the higher tested temperatures combined with the lower printing speeds increased the overall mechanical strength of produced scaffolds. Low temperatures and high printing speeds were found to limit the amount of material possible to be extruded due to viscosity issues, and introduced scaffold defects. Creating staggered scaffolds with offsets between layers, decreased the resulting scaffold mechanical performance.

Keywords: Scaffolds, Fused filament fabrication, Tissue replacement, Mechanical properties

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Strategies for Obtaining Porous Media through the Process Planning in Material Extrusion Additive Manufacturing

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Abstract:

Porous materials or porous media (PM) are found in many applications. The design of the porous structures for specific applications presents challenges that involve their geometric modelling and manufacturing. Additive Manufacturing (AM) has a great potential in this area since it allows porosity planning. In particular, the AM based on the material extrusion principle allows obtaining PM with a planned macro porosity without the need to model it geometrically. This is possible because this principle allows varying a number of manufacturing parameters in the production of lattice geometries. Although there are parameters that allow the creation of PM, the current process planning software still have limitations on the level of customization of the part filling. This work presents the potential of the process planning software called RP3 (Rapid Prototyping Process Planning) to obtain PM with the material extrusion AM technologies. For this, some specific filling strategies were developed such as the staggered raster and the joined filaments. The efficiency of the process planning system was evaluated by manufacturing PM in an open source printer.

Keywords: Additive manufacturing, Porous media, Material extrusion, Process planning, Tailored filling

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Use of Photogrammetry Technique as Reverse Engineering Tool for Modeling in Additive Manufacturing-Case study

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Abstract:

The development in technology has introduced many innovative methods, based on reverse engineering and additive manufacturing, in solving many problems arriving due to complexity in design. Apart from many traditionally available reverse engineering techniques, photogrammetry is a technique of generating 3D models using photographs taken in a sequential order. Short range photogrammetry is a technique in which a set of photographs are taken from different angles. Among the various factors, three factors, namely mesh size, geometry of the camera position, and proximity of the object of interest have been investigated through a case study. Photographic blending tools are used to stitch them to generate a 3D surface model. The generated surface models are then extruded to free form solids and are manufactured using any of the additive manufacturing technique. The study provides the optimum values of each of the factors that can result the best possible 3D model.

Keywords: Photogrammetry techniques, Reverse engineering, Additive manufacturing

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- ReCap TM, Autodesk Incorporation

Optimization Techniques for Automatic Reconstruction of Dental Computed Tomography Images

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Abstract:

Panoramic reconstruction of the dental arch is commonly used in dental health clinics for diagnosis and surgery planning. Panoramic images are typically obtained with X-ray. However, nowadays panoramic reconstructions are more and more obtained through computed tomography (CT) medical images. In fact, dental CT equipment emit lower-dose radiation compared with X-ray and other CT machines. In order to reduce costs, there are some CT equipment that are not able to generate the dental arch panoramic reconstruction. Therefore, a novel methodology for automatically reconstructing the dental arch (panoramic image) based on CT images is developed and evaluated in this work. The proposed method employs optimization methods to find the B-spline curve that best fits the dental arch. The methodology is composed of 6 steps, but all steps are fully automatic, such that the tool is user-friendly and could be used in any dental health clinic.

The CT files are the input to the tool, whereas the output is the dental arch panoramic image. In the first step, volume segmentation is applied to isolate the jaw through a thresholding technique. In the second step, each slice is automatically analysed and the one with more number of segmented pixels is selected. Next, a morphological dilation operator is applied to link regions with small discontinuities. Then, a smoothing algorithm is employed to avoid ramifications. In the fifth step, the major continuous element is selected and the dental framework line is obtained. In the sixth and final step, an optimization method is utilized to define the B-spline that best fits the dental arch, by means of only 3 or 4 points. The B-spline is necessary since it is a simple and continuous curve and allows the definition of other parallel curves. These B-splines are then employed to generate one or more panoramic views. Steepest descent method is used in the optimization procedure. The proposed automatic reconstruction method is applied to different patients CT images. The tool is implemented in Python programming language with Scientific Python (SciPy) and Visualization Toolkit libraries.

The computational time required for the dental arch reconstruction is less than 30 seconds in a dual-core notebook computer. The reconstruction process is fast and provides satisfactory results, which could replace panoramic X-ray images, reducing the exposure to radiation for patients and medical/dental staff. Experiments are conducted on several image data sets to demonstrate the effectiveness of the proposed methodology. The use of CT images, instead of X-ray images, allows a proper level of details about the patient's oral health with less radiation dose. The developed methodology has great potential to be used as a valuable tool for dentists.

Keywords: CT-image, Dental arch, Optimization

Efficient Tailoring of Geometrical Based Laser Parameters for Design-Elements on Universal SLM Machines

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Abstract:

Selective Laser Melting (SLM) is a powder metallurgical process that describes the layer-wise production of three-dimensional components using a laser beam. It allows the production of almost completely dense components and offers a high degree of geometric freedom. Nevertheless, the surfaces of SLM printed components often do not meet the quality requirements, since a high surface roughness exerts a significant influence on the material properties and requires time- and cost- intensive post-processing. By selecting appropriate geometry and process parameters, surface roughness and density can be improved.

The aim of this work is to create an empirical model for the influence of the process parameters laser power and scan speed as well as the influence of the geometry parameters orientation and surface angle for the stainless steel AISI 316L and the titanium alloy Ti-6Al-4V. By means of a central composite design, the reciprocal influences and main effects of the respective parameters are visualized, quantified and interpreted and the results are validated on the use case of a pipe geometry. It was shown that the laser power has only a small influence in the investigated range up to 100W. A significant influence can be observed in surface angle, and scan speed. By applying combinations of the determined parameters, the density of the pipe geometry could be increased and the roughness reduced. Appropriate parameters can be selected to either calculate optimum process parameters for roughness and density or to develop the best possible design. In addition, the presented method allows the quick and easy determination of optimal parameters and can be adapted, for example, for the validation of new materials as well as for the improvement of further target parameters such as hardness or tensile strength.

Keywords: Industry 4.0, Portuguese industry 4.0 readiness, Information systems, Modelling.

Programming 4D Printed Parts through Shape-Memory Polymers and Computer-Aided-Design

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Abstract:

This paper aims to provide an overview about 4D Printing (4DP), the use of Shape Memory Polymers (SMP) and how Computer-Aided Design (CAD) can be applied to programme shapes to perform controlled behaviours of 4DP parts when subject to environmental stimuli, leading to potential applications and outlining future challenges for this emerging field of multi-disciplinary science. One of the main barriers outlined in this work concerns the early stages of Design for 4DP (Df4DP), in which communicating the intent and the shape change behaviour is important for designers, engineers and manufacturers.

Keywords: 4D printing, 5D printing additive manufacturing, Shape memory polymers, Computer-aided-design, Stimuli responsive materials

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Modelling and Simulation of a Novel Functional Brace for Large Bone Defects

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Abstract:

The treatment of large bone defects often requires the use of an external fixator. However, these fixators present some limitations in terms of pain, morbidity and risk of infection. This paper presents a novel functional brace, being designed to be an alternative to current external fixation devices. Main design requirements are presented in this paper aiming at improving performance and comfort, and reducing costs and weight. The functional brace was tested under impact using finite element analysis (FEA).

Keywords: Additive manufacturing, Brace, External fixation device, Finite element analysis, Prostheses, Stress concentration

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AM tooling for the mouldmaking industry

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Abstract:

Additive Manufacturing (AM) has proven its value both on the supply-chain and process tooling. Concerning the mouldmaking industry, many studies have been conducted, providing useful information about this manufacturing approach on the mould insert's effectiveness on the mould's cooling stage. Therefore, it is important to assess the feasibility of the use of AM in other mould components where temperature also plays an important role on cycle time. Furthermore, the freeform capacity of the manufacturing process also enables innovative and/or optimized solutions for mould components, providing a significant economic impact, resulting both from mould operation (reduced cycle time) and component's production (conventional manufacturing vs. AM). This work aims also to evaluate the concept of mass customization by developing a common geometry for a hot-runner nozzle bushing, enabling its automatic customization depending on the hot-runner nozzle manufacturer and the cooling requirements of the nozzle. Additionally, generative design is also used to optimize the bushing's volume, reducing build time and costs, providing a more effective cooling of the hot-runners nozzle tip.

Keywords: Additive manufacturing, Mould making, Generative design

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3D printing: an innovative technology for customised shoe manufacturing

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Abstract:

Nowadays, consumers are changing the market dynamics. They have become more critical, active and informed. They pursue more personalised products/services and like to be involved in the design process. Additive manufacturing technologies allows this personalisation of products and new business models should embrace these trends to differentiate and gain competitive advantages. The application of 3D technology is widely spread in different areas including textile and apparel manufacturing. From a physical model, it is possible to create a digital model using 3D scanning technology for redesigning purposes. Among the various applications, the apparel industry has expanded with relevant gains, namely fitting and customisation. Several applications of 3D printing for garment, fashion accessories and footwear are described. These applications are based on 3D models that are digitised through 3D scanning and then modelled using CAD software. A case study of shoe redesign is presented in which engineering design tools are implemented, namely, topological and lattice structural design.

Keywords: Personalisation, 3D scanning, 3D printing, Apparel industry, Footwear, Design optimisation

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Polymer matrix nanocomposites for 3D printing

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Abstract:

Additive manufacturing has a great potential since it allows the production of objects with complex geometries, often without auxiliary tools, while still using a wide range of materials. An example is Fused Filament Fabrication (FFF), one of the technologies frequently referred to as 3D printing. One of the most widely used thermoplastic material in FFF is poly(lactic acid) (PLA). This polymer has superior mechanical properties compared to common polymers, in particular the modulus of elasticity, becoming a good substitute in agricultural applications and packaging. However, in sectors such as automotive and electronics, the application of PLA has some disadvantages, such as: low thermal resistance; low thermal deflection temperature; low crystallization rate and reduced impact resistance. With the rising demand for 3D printing solutions, especially for small size parts with specific properties, the development of new materials to suit those demands became of the utmost importance. Thus, one solution that has been adopted in re-cent years is the incorporation of nanoparticles in the thermoplastics. In this paper, an experimental setup was developed regarding the processing and characterization of two sets of PLA nanocomposites, one with carbon nanotubes (CNT) and another with graphene. The processed nanocomposites' properties were tested through mechanical and melt flow index characterizations to study their suitability for 3D printing.

Keywords: Fused filament fabrication, PLA, Nanocomposites, Graphene, Carbon nanotubes

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Morphology and thermal behaviour of new mycelium-based composites with different types of substrates

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Abstract:

The need for new green and sustainable materials has been fostering the development, research and introduction of biodegradable materials from natural and renew-able sources. Commercially available biodegradable plastics, while minimizing their environmental impact and exhibiting a set of properties that enable the obtainment of industrial components, usually require complex processing methods, are costly and have limited applicability.

A new growth of natural resources based paradigm applied as production process is increasing its relevance as an alternative production process. New materials that combine fungal mycelium with waste materials as coffee grounds or wood waste can be considered as promising to fulfil this new paradigm.

This new biomaterial mycelium based composites present controllable and adjustable properties during their growth, being able to grow and penetrate organic substrates, thus forming a tangle of branched fibres and a structure that presents some thermo-mechanical properties similar to the ones of plastics.

The aim of the present study was the selection of the optimal inoculation temperature, light, humidity and the best substrate for the fastest and consistent mycelium growth. Four types of mycelium were incubated, namely *Pleurotus ostreatus* (382), *Hypsizygus ulmarius* (420), *Ganoderma lucidum* (560) and *Trametes versicolor* (620). The influence of the three substrates (coffee grounds, pine waste and general wood waste) on the growth was analysed both morphologically and thermo-mechanically by means of differential scanning calorimetry (DSC) and X-ray micro computed tomography (microCT).

Keywords: Mycelium-composite, Biomaterials, Differential scanning calorimetry

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Developing sustainable materials for marine environments: algae as natural fibres on polymer composites

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Abstract:

There is an increasing demand for the use of sustainable materials in marine applications. Thus, the ability of using raw-materials directly from ocean waste effectively contributes to enhance circularity by design in these sensitive ecosystems. Considering the favourable strength-to-weight ratio of composite materials, they usually tend to get selected for nautical applications. In these polymer composites, glass fibres and carbon fibres are usually chosen as reinforcements due to their specific strength and ease of manipulation. However, the use of natural fibres as fillers for composites in marine applications would be beneficial due to the fact that they are biodegradable and have a much lower environmental impact than glass or carbon fibres. Thus, the purpose of current research is to test and assess the use of red algae as filler for polymer composites in marine applications.

Keywords: Natural fibres, Composite materials, Red algae, Marine applications

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On the effect of deposition patterns on the residual stress, roughness and microstructure of AISI 316L samples produced by Directed Energy Deposition

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Abstract:

Despite the extensive capabilities of Laser-Powder Directed Energy Deposition (LP-DED), compared to other metal additive manufacturing process-es, the use of LP-DED in industry is still limited as a result of the limited knowledge on the relationships between the process parameters and mechanical behaviour. In this work, the quality of AISI 316L samples, produced by means of LP-DED and evaluated in terms of surface roughness, residual stresses and microstructure, is linked to the scanning strategy. The outcomes confirm that the deposition strategy plays a key role in the definition of the final properties of specimens.

Keywords: Laser powder-directed energy deposition, 316L, Residual stress, Surface roughness, Microstructure

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A novel specimen geometry for fatigue crack growth in vacuum

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Abstract:

Selective Laser Melting (SLM) is a technology for additive manufacturing consisting in the fusion of a fine metal power layer by layer. This procedure is very interesting to generate components with complex geometry and eventually composed of different materials. This novel technology opened new opportunities. A cylindrical geometry is proposed here, with an internal circular crack placed at the centre of the specimen, as shown in Figure 1. This new specimen geometry is interesting to study fatigue crack growth (FCG) in vacuum, which is important for a better understanding of FCG mechanisms. The environment inside internal cracks is likely similar to a vacuum environment since it is shut off from air, leading to negligible effect of oxidation or gas absorption. This way, the complex apparatus typically used to develop fatigue studies in vacuum, is avoided.

Keywords: Selective laser melting (SLM), Fatigue crack growth, Vacuum, Novel cylindrical specimen with interior crack

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Fatigue life prediction in selective laser melted samples under variable amplitude loading based on two constant-amplitude tests

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Abstract:

This paper addresses the fatigue behaviour of selective laser melted samples subjected to variable amplitude loading. In a first stage, a series of low-cycle fatigue tests is performed to identify an energy damage parameter able to correlate the load history with the fatigue lifetime. In a second stage, an energy-life curve is established on the basis of two tests performed under pulsating loading conditions. Finally, fatigue lifetime of samples tested at variable-amplitude loading are successfully predicted using the energy-life curve previously established along with an adequate fatigue damage accumulation law.

Keywords: SLM, SED, 18Ni300, Lifetime prediction, Variable amplitude

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Study of Laser Metal Deposition (LMD) as a manufacturing technique in Automotive Industry

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Abstract:

The last few decades in the automotive industry have been marked by a heavy concern with the environment, saving energy and reducing material wastage, while aiming to maintain good mechanical properties, essential in the components usage. Additive manufacturing (AM) techniques present themselves as a viable option in the matter, with Laser Metal Deposition (LMD), rising as one of the most promising techniques within this category, capable of producing near-net shape components, with a layer upon layer construction of three-dimensional solid parts from a 3D CAD model, with good mechanical properties and acceptable surface finishing. Laser Metal Deposition is a relatively recent technique, which is made noticeable by the lack of clarification about the influence of several parameters in the final components characteristics, ultimately leading to a scarce availability of the process in the market. This paper aims to clarify and evaluate, how LMD produced parts can suit the automotive industry, by measuring and analysing their behaviour under several mechanical tests. These mechanical tests have specific focus on wear and abrasion behaviour, as well as elastic properties determination, as these are the characteristics that allow a better overview over the expected performance of LMD components for automotive applications.

Keywords: Laser metal deposition, Additive manufacturing, Automotive industry

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Photocurable Alginate Bioink Development for Cartilage Replacement Bioprinting

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Abstract:

Bioink design and assessment for tissue engineering replacement is a key topic of research. This article investigates suitable photocurable alginate bioink precursors for bioprinting and the fabrication of 3D constructs for cartilage replacements. Alginate chemically modified with methacrylate anhydride groups is considered and assessed using different techniques. 2% Alginate methacrylate (AlgMA) solutions containing different concentrations of methacrylate and different reaction times were investigated. Nuclear magnetic resonance (NMR) results show the ability to tune the unsaturation degree by changing the reaction conditions. Rheological characterization results show that all alginate methacrylate pre-cursor solutions exhibit a shear thinning behaviour. Biocompatibility and cytotoxicity results were no cytotoxicity was observed.

Keywords: Alginate polymers, Rheology, Bioprinting, Tissue engineering

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Composite scaffolds for large bone defects

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Abstract:

This paper investigates the use of polymer-ceramic composite scaffolds for bone regeneration. Different ratios between Poly-εcaprolactone (PCL) and Hydroxy-apatite (HA) were considered. Scaffolds were produced using two different lay-down patterns (0/90° and 0/45°), and pore sizes (350µm, 500µm and 700µm). Compressive and cell proliferation tests are reported. Human adipose derived stem cells (hADSCs) were used for the biological characterization.

Keywords: Hydroxyapatite, Bioprinting, Additive Manufacturing, Tissue engineering

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Bi-material electrospun meshes for wound healing applications

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Abstract:

Skin is a complex and very important tissue, playing a significant protective and regulatory function. It is also prone to a large number of wounds and defects due to external factors such as temperature, chemical agents, and radiation. However, minimizing the risk of infection in the wound area and accelerating the skin healing process are still relevant research challenges. This paper investigates a novel wound dressing based on polycaprolactone (PCL), a synthetic biocompatible and biodegradable polymer, and honey- Surgihoney®. Wound dressing meshes were produced using solution electrospinning. Different polymer solutions were prepared by mixing PCL and Surgihoney® with acetic acid. Process conditions were optimised to create suitable meshes with uniform fibre diameters and minimal presence of beads. Fourier transform infrared spectroscopy analysis (FTIR) was used to investigate the incorporation of Surgihoney® on PCL meshes. Meshes were also biologically assessed using human adipose-derived mesenchymal stem cells. Results show that the presence of Surgihoney® has a positive impact on cell attachment and proliferation.

Keywords: Electrospinning, Honey, Polycaprolactone, Wound healing

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Fabrication of cellulose hydrogel objects through 3DPrinted sacrificial moulds

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Abstract:

Effects of mould removal methods in fabrication of cellulose hydrogel objects were investigated in the present work. Cellulose was dissolved in 7 wt.% NaOH/ 12 wt.% urea aqueous solution and thermally gelled at 55°C in three different mould materials, Acrylonitrile Butadiene Styrene (ABS) as a common 3D printing material, Solidscape™ wax, specifically designed as a 3D printing cast material, and sacrificial casting wax (Lost Wax), commonly used for casting. After completion of the gelling process, the moulds were removed from the cellulose gel by using a solvent for the ABS mould and melting the waxes in hot water. At the same time, the solvent was extracted from the gel and the cellulose hydrogel re-generated. The results show that mould materials and their associated removal methods have a significant effect on the mechanical properties and microstructure of cellulose hydrogel and cause shrinkage. Larger pore sizes decreased the compression strength and modulus of cellulose hydrogels samples. A balance between the porosity and density for a cellulose hydrogel part must be established for the specific applications.

Keywords: Cellulose, Hydrogel, Manufacturing, Mould, Casting

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3D printed geometries on textile fabric for garment production

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Abstract:

Within the fashion industry, 3D printing can be used for producing individualized products by 3D printing on textile fabrics. One of the main issues of 3D printed geometries on textile fabrics is the adhesion between both materials. Continuing our previous research, other textile fabrics are used as substrate for 3D printing. Again, washing tests which simulate the real use of the textile fabric for garment production indicate that round shapes and thin objects are uncritical to be washed compared to higher objects and square shapes, which tend to separate after the first or the second washing cycle. For nine textile materials under investigation, no separation was found at all for the first 5 washing cycles for two of them. Finally, a full construction cycle including 2D and 3D design, simulation, 3D printing and garment production is presented.

Keywords: 3D printing, Textile fabric, Garments production

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Moving forward to 3D/4D printed building facades

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Abstract:

Nearly Zero Energy Buildings will require high-performance building envelopes, though the building sector is currently a major contributor to the world's energy consumption and CO₂ emissions. Smart and functionally graded materials are being developed to protect natural resources and better adapt buildings to a changing environment. This paper presents a brief overview of novel advanced materials for passive/kinetic facades. There is a great potential for 3D/4D printing building components to address actual and future built environmental challenges. Several limitations and barriers still exist for 3D/4D printing in buildings, though architects and engineers must keep looking forward. The rise of 4D printing design by the integration of adaptive self-assembled materials could bring “life” to buildings.

Keywords: 3D/4D printing, Smart materials, Functionally graded materials, Shape memory materials, Phase change materials

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ATOS – Optical 3D Metrology in Industrial Quality Control

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Abstract:

Optical 3D coordinate measuring machines are replacing tactile measuring systems and gages in many areas of industry. They capture more detailed and easier to interpret quality information about an object with significantly shorter measuring times.

While mechanical measuring systems capture data in a point-based or linear manner, optical measuring systems provide full-field data about deviations between the actual 3D coordinates and the CAD data. As this measuring data contains all the object information, in addition to the surface deviations from the CAD, the software also automatically derives detailed information such as GD&T, trimming or hole positions.

The accuracy of optical measuring machines is not due to expensive and high-maintenance precision mechanics, but is rather based on state-of-the-art optoelectronics, precise image processing and mathematical algorithms. A few precision standards and automated calibration that can be performed by the customer ensure the accuracy of the machine. This also means no loss of accuracy due to wear under harsh conditions. As with the tactile machines, measuring uncertainty is certified with the help of ball bars or step gage.

Keywords: Atos, Gom, Dimensional control, Metrology, Optical

3DXPERT – A New Additive Manufacturing Experience

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Abstract:

3DXpert is an all-in-one integrated software to prepare, optimize and manufacture 3D CAD models using additive manufacturing (AM). Supporting every step of the additive manufacturing workflow from design to post-processing, 3DXpert streamlines your process to quickly and efficiently transition from a 3D model to a successfully printed part.

This powerful software enables you to: Achieve successful, quality prints - Prepare designs for additive manufacturing; Optimize design structure - Get the most out of additive manufacturing with lighter weights, enhanced functional properties, etc. Shorten design to manufacturing lead time - Streamline your preparation and optimization workflow. Minimize manufacturing Total Cost of Operation (TCO) - Reduce print time, material consumption and post-processing.

Keywords: 3dxdpert, 3dsystems, Additive manufacturing, Simulation

ARAMIS - Optical 3D Deformation Analysis

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Abstract:

ARAMIS provides accurate 3D coordinates, 3D displacements, velocities, accelerations, strains and measurements of 6 degrees of freedom (6DoF) for static or dynamically loaded specimens and components. Based on this measuring data, material characteristics are determined, finite element calculations are verified, component collisions recorded, motion trajectories checked and component deformations analysed.

ARAMIS is a non-contact and material independent measuring system that is based on the principle of digital image correlation. ARAMIS offers a stable solution for full-field and point-based analyses of test objects of just a few millimetres up to structural components several meters in size. Measurements are conducted independent of the specimen's geometry and temperature, without time-consuming and expensive preparation. With high-precision measurements, 3D measurement resolutions into the sub-micrometer range are achieved.

Keywords: Aramis, Gom, Mechanical testing, Deformation

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