Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences
Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

<table>
<thead>
<tr>
<th>Personal information</th>
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<tbody>
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<td>Name</td>
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<td>Student number</td>
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<td>Telephone number</td>
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<td>Private e-mail address</td>
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<th>Studio</th>
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<td>Name / Theme</td>
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<td>Teachers / tutors</td>
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<td>Argumentation of choice of the studio</td>
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<th>Goal</th>
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<td>Location:</td>
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<td>The posed problem,</td>
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in the wrong way will encourage decay. This has mainly to do with the orientation of vibers in wood. Using wood in an additive manufacturing process could solve these problems with the advantage that designs which are not possible with ‘old fashioned’ production methods become possible.

<table>
<thead>
<tr>
<th>research questions and design assignment in which these result.</th>
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<td>- What are the esthetic material properties of wood.</td>
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<td>- What are the structural material properties of wood.</td>
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<td>- What substances does wood have?</td>
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<td>- What is additive manufacturing</td>
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<td>- What is the state of the art technology in the usage of wood in an additive manufacturing process?</td>
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### Process

#### Method description

**Problem statement**

Additive manufacturing is a production technology which has developed into a widely used technology. Especially for small production batches additive manufacturing is a profitable production technology. Also it is used for the creation of mock-ups or prototypes. Another benefit of additive manufacturing is the fact that the labour can be outsourced to the machines which are used for this production technology. The 3d cad models which are needed for this production technology can easily be shared and reproduced at another printing device.

Another advantage of additive manufacturing lies in the fact that complex shapes can be made which are not feasible or not remunerative with conventional production technologies such as milling, cutting drilling or turning. These stated technologies are also known as substracting manufacturing technologies which means they remove material in order to shape the material to the final needed shape. The waste material is often used for wood based building materials or even used as fuel. Additive manufacturing adds material which means it only uses the amount of material which is needed. This means there is no waste material. This could potentially save a lot of wood, which could be beneficial for the climate and ecosystem.

Additive manufacturing is developed to use various sorts of plastics, metals, composites and concrete. until now, the most used composite in building materials, natural wood, has not been used in an additive manufacturing process. The potential of using wood in an additive manufacturing process lies in the complex shapes which could be made, the savings of
materials, the wood properties which could be used in a more optimal way and the ease to reproduce an object with high accuracy without the costs of labour.

This research will investigate if there are options to use wood in an additive manufacturing process such as 3d printing.

GOAL

Exploring the opportunities of the use of wood in an additive manufacturing process

RESEARCH QUESTION

Can wood be used in an additive manufacturing process?

SUB QUESTIONS

- What are the esthetic material properties of wood.
- What are the structural material properties of wood.
- What substances does wood have?
- What is additive manufacturing
- What are the advantages of additive manufacturing?
- What is the state of the art technology in the usage of wood in an additive manufacturing process?

PROCESS

METHOD DESCRIPTION

Phase 1: Literature & exploratory reading
In order to get a clear mindset on the goal of this research, exploring the opportunities of the use of wood in an additive manufacturing process, literature was needed. First of all, literature on the state of the art of using wood in an additive manufacturing process was needed. This resulted in various sorts of processes which are related, but use parts of the composition of wood. These processes will be described in the report in order to give a clear view on these methods. Sources which were used are research papers, internet video’s for processes which were not described in research papers, and contacts with researchers of Wageningen University. Search terms which were used are:
The next step which was taken is doing research on the material wood. In order to do so, various books on wood were read, research papers were read and researchers from Wageningen University were contacted. Search terms which were used are:

- wood
- wood properties
- structural properties of wood
- esthetic properties of wood
- composition of wood
- cellulose
- lignin
- timber

The next step was to do research on additive manufacturing, in order to get a clear view on this technology and its advantages. Sources such as research reports were used to gain information.

In order the following search terms were used:

- 3D printing
- Additive manufacturing
- Rapid prototyping
- Additive fabrication
- Stratified additive manufacturing

phase 2: Literature survey
The first part of the report will give answers to questions such as

- What are the esthetic material properties of wood.
- What are the structural material properties of wood.
- What substances does wood have?
- What is additive manufacturing
- What are the advantages of additive manufacturing?
- What is the state of the art technology in the usage of wood in an additive manufacturing
process?

This to give a clear understanding on the material wood, the technology additive manufacturing and the state of the art in using wood in additive manufacturing processes.

Offcourse this needs to be narrowed down. The questions about wood will focus on esthetic and structural properties of wood in general. This means that these values are not specified per specie of wood, but are specified as ratio’s for for example softwood or hardwood. Esthetic characteristics will be explained in such a way these are not wood specie related but more explained as general characteristics of wood.

Also multiple processes of additive manufacturing will be explained, so we have a clear view on potential processes which could be used for the use of wood in an additive manufacturing process. Finally we will do some investigation on the state of the art of the use of wood in an additive manufacturing process. The results of this part will be elaborated in the report, in order to see if there are some interesting starting points for further research and development.

Phase 3: concepts
Based on the results of the literature survey some basic components of wood will be bought and used in some tests. The test methods, will depend on the outcome of the literature survey and the state of the art in using wood in an additive manufacturing process. The goal of these tests is to see if it is possible to use basic components of wood in such a way that the components are bond together in to a solid material. In this stadium the material need to be checked on things as esthetic properties and some (structural) material properties in order to see how they relate to wood. Multiple methods will be tested and the results will be elaborated.

Phase 4: design of wooden node & production
In phase 4 a node made out of wood will be designed which is difficult to be made with traditional woodworking methods. The goal is to produce this node with additive manufacturing methods so the methods of phase 3 can be tested. The physical models which are the output of the production tests in phase 4 need to be tested. This means that during phase 4 structural calculations need to be done on the designed node. In order to do so, a design will be made in grasshopper and structural calculations will be done with the plugin Karamba. The output from these simulations are needed in phase 5 to see how the printed material behaves compared to wood.

Phase 5: Testing and verifying results.
The node which is made in phase 4 need to be tested. Therefore the structural calculations of phase 4 are needed. The node will be tested in compression and tension tests in order to see how it behaves. the values from the physical test will be compared with the values from the computer calculations.
Phase 6: Final product
The final product will be the elaboration of a node which is made with one of the methods of phase 3.
The final product will be supported with schematics, calculations, simulations and drawings. and can be used for further research in order to see if it is applicable on industrial scale.

Literature and general practical preference
Books, research papers, researchers, companies
Trying to get in contact with Wageningen university

Reflection
Relevance
Additive manufacturing has become a more used production technology for small production batches of various products. Where complex shaped products were expensive and timeconsuming to built, nowadays even shapes which can not be build with conventional methods can be build with an additive manufacturing process. Thanks to the ability to split up objects in layers and compose them layer by layer, even the most complex shapes have become possible to build.

The additive manufacturing process, which can be described as a production process based on adding layers of one of material and bind these without the use of an additional type of material such as a glue, has been developed to use various sorts of plastics, metals and concrete. Suprisingly, natural wood, one of worlds most used building materials, is not developed yet to be used as a stand alone material in an additive manufacturing process.

Current production processes which are used for natural wood are substracting manufacturing processes. These processes can be described as processes where material is substracted in order to shape the matrial to the need of its final design. Examples of these techniques are cutting, milling, planing or even simple things such as driling. The result, lotts of waste material what can’t be used as natural wood and is used as bio-fuel or is processed into wood based building materials.

With the technical development of mankind in the past two centuries, nowadays recourses are depleting more rapidly than ever before. Allthough timber is a natural material what can be harvested from trees, the timecycle to grow a tree is much longer compared to the amount of timber that is needed within this timespan. As result, rainforests are harvested with major effects. Animal species are threatened with extinction and climate change is encouraged.

The use of wood in an additive manufacturing process would not only release new production options, it could also have technical and environmental benefits. which in the end will benefit human mankind.