STARTS Residency
Public Report
OS.WAAM

by Sebastien Wierinck
in collaboration with
Print Pioneers (B.I.G. group)

Authors
Sebastien Wierinck - Artist and designer - OnSite Studio
Daniel Bärwolff MSc - Berlin.Industrial.Group – devision manager Print-Pioneers
Nicolas Wierinck, Producer - Gluon, Archer & Weaver

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ABSTRACT

The residence pursued the goal of examining a technology that had previously been used heavily in industry for possible applications in the aesthetic, artistic field, such as architecture and design. After an initial project meeting in Berlin, ideas and visions of possible applications were exchanged between Sebastien and Nicolas Wierinck (artist and producer) and the Print Pioneers and Flying Parts (project manager, 3D metal printing experts). At the same time, this first project meeting, under the direction of Mr. Puissant (Vertigo), served to set out the time frame and content of the project, which took 4 months in total.

The special feature of this project was the printing technology to be used for this purpose, which uses arc and wire to produce large format metal objects on a CNC-based system. For the production, the artist was provided with a 3-axis system from the company Gefertec, which enabled the design of the first digital models after intensive instruction in the process-technical challenges.

As a special feature, it should be mentioned that this printing process is a high-tech welding process whose operation requires considerable expertise. The cooperation therefore took place in spatial distance through intensive exchange by mail and telephone.

In intensive cooperation with all parties, various printing tests were carried out in the relatively short project duration. The focus was not only on the form language but also clearly on the technical feasibility of printing, as the process works with liquid metal without support structures. One of the biggest challenges was therefore the design of a complex object, which takes into account both the technical constraints and the economic aspects. The creative result was an elegant art object that could exceed technical limitations by skillfully designing support structures.

I. INTRODUCTION

Through artistic input, the residency at Print Pioneers pushed the technical limits of large-scale metal 3D printing. The main goal was to develop a new workflow for the production of a series of structures halfway between the public art piece and the urban furniture, which should allow to raise public awareness of the multiple possibilities of this new design and

production system at several scales, from small objects to larger environmental and architectural integrations.

Having first explored the potential of standardized flexible plastic materials supported by metal laser-cut frameworks in a series of temporary objects and installations (OnSite), then secondly the potential of CNC free-form bended metal pipes (BenchMark) for permanent urban projects, Sebastien Wierinck analysed the potentials of 3D metal robotic additive large scale printing at Print Pioneers as a further development of his previous OnSite projects: site specific public functional sculptures and furniture.

The challenges of the project exist on several levels and laid partly on finding the sweet spot between economic feasibility and added value. Although the 3DMP-Technology from Print Pioneers is one of the fastest additive manufacturing processes, it is still expensive. We believe that additional value for end customers and the creative sector can be created, yet, pivoting the economic and technical constraints against functional and aesthetic advantages is one challenge.

Originally the 3DMP-technology was developed for large industrial metal parts, e.g. for ships or airplanes. For these industrial applications the surfaces of the printed part have to be milled in order to function properly. Yet, the unprocessed artisanal surfaces can be used as an artistic feature in creative segments and distinguish it from other technologies. Print Pioneers is an internal spin-off of B.I.G. Group that aims to unveil and develop economic business cases for large scale metal print in the fields of architecture, art and design.

Compared to other 3D metal printing methods the technology is cost efficient and enables the designer to think on a large scale (up to 3 cubic meters) and create real size objects that are sustainable and functional. This lifts 3D-printing from the status of “prototyping” to the status of “production”. Additionally, it is the only additive manufacturing technology which offers the possibility to combine different metals during the print process.

II. ARTWORK

The emergence of IT, numerical control, parametric and generative design, additive production strategies establish a new paradigm for the design world. From pro-users to complex data management, alternative design and production strategies seems to give us endless possibilities for both user and designer.

The aim of the artwork is to produce functional public sculptures using 3D metal large scale printing. In order to achieve the greatest possible synergy between all parties, the vision of artistically inspired street furniture was pursued, with which both Print Pioneers and Flying Parts as well as Sebastien and Nicolas Wierinck could identify. The idea was to test a new formal language for architectural elements that has the potential to fundamentally rethink public space.

The main goal of the project is to define a design-system for customized objects in which the design can be adapted to user needs (functions) and/or site specifications (context). The use of a parametric design strategy is in the context of 3D printing - which avoids expensive molds - relevant. With the objective to propose site specific integrations, variability in both combination and form through a specific parametric design system of a module seemed a valuable working strategy.

3D metal printing may give use the illusion of infinite possibilities, there are still a large amount of limitations and restrictions that rules the design and production process. For example the

low resolution of the printing process - the fusion of metal wire on a specific path - results in interesting and unpredictable material behaviors and pattern design which makes each print unique. Both unpredictability and production restrictions gave the impulse to the creative process of transforming material into a form.

Technically, the main challenge of the printing project is the integration of the overhang limitation specific to the 3-axis printing machine. The design of the final artwork is thus conceived to integrate both construction support (scaffolding) and outer surface into one single hybrid form. The relation between the outer surface and the inner structure is an essential part to the understanding of the final form.

Inspired and challenged by these given restrictions, an evolutionary process resulted in an increasingly complex artwork, which in some areas tricky stages limiting angles above the 30 degree limit

The final prototype represents 3 variations of the so called ‘parametric module’ combined into one composition. They represent a sample from the various possibilities of the design and production system. The result can be interpreted as a sculpture - functional or not - or as a scale model of larger architectural models.

III. METHODOLOGY

The process of wire arc additive manufacturing (WAAM) consists in the method of melting metal wire using an electric arc. Starting from a metal base plate and controlled by a robotic arm (CNC XYZ axis) multiple layers of metal are 'printed' to produce a volume.

Like any CAD/CAM process (computer aided design and computer aided manufacturing) a computer (numbers) is used to define a toolpath that will direct the motion and speed of the machine. This is -done by translating a 2D or 3D geometry into a G-code format that gives the instructions to the robot (start and stop, direction, speed, etc).

For the artwork, an arc-based printing process from Gefertec was used. The production was carried out on a GTARC-403, behind which a CNC-based build-up welding process is concealed, which has an installation space of 740x700x900mm (XYZ). With this system, the object generation is possible in 3 spatial directions (XYZ), which means that, compared to a 5-axis system (GTARC-405), different build-up strategies and limiting angles must be taken into account.

Each machine has it owns specification and limitations: The 3-axis (three dimensional cartesian coordinates x,y and z) machine can realize overhangs up to 30 degrees. Any overhang over a 30 degrees will need a printing support. The 5-axis machine will be able to print more complex forms by moving also the printing plate into two mores directions. Other limitations of the WAAM technology are related to volume restrictions, production optimisation (time/budget), a low resolution output, residual stress and distortion.

Due to the process, the metal printing has to take place on a metallic base plate onto which the wire is fused. For the production of the artwork, the question arises whether the base plate should fulfill a later role or function in the object, or whether it should be removed after the actual geometry has been built.

In the present case, the artist decided on a fixed integration into the design, whereupon the base plates were adapted to the later geometry by means of flying parts by laser cutting. From an economic point of view, this point should not be neglected, since a subsequent

correction of the base plate can often only be realized at great expense. Depending on the design, the accessibility during post-processing can conflict with the built-up geometry, as the milling, cutting or eroding head can collide during cutting.

IV. CO-CREATION PROCESS

The research team for this project is composed by the artist/designer and the tech partners - Print Pioneers and Flying Parts team. In addition, Tom Pawlofsky (Craftwise), who is specialized in robot programming, was involved as an external tech consultant and mediator. And the producer Nicolas Wierinck as facilitator and coordinator of the residency.

For this residency project we worked through a '*short feedback loop'* strategy to improve gradually the design proposal. Starting from a series of formal proposals and resulting 3D printing tests (prototypes), we created a short feedback loop that served as an input to the development process of the final design project. The use of CAD/CAM technologies - and more specifically the use of 3D printing technology - gives the design and research team the tools to shorten the time in between the design and the production phase (idea and result) and fasten this way the feedback loop during the development phases of the project.

Before the actual artwork could take place, the artist Sebastien Wierinck and his producer Nicolas Wierinck were instructed in the procedural and process-technical particularities by Flying Parts and Print Pioneers. In addition to a first kick-off in Berlin, design guidelines in digital form as well as e-mail support for the design were provided. In addition to the dimensionality, the information mainly concerned the understanding of the process technology, since the process works without additional support structures. This knowledge has a clear feedback to maximum angular positions or overhangs, which significantly define the outer shape as well as the build-up strategies for the later production.

After this visit - and a first level of understanding of the capabilities and potentialities of this partnership - a series of artistic proposals designed by Sebastien Wierinck and using Rhino 3D and related Grasshopper components (procedural and parametric design extension) were sent to Print Pioneers for presentation and validation in November 2019. The vision and its inspirational basis was shared visually via Dropbox and made available as a digital CAD design. After constructional inspection of flying parts, first print tests were carried out, which confirmed a basic feasibility. However, the expanding object area was identified as challenging, as the material overhang was well above the permitted 30°.

For the artist, this first prints enabled him to understand the needed tech implementations that would be necessary to be discussed with all involved partners. The artist learned that Print Pioneers didn't use any automated scripts to implement the overhang limitations of a printing geometry. The result of this first test is a prototype that uses as printing support a full volume of printed metal. The consequence is a long printing time, important material uses and a heavy distortion of the final volume.

From a constructional point of view, too much material overhang means that the melted material can sag down laterally and the construction height in the Z-direction is reduced. Excessive overhangs therefore lead to connection errors, as the welding torch moves upwards faster than the material is actually built up. The consequence is backfiring and consequently holes in the later outer skin of the component.

Only when the project was defined Tom Pawlofsky (Craftwise GmbH) was involved as an external advisor. Having both the knowledge of art production and robotic programming and

production, his advice helped us to define new and alternative strategies within the Print Pioneers - Flying Parts environment. Pawlofsky proposed a series of alternative printing strategies within the programming limitation that was defined by Flying Parts and their CAD/CAM environment. After several exchanges in between Tom Pawlofsky and Marcel Quilitsch they finally produced a series of test prints that could be interesting for both specific artwork production and for more global printing support strategies. Due to time and budget restriction those tests were stopped to focus on the final artwork production that needed to be printed within a short time period.

During a second loop the artist/designer worked on the modification of the surface curvature from the initial model. By folding and ripple the outer surface of the geometry he could gain in surface curvature and avoid the printing support.

In January, a fundamental redesign of the artwork design was carried out, which detached itself considerably from the external, previously clearly defined geometry and openly established necessary supporting structures as a striking design element. From a printing point of view, this approach can be considered a successful and, above all, economically charming composition, as it reduces function and aesthetics to the essential. In this third loop, the designer worked out the support-surface method by combining both support and outer surface into one single print geometry. The geometry was created by constructing the volume from several internal structural supports arranged into a star pattern and merged with the outer surface. The outer surface was also modified to integrate the 30 degrees overhang limitation. For the final artwork production, an intensive exchange occurred in between SW and MQ. Several 3D file modifications and updates were needed as the print tests showed the usability and faults of the proposed geometric strategies. It was ultimately that the 3 final prototypes were printed using the latest discoveries from the research as a result from this particular exchange in between the artist and the tech partner.

V. IMPACT

A. Research Impact

Looking at the results from a research perspective, exciting opportunities as well as challenges arise in the field of construction and railway planning strategies. Especially support structures are clearly in the solution focus, since the arc-wire process does not use any additional support structure.

B. Artistic Impact

As a designer I have through the past experienced the transformation of standardized material through various CAD/CAM processes (laser cutting, CNC wood cutting, freeform bend pipe bending, etc) to produce objects and spaces. This process involves only standard production material that are by fact industrial artefacts (wood panels, metal sheets or profiles, etc). The particularity of the WAAM 3D printing technique - and probably what makes it so unique - is the fact that even if the raw material is a standard (metal wire), the outcome do not reflects the initial material. By fusioning the material is liquified and converted to a ‘new standard’ of randomness. This new status pulls the outcome of the 3D WAAM technique somewhere in between the standardized - and over controlled - environment of industrial production processes on one side and the subtle randomness of craftsmanship and accidentality on the other side, exploring this way an alternative dimension of modern digital numerical controlled CAD/CAM techniques.

New forms are the ones you can’t really understand at first sight, they need time to be interpreted and rationalised. This process may take several days or even months. Mostly the

emergence of new forms is related to new technologies - as each technique and related outcome is unique. In this perspective, the research and collaboration project has been a very fruitful experience. Not only it demonstrated the flexibility of forms that could be printed by Print Pioneers and the interest that designer and artist may have to experience those new production facilities, but it also gave access to a new expressive tool, defined by its particular language, resulting from technical and formal 'rules'.

The physical impact of the printed results has been a real experience of aesthetic and conceptual exploration. This will have for sure an influence on my further work, related to 3D printing or not.

VI. ART-SCIENCE INTER-RELATIONSHIPS

As a technologically relevant bridge, it is above all the design language which, through the multi-faceted open representation of supporting structures, enables additional secondary functions such as improved visibility. Furthermore, art is to be seen as an essential element of success for a widespread acceptance in the dissemination of technology, as it presents the technology to the public purely and undisguised. Additional covers, which often arise in functional but unattractive components, can now be consistently thought through to the end in a single design, which reduces manufacturing and assembly costs.

For decades artists and researchers have tried to bind the two different fields of art and science in order to highlight their differences and their possible inter-relationship. However, even though art is not science and science is not art, separating science from scientific or technological research and art from artistic approach, experimentation can be a common language for both. In this sense, experimentation, trial-and-error methodology, thinking out of the box gave us new perspectives and new processes in the creation during this residency. Craftsmanship and High-Tech need to be interlinked. All the technology of WAAM technology is in a way hidden behind the design of the art piece. Because you can't really see it, that creates the experience.

VII. FUTURE DIRECTION AND ACTIONS

Currently, there are considerations to intensify the cooperation in the field of design. This concerns objects in the field of street furniture, as well as luminaires or even high-quality fireplaces, which are to be produced using the arc-wire process. The basis for this is a comprehensive understanding of manufacturing and finishing costs, on the basis of which initial price and calculation models can be made for addressable market segments.

VIII. CONCLUSION

A. Concluding Remarks

The Vertigo Residency, especially the interdisciplinary exchange between artists and industrial companies, provides exciting approaches with the potential to discover new markets. The interaction not only provides new perspectives, but also promotes an awareness of technical developments that can have a lasting effect on the value of the customer. The path to this goal, however, is marked by borderline experiences, as new thinking often leads to the limits of what is technically possible. Especially with products that require a lot of explanation and cannot or may not be operated by the artist himself, there is an increased support effort that is difficult to estimate in advance. In combination with a shortened project duration and an evolutionary design process, a longer project duration would have been desirable. However, if you look at the result, a positive balance can be

drawn, which is not least due to the extremely appreciative communication and the professionalism of the project partners.

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