Hogeschool van Arnhem en Nijmegen
HAN University of Applied Sciences

HAN Master Major Project

Major Project Plan

Using FANUC R-2000iC/210F (6-axis robot) for improved efficiency in FRC parts formation

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Background

Fiber-reinforced composite materials (FRC) are seeing a widespread use in a large number of applications ranging from aerospace systems over renewable energy production to automotive parts [5] [2]. These composite materials generally provide high specific strength and improved stiffness compared to other materials [3]. Through the combination of different materials, desirable mechanical properties like low weight with high stiffness can be achieved that would be hard or near impossible to recreate with single compound materials [7]. The attributes of an FRC can generally be described as the combination of three components [6]:

- The matrix, made of a polymer. This polymer can either be applied as a resin that hardens irreversible or a thermoplastic is used, that needs to be heated for application.
- The reinforcement component which consists of fibres with high strength and modulus. These days preferred materials are glass, carbon or polyethylene fibres.
- The fine interphase region. It's the interface between the matrix and the reinforcement that transfers the load between these.

FRCs can look back to a long history since the beginning of the 20th century with phenolic sheet Bakelite being the first fibre-reinforced plastic. Bakelite, a thermoset being the matrix was combined with different fibre materials like paper, cotton fabrics, or synthetic fabrics to create parts that can meet diverse mechanical, electrical and thermal requirements. [4]

In this project, a thermoplastic matrix will be used together with carbon or glass fibres. Besides the use of more modern polymers and fiber materials, new production techniques are incooperated. The mixed reinforced thermoplastic being supplied as pellets in various sizes for different properties is dried and then melted in an extruder through a continuous process. The material is then portioned into pieces by a guillotine and combined and stacked into assemblies by a delta robot. These assemblies are then brought to temperature again before being loaded into a hydraulic press with a mould by a FANUC R-2000iC/210F 1.1 industrial robot arm. [1]

Problem Definition

Assemblies of hot, formable Thermoplastic are delivered on a conveyor belt in varying positions after being reheated in an oven. The assemblies then need to be picked up with a FANUC R-2000iC/210F 6-axis Industrial robot arm from the conveyor belt through a small window in a heat shield that keeps the assemblies warm. The Industrial robot then swings over to the press when it is open and the mould is free. The assemblies are then placed inside the mould at desired spots while making sure, the robot arm does not collide with any part of the press. After all parts are placed, and the robot arm has pulled back in a safe position, the press is activated and forms the parts with heat and pressure. When the forming process is finished, the press opens, the product is picked by the robot arm and placed on another conveyor belt for further processing. As the press is free, the cycle can repeat. [1] The overall goal of the Smart Production Cell is to drive down cycle time for these composite parts from ca. three minutes to one minute. Also the robot needs to cooperate with different parts of the process like the oven and the press and it plays a major role in synchronization between the subprocesses.

Figure 1.1: FANUC R-2000iC/210F 6-axis industrial robot arm

Project Objectives

A control strategy for a robotic arm with efficient movements guided by information from previous subprocesses needs to be implemented in Software.

Requirement Analysis

Certain conditions need to be fulfilled to make the project a full full success. These can be split up into external and internal factors.

External requirements:

Power Supply In order to supply the whole production line with enough energy, 400A fuses need to be installed in the 400V 3-Phase building connection.

Surrounding Subprocesses All subprocesses (extruder with supply hopper, conveyors, delta robot with gripper, press with mould, robot gripper, oven with heat-shield) need to be in place and running on their own.

Test Material Some kind of test material needs to be supplied to demonstrate all abilities of the robot arm.

Internal requirements:

Fieldbus An Ethernet network needs to be set up to host the communication via Profinet between the subprocesses.

Software For simulation Visual Components and for control ROBOGUIDE with Karol Programming Language as well as TIA Portal need to be made available, installed and configured.

Robot Placement The final placement of the robot is not yet determined and the robot needs to be bolted to the ground in its final position before it can be used.

Robotic Gripper Another member of the SPC-team, Laurence Potter, currently develops a robotic gripper for dual functionality of picking the raw assemblies as well as the final product. The progress needs to be monitored and design choices need to comply with control choices.

Activities and Products

With regard to the goals, following activities need to be carried out which produce below mentioned Products.

Activities:

Mounting and Floorplan All parts involved in the process except from the press are not yet bolted to the ground. A floorplan needs to be developed based on simulations in Visual Components. Together with the SPC team and consultants from Quing this floorplan will be developed. Then the FANUC R-2000iC/210F together with all other components can be moved to their final position and bolted to the ground.

Wiring The FANUC R-2000iC/210F is not connected to power and to its accompanying R-30iB controller. Cables need to be connected to the robot and the controller.

Commissioning The FANUC R-2000iC/210F although being a second hand robot has never been put into operation at the SPC. The robot and its R-30iB controller need to be placed into operation step by step with several function tests.

Fieldbus - Hardware A Profinet fieldbus network needs to be designed and installed to connect all components with each other for exchange of data and commands. For this, an Industrial Ethernet network needs to be set up with a Profinet Stack. Twisted-Pair-Cables need to be cut in the right length and equipped with RJ45 connectors. Also additional network components like an industry grade switch for routing and Ethernet hubs as well as USB network adapters for package sniffing need to be selected and procured.

Fieldbus - Software To use Profinet, all involved network interfaces, input and output of data as well as global commands and flags need to be configured to make all devices communicate with each other.

Modelling To develop and test a controller for the FANUC R-2000iC/210F, a simulation in software will be made with the help of Visual Components. To get a deeper understanding of the robot arm, a kinematic modelling will be done.

Sensors All virtual and physical sensors necessary to guide the FANUC R-2000iC/210F will be identified, and connected to a Profinet member.

Control Scheme A control scheme for the FANUC R-2000iC/210F will be developed with the help of an iPendant connected to a R-30iB Plus controller and Karel Programming language in the software ROBOGUIDE to fulfill the desired tasks.

Programming Parts of the program for integration of the FANUC R-2000iC/210F robotic arm into the overall production line will run on a Siemens Simatic S7-1500 Programmable Logic Controller (PLC). This PLC is the brain of the plant where all information from different subprocesses comes together and is processed.

Testing After developing a program to control the robot, extensive testing is needed to verify safety and assure 24/7 operation.

Report A report will be made, and drafts will be sent to the supervisors for feedback.

Fine Tuning When all subprocesses work properly together, fine tuning can be applied based on observations to drive down the cycle time or reduce energy consumption.

Products:

Floorplan Floorplan including all major relevant components

Model and Simulation Model and simulation of the robot arm

Control Scheme Control scheme implemented in software

Presentation and Report Major project report and a real-life presentation of the movements of the Fanuc R-2000iC/210F

Safety plan A basic summary of procedures for safe operation of the robot

Organization

HAN Automotive has founded a Smart Production Center(SPC) in order to research the possibilities for improvement in mass production of lightweight automotive parts using Fibre Reinforced Thermoplastics (FRT). The SPC is located in the Mobility Innovation Center (MIC) in Industriepark Kleefse Waard (IPKW) in Arnhem.

The SPC provides a room for companies to collaborate with the HAN. Some of these companies interested in the project and inclined to help are located in the direct surroundings of the MIC building such as Quing who are involved with the simulations.

Peter Verschut, the Program Manager of Automated Composites and Didier Polling, researcher in lightweight structures, keep an overview over the activities of all students involved. Suzanne Ezendam is Project coordinator and head of the building and labs.

Master Level

This Thesis project demands creating a model of the robotic arm. The modelling of the 6 axis FANUC R-2000iC/210F will require knowledge from Systems Modelling. If parameters cannot be determined, they can be found with techniques from Systems Identification. Based on this model, a controller can be developed and a range of paths can be found through inverse kinematics. This controller is an extension of the subjects taught in the module Advanced Controller Design. The number of resulting paths can then be narrowed down

further, for example based on safety restrictions or the desired working area of the robot. This will be a further development of the knowledge conveyed in Applied Control Strategy from the module Applied Control. This results in a control scheme that can be implemented in Matlab and simulated numerically, and probably also graphically. The basics of implementation were shown in Controller Implementation from the module Applied Control

I will demonstrate my master level by understanding and simulating the dynamics of a 6 axis Robot arm.

Restrictions

- To fully demonstrate all abilities of the FANUC R-2000iC/210F, all sub-processes need to be complete. Also test material will be needed that can be picked up and placed.
- The robot arm currently does not have a gripper. To demonstrate the picking abilities in real life with test material, this gripper will need to be designed in time.

References

[1] Jens and Timo Jacobs Lubbers. *Smart X-Cell Production SYSTEM RQUIREMENTS DOCUMENT*. Tech. rep. HAN automotive Research, Jan. 2015.

[2] C.A. Lawrence. *High Performance Textiles and Their Applications*. Jan. 2014, pp. 1–437.

[3] Angela Madeo. *Generalized Continuum Mechanics and Engineering Applications*. Elsevier Science, Sept. 2015. ISBN: 9781785480324.

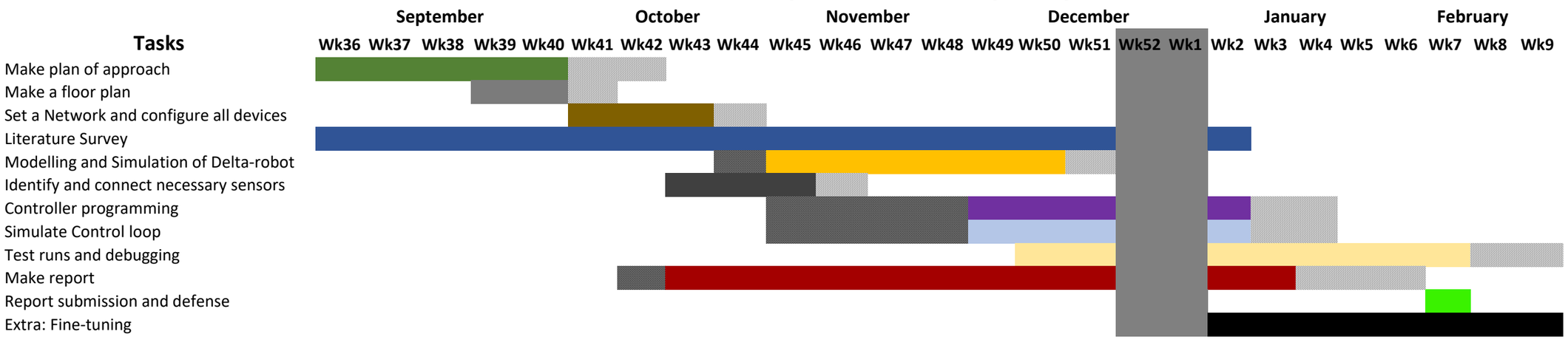
[4] nimrodplastics. *Bakelite*. URL: `http://www.nimrodplastics.com.au/product-bakelite.htm`.

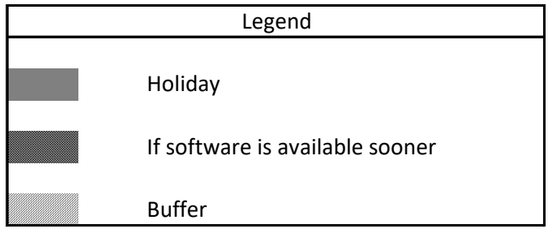
[5] S.J. Park and M.K. Seo. *Interface Science and Composites*. Interface Science and Technology. Elsevier Science, 2011. ISBN: 9780123750495. URL: `https://books.google.nl/books?id=DewhZ53WgLwC`.

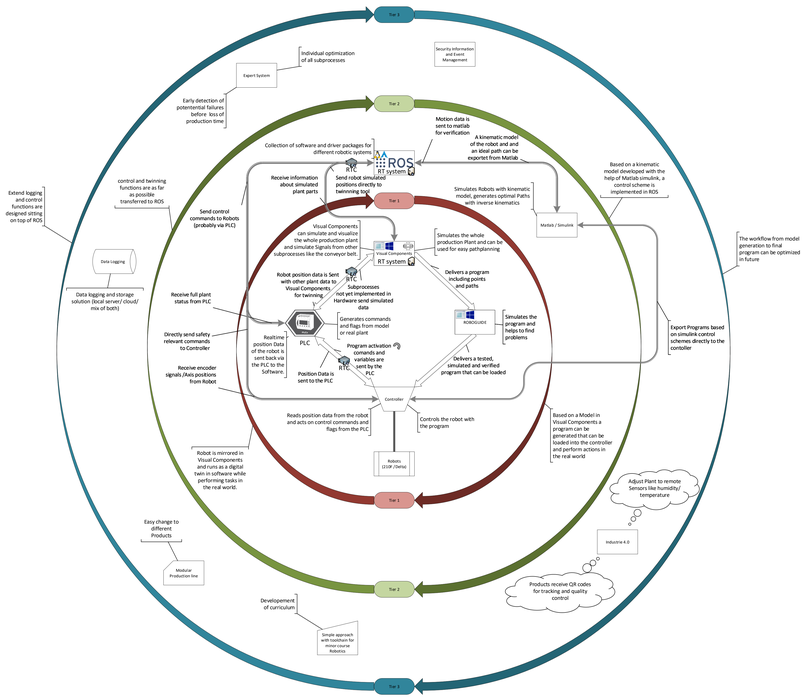
[6] Zohaib Sultan et al. *Advanced Dental Biomaterials*. June 2019. ISBN: 9780081024768.

[7] George Voyiadjis and Peter Kattan. *Advances in Damage Mechanics: Metals and Metal Matrix Composites With an Introduction to Fabric Tensors*. Jan. 2006. DOI: `10.1016/B978-0-08-044688-2.X5000-0`.

Time plan for Master Major Project







Stefan van Stenkenberg – Ground switch?

Repro for Poster

Part of greater cybersecurity concept, maybe including honeypot etc.

Tier1

Plant integration

Plant setup
Visual Inspection of the Plant and reading of datasheets
Planning of the fieldbus for power, data exchange and control messages
Ordering of parts
Configuration of Flexi Router
Installation of the fieldbus
Firewall design
Connection to existing MES network
VPN Access
Plant setup

Measurements and Floorplanning
Current Status
Defining ideal Positions with VC
Are Other components ready?
Current Status
Moving to ideal position
Bolting components ready for final installation on the ground
Are all necessary components in place?
Analyze Safety requirements
Read about safety standards with robots
Expert Interview with students responsible for safety
Design of Fence and other safety relevant equipement
Installation and implementation of safety features
Testing of safety features

Current Status

Robot Movements

Robot Comissioning
Inspection of the Plant and reading of datasheets
Learning to
- load a file from USB
- load a program
- steer the robot
- set the userframe
- additional functions...
Getting familiar with the controller and Flexpeder
Current Status
Is electricity available?
Connect Controller to electricity and robot
Minor functional tests without movements
Is the controller set up in a safe test configuration?
Test Movements
Load a small program created in Robogudie
Does the robot perform as expected?
Connect Controller to the PLC
Introduce Controller to commands form the PLC
Robot Comissioning

ROBOGUIDE program adjustment

ROBOGUIDE Setup
Getting familiar with Robogudie
RTFM!
Loading a Program from VC
Is the program loaded and movements simulated Robot arm without throwing error messages regularly?
Current Status
Analyze the program code by comparing with a program created in ROBOGUIDE
Debug
Change settings in ROBOGUIDE
Change the export Script in VC
Connect Robogudie to the controller
Online testing of the program
ROBOGUIDE Setup

Twinning

Visual Components twinning
Modifing of the plant with exact positions
Generation of a control Program
Export of the program to ROBOGUIDE
Current Status
Connect to PLC
Make of existing Visual Components a Server values available
Test Plant behaviour in Visual Components
Adjust twinning VR to comply with realworld coordinates
Visual Components twinning

Showcasing

Showcasing in November
Current Status
Prepare Program
Prepare Robots
Prepare rest of the plant
Are Robot, Controller and plant ready to execute the planned movements?
Short observed test
Install VC Twinning and VR system
Set up cameras, remote access and failure detection equipement
Long test run 24h+
Design and install „Show effects"
Persare Presentation for companies
Briefing of Staff
Showcasing in November

Tier 2

Modelling

Robot Model
Visual inspection of the Robot and reading of datasheets
Search plan
Current Status
biological comparison (Arm)
Expert Interview with Trung for Modelling
Collection of Papers on Modelling of a 6 axis Robot arm
Process Definition
Combination and summary of collected knowledge
Data Flow Diagram
Model equations
Mathematical Modelling
Probably with inverse Kinematics (Trung's preferred approach)
Simulation
Implementation of the model in Matlab/Simulink
Simulink robotic toolbox petercorke
Robot Model

Controller Design

Robot Controller
Current Status
Data collection through programs created with ROBOGUIDE
To get an idea of the robots behaviour
Expert Interview with Trung for Control
Collection of papers on control of a 6 axis robot arm
Combination and summary of collected knowledge (written)
Mathematical development of a robust robot controller
Implementation of the controller in Matlab/Simulink
Robot Controller

Matlab Secure code?

ROS Implementation

Robot and Plant control with ROS
Current Status
Get used to ROS
Others = Guy who set up computer with ROS, another guy at DELFI
RTFM!
Read Book on ROS
Expert Interview with Trung (and others) for ROS
Remeber! A few hours of trial an error can save you sevral minutes of looking at the README
Combination and summary of collected knowledge (written)
Set up ROS for our needs
Import Model with Controller to ROS
Connect to PLC
Make simulation and control function in ROS
Connect to Robot via PLC
Control Robot live via ROS
Robot and Plant control with ROS

Overall Control strategy

Overall control strategy
Overview over all subprocesses
Expert interview with engineers responsible for their subprocesses
Current Status
Are all subprocesses ready and connected?
Determine timings and cycle times
Expert interview with engineers responsible for their subprocesses
Design overall strategy with subprocess experts
Improve overall strategy with subprocess experts
Test
Observe and measure
Do all subprocesses work together seamlessly?
Collect problems
Presentation to Project owner
Overall control strategy

Thesis Report

Why individual control strategy