CNC Compliant Methods of Design

Understanding Technology

Pia Fricker, Oskar Zieta
Institute of Building Technology, Department of Architecture, Swiss Federal School of Technology, Zurich, Switzerland
http://www.caad.arch.ethz.ch, fricker@hbt.arch.ethz.ch, zieta@hbt.arch.ethz.ch

This paper investigates new design methods, showing the experimental use of new digital tools, CNC-techniques and technologies so as to expand the definition of contemporary architecture. This investigation of new technologies extends the traditional practice of architectural design to include issues of design, multimedia, programming, control systems and fabrication by using computer controlled machines. The main teaching and research focus of the Master of Advanced Studies in Architecture (MAS), Specialization in Computer Aided Architectural Design (CAAD), Prof. Dr. Ludger Hovestadt, is the computer based architectural design and its automated production.
The aim of our research and teaching project is to achieve a close connection between design and production by embedding the "digital chain" in the whole process. The digital chain is a design and production sequence with no analogue steps; the process offers high flexibility in terms of design and production. The use of new digital tools in architecture extends the profession beyond traditional design.

Keywords*: Digital Methods of Construction; Representation; Integration of CNC technology in Education; "Digital Chain"*

Historical Background

During the last five years, the Chair for CAAD at the ETH Zurich is searching for strategies on how to implement the "Digital Chain" into the architectural practice. Research and teaching focus is to develop a design and production process, which is at any point computer supported and provides digital interfaces. Questions like: "What effects has the application of the theory of mass customization on building production and the formal language of architecture?", are subject-matters of our work. These questions are driven by the current development of contemporary architecture. There is an obvious trend to free-form architecture with a complex geometry and structure. Aspects like efficiency, complexity and refinement are basic principles of any architectural design, which have to be solved in an adequate manner.

Introduction

The use of CNC fabrication machining and the in-

Figure 1
Overview of the introduced CNC machines.

teraction between design and production was the focus for the final three-week module "CNC-Design with Sheet Metal", of the last years MAS course.

Within this course the students were limited to one material – structural plate steel. The use of this material removed the students from their previous experiences. Short skill building workshops provided a foundation in the skills of welding, CNC laser cutting, and CNC folding and forming of the steel.

The use of sheet material focused the primary design topic onto issues of geometry, folding and forming. From a manufacturing perspective, the materiality, working process, and fabrication efficiency were addressed. From an architectural perspective, the relation between two-dimensional material and the three-dimensional form raised issues of structure, assembly, and design.

The usage of the building material steel was strongly increasing within the last decades. Obvious reasons are the profitable material properties and on the other hand the further development of the production possibilities, especially the usage of CNC machines, which allow a precise and affordable machining of steel.

These machines are nowadays able to e.g. bend products, which until these days, had to be assembled out of several pieces, complex outlines of free-form elements can be laser cut. Punching machines punch programmed ornaments out of 5mm thick material. Therefore the integration of CNC machines is more and more effecting the appearance of an architectural design.

The specific power of the digital tools should be

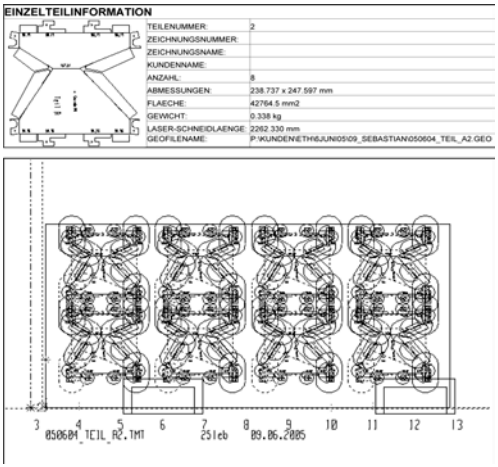


Figure 2
Automated cutting plan

investigated into the design process, in a technical and aesthetical point of view.

During the three weeks time period, the students were asked to fulfill four assignments. The combination of innovative concepts of CAAD & advanced fabrication machines allowed the participants first hand experience with the future of architectural design and production.

Digital Chain

The digital chain is a design and production sequence with no analogue steps; the process offers high flexibility in terms of design and production. The single steps are programmed units, which are connected via several programs. The computer is not regarded as a passive drawing utility, but rather as an active tool influencing the design process.

The architect develops rules, relations and the idea of the final product, which can be optimized by the program. The traditional role of an architect as a "form designer" moves to the role of a "process designer".

This method allows an efficient construction of complex structures as well as the development of new construction possibilities which result of the specific criteria's of the machine.

Course Description

In cooperation with the Trumpf AG Swiss, the students were asked to develop in four assignments "steel-objects", whereas the form and the details result through the limitation and potentials of the machines and the preset material.

New technologies allow the direct output of digital design into physical architecture. The course ended with a group work, combining all aspects of the "Digital Chain". As mentioned in the chapter "Historical Background", the aspects of efficiency, complexity and refinement should be significant characteristics of the research work. Efficiency: through programming and the usage of parametric units, the design can be produced in variants, without additional expenditure of time. Mass customization is getting affordable. Complexity: by programming single components of the design, complex structures can be realized. Refinement: CNC machines are producing the components with an accuracy, which can hardly be reached in a traditional way.

Assignment 01-04

The goal of the first assignment is to design an object with a given volume, using a CNC laser-cutting machine and a pneumatic bending machine. The designed object can either be without scale, an interpretation of a construction method, or an architectural object.

Within the first task, students achieved first working experiences, investigated the material properties and the knowledge of using CNC machines. Design aspects, which result of the possibilities of the machines, were implemented in the design process of the students.

The second assignment focuses on designing with the materiality and the assembly of steel, using specific CNC equipment. The task for this assignment is the design and construction of a "paravent", a semi-transparent movable wall construction. The design may be either hanging or freestanding, and should focus on the tectonic and aesthetics of the material and assembly system.

A special machine, a laser-press-machine was used for this task. This machine, both cuts and bends material, and has several proprietary steel connection designs that can be used as a starting point for design.

Already after their first task, the students changed their way of designing. They carefully investigated the possibilities of the machine and included the technical aspects into their design process. The form of their wall-construction was not any longer a pure aesthetical process; the economical aspects and the profound acquaintance of the machine introduced the students a new way of designing.

The third project, a group work, is a symbiosis of both, the production skills and the design skills, in-

Figure 3
Final objects of the first assignment: Rafael Schmidt, Tobias Bonwetsch, Bergit Hillner, Jan Przerwa, Bart Mermans and Arno Schlueter.

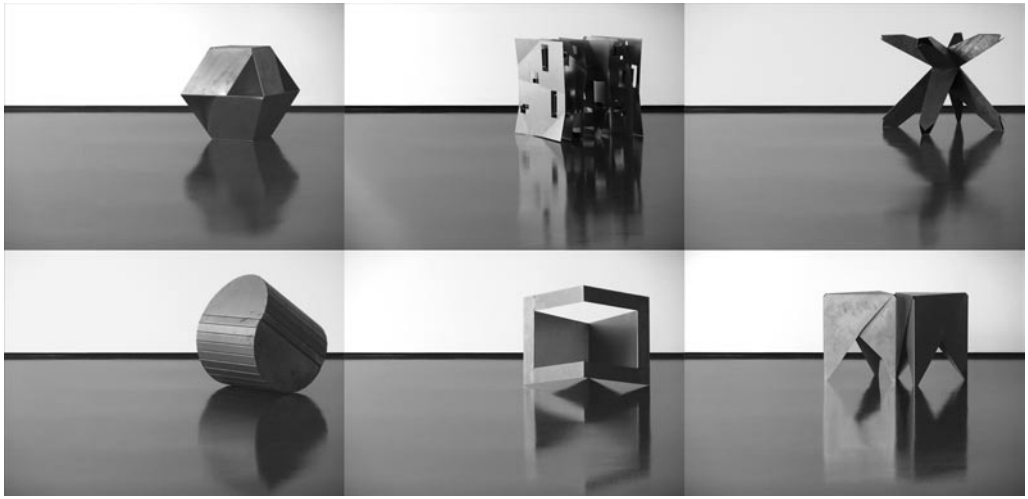
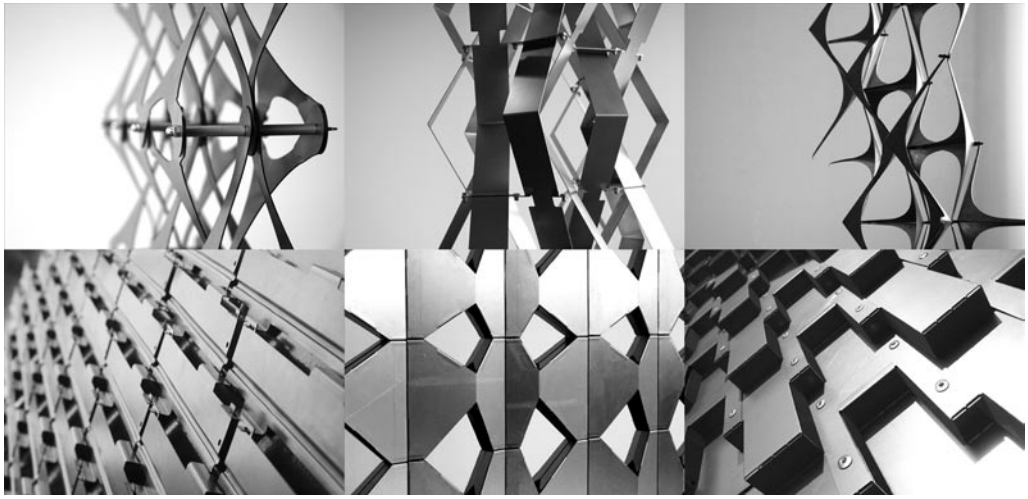


Figure 4
Final objects of the second assignment: Arno Schlueter, Jan Przerwa, Rafael Schmidt, Bergit Hillner, Sebastian Gmelin and Oskar Zieta.



cluding the programming of the design work.

This group project is to design, develop, and produce a simple prototype for a table or bench construction. The entire process will take place over a single day in cooperation with professional craftsmen. The competence and understanding of the material and processes of fabrication, the speed of development, and the professional usage of the machines are the main focus for this assignment.

The designs should be worked at the formal and detail level, and should be creative interpretations of the analysis so as to accommodate new concepts for usage.

For the final assignment, the participant groups are asked to analyze the requirements for outdoor furniture, as well as the requirements, commercial

Figure 5
Final Object of the third assignment: group work.

and structural, of seating objects and to produce a prototype of their design.

In collaboration with the Swiss company Burri AG, the students worked in groups for the analytic component of the task. After the analysis, the craftsmen introduced the machine to the students and made them familiar with different possibilities of steel-connections and welding seams.

The assembly and the connections of the outdoor furniture came to the fore. The Students reached the level that they could understand the whole system and could develop out of this knowledge a design project. They were searching for parametrical solutions to reach a high level of efficiency.

Outlook

Modern computer-3D-modelling-software makes it nowadays easy for architects to design complex free-form structures. Therefore the designs are getting more complex and often almost impossible to realise. As long as a complex design form is not programmed, even minor changes will rise up the amount of work and are often changing the whole project. Our course for postgraduate students is focusing on that issue and is searching for interfaces between information technology and architecture.

A design of a project should be regarded as a dynamic process. Besides the planning period, we consider the architect also responsible for an efficient workflow during the production. Especially in complex building projects, the architects and clients are searching for an efficient solution for the realisation. The aim of the course is to introduce architects into the "Digital Chain", to make them familiar with the programming technologies already in the design phase of the project and the integration of the technical aspects of the CNC production.

By integrating the knowledge of the possibilities of CNC machines, architects are capable to influence the outlook of a design. The CNC machines can be regarded as a "design input". The chair for CAAD introduces recent developments of information technology and integrates them into a practical context.

Within the course the scale of the product was on a smaller level, which encourages students to work in a more experimental way. We could observe a shift in the design methods during the weeks, starting from a traditional way and passing to an experimental way of designing. The achievement of an

Figure 6
Final object of the fourth assignment: group work.

integration of new design methods into their profession is the main goal of the course.

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References

Huber, B. E.: 1971, Jean Prouvé: prefabrication: Structure and Elements, Praeger Publishers

Huber, B. and J. Prouvé: 1971, Jean Prouvé une architecture par l'industrie. Artemis, Zurich.

Matthias, L.: 1998, Mobile Architektur: Geschichte und Entwicklung transportabler und modularer Bauten, Deutsche Verlags-Anstalt, Stuttgart.

Rèuegg, A., B. Krucker: 2001, Konstruktive Konzepte der Moderne Fallstudien aus dem 20. Jahrhundert. Verlag Niggli, Sulgen.

Schmiedel, K.: 1993, Bauen und Gestalten mit Stahl Entwerfen, Konstruieren, Erhalten. Expert Verlag, Ehningen bei Böblingen.

Sulzer, P. and J. Prouvé: 1991, Jean Prouvé - Meister der Metallumformung: das neue Blech, Móller, Köln.

Sulzer, P.:1999: Jean Prouvé: oeuvre complete – complete works, Birkhäuser, Basel.

TRUMPF: 2004, Faszination Blech, TRUMPF Werkzeugmaschinen GmbH + Co. KG.

Vénacque, Axel: 2001,Jean Prouvé: le pavillon du centenaire de l'aluminium, 1954-2000 : un monument déplacé , Jean Michel Place, Paris.

Vondran, R.: 1999, Stahl ist Zukunft von der Weltausstellung London 1851 bis zur EXPO 2000 in Hannover, Klartext Verlag, Essen.

Wachsmann, K.: 1959, Wendepunkt im Bauen. Krausskopf, Wiesbaden.