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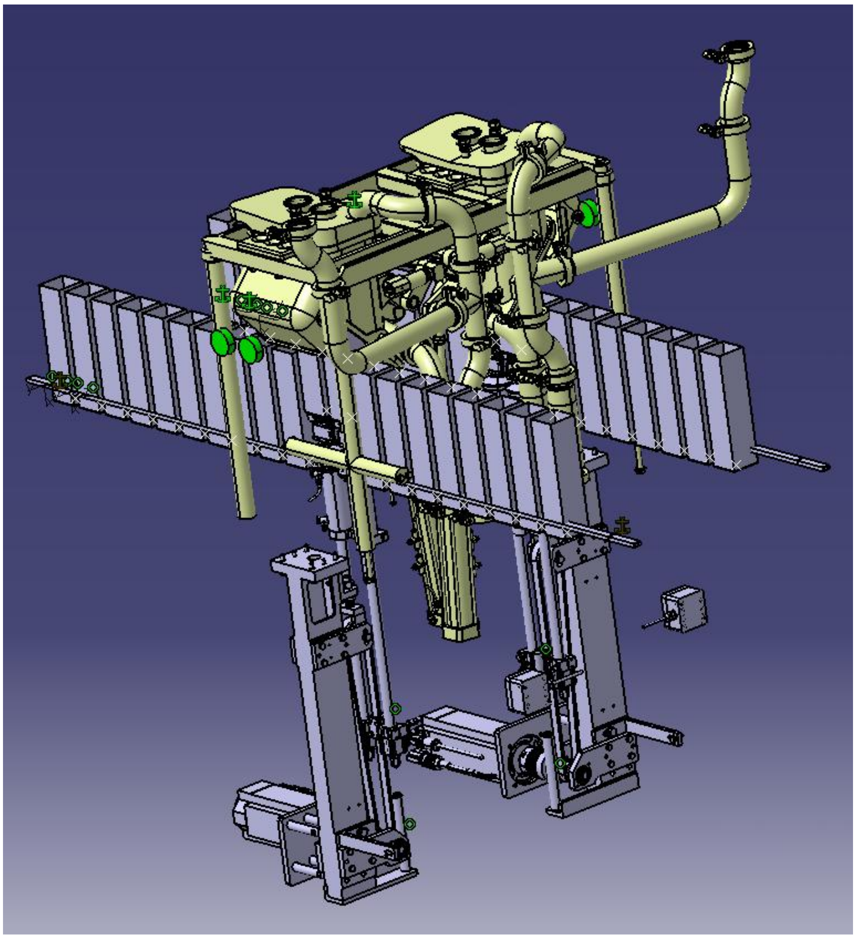

Virtual preparation of Tetra Pak Filling Machine

Master of Science Thesis in Systems, Control and Mechatronics

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Abstract

Tetra Pak who is the world's leading food processing and packaging solutions company, is interested in shorten the Time To Market when developing new machines. By introducing simulation in a virtual environment it will be possible to work on both the mechanical design and control software in parallel. Using a virtual environment also provides tools for testing and validating control code prior to live testing. When introducing simulation tools, it is also important to maintain efficiency and not redo work that already been done. Therefore the ability to reuse the work from the mechanical engineers in the simulation is essential. Another aspect is the possibility to use the simulation for optimization and generating control code for the machine. Existing CAD-files can be used in the simulation software if translated and there are a lot of tools for translation of files between different CAD formats. Many of them are standalone 3rd party software, but there are also a few add-on developed by the developer of the simulation tools. Most of the translation tools can handle both the geometry and topology, but none are capable of transferring kinematic information.

Different tools for simulations were examined and evaluated according to their abilities to use existing CAD files and ways of extracting data that can be used for generating control code. A virtual model of the filling station in the Tetra Pak TR/28 was created in DElMIA by importing existing CAD-drawings and fitted with kinematics and internal logic.

Keywords: Simulation, Virtual production, Pro/ENGINEER, DELMIA, Process Simulate, 3DCreate, CAD translation, MultiCAx

Preface

This report describes a master thesis, performed during spring semester 2011 at the master's programme Systems, Control and Mechatronics at Chalmers University of Technology in Gothenburg, Sweden. The master thesis includes 30 high educational credits and has been performed at Tetra Pak and at the Department of Signals and Systems.

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Nomenclature

CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacturing
CGR	CATIA Graphical Representation
CNC	Computer Numerical Control
DMU	Digital MockUp
DS	Dassault Systèmes
HiL	Hardware in the loop
HMI	Human-Machine Interface
IGES	Initial Graphics Exchange Specifications
PLC	Programmable Logic Controller
PLM	Product Lifecycle Management
PPU	Product and production development
SiL	Software in the loop
STEP	Standard for the Exchange of Product model data
TTM	Time To Market

Contents

1 Introduction

1.1 Background

Tetra Pak who is the world's leading food processing and packaging solutions company, has a goal to shorten the the Time To Market(TTM) starting from the initiation of a new development activity to the delivery of a functional and verified solution. The present development process is highly sequential and essentially based on physical testing. It is assumed that an increased use of virtual development and verification methods as well as an increased degree of parallel activities will shorten the time to market as mentioned above. Tetra Pak is interested in methods of doing this. One mean of achieving this is to use virtual simulation tools in order to reduce the time spent building and testing on physical prototypes. Simulations are useful since they are cost effective, safe and investigative. One can try different concepts with no need to manufacture hardware, and thus able to test various errors without risking damage to human and machine. Simulation also improves the software side of a development project since a good virtual model can be used for testing and refining control code. In order to succeed with this there has to be an information model that ensures consistency with the CAD model[1]. Previous master's thesis[2] has investigated Hardware in the Loop using 3DCreate and exception handling during machine development. The filling station of a machine still under development was modelled in 3DCreate together with a HMI. It was controlled by a real PLC from Rockwell Automation and the communication was done with OPC protocol.

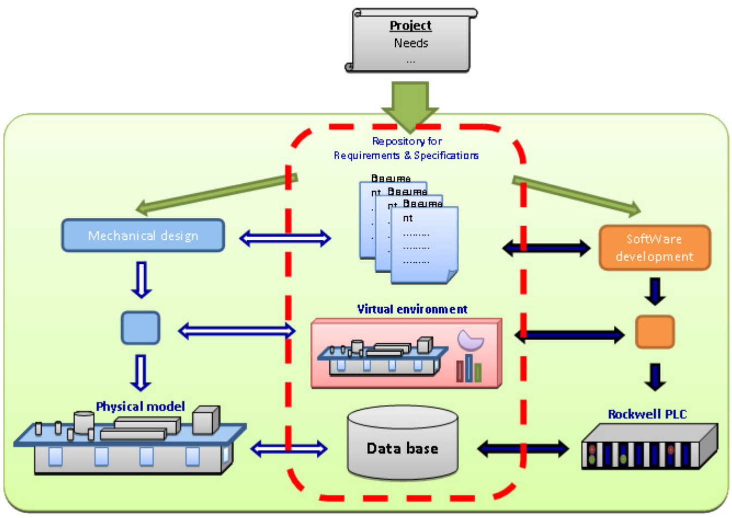


Figure 1: Concept vision of the preferred work flow at Tetra Pak.[3]

Tetra Pak in cooperation with Chalmers University of Technology has initiated a five year project where the goal is to to study virtual design methods and suggest suitable development work flows that enable better understanding of technologies in an earlier stage of a project. A visualisation of the preferred work flow is shown in Figure 1. To achieve this workflow, a common virtual environment has to be agreed upon so that models can be verified and developed in parallel.

1.2 Problem description

As part of the joint venture between Chalmers University of Technology and Tetra Pak, this thesis will investigate the current work flow for developing a new packaging machine. When designing a filling machine there are several tasks that are involved, based on the product and the required activities for fulfilling the product specifications, ranging from early design of the system to control functions. The machine must also be designed with consideration to cycle times which need to be not only short, but the same as the rest of the system so that a balanced flow through the machine is achieved. Another important aspect is the operations sequence and to find the best sequence is of great importance. Many aspects have to be considered based on mechanical and control solutions in order to design an optimal sequence of operations[4]. The focus for the thesis is marked in Figure 2.

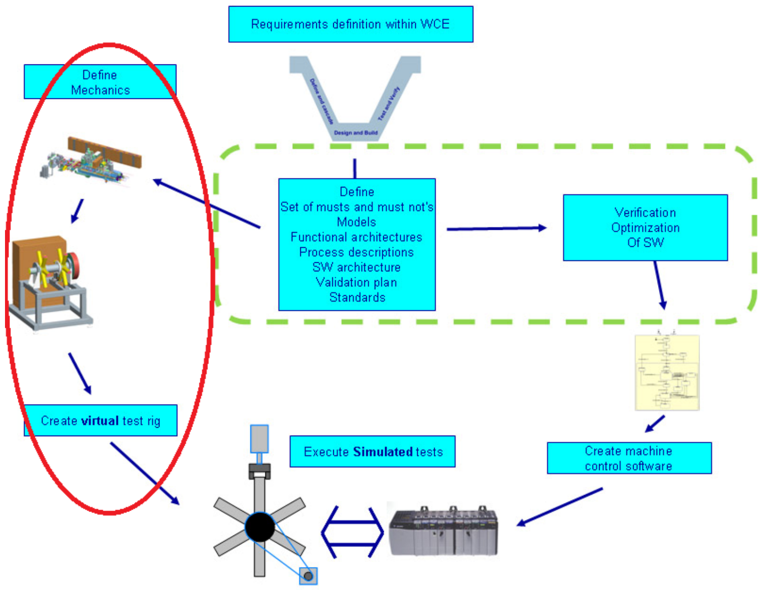


Figure 2: The area circled in red is the focus of this thesis.[3]

1.3 Purpose

There are lot of different tools for simulation to choose between. They all have their own advantages and limitations that need to be taken into consideration. The purpose of this thesis is to gain an understanding on the work flow of Tetra Pak and to learn the advantages and limitations of using specific simulation in a virtual environment.

1.4 Goals

The main goal is to find a suitable simulation tool for designing a virtual test rig, and to create a test rig in the simulation environment for the packaging machine Tetra Rex 28(TR/28) from Tetra Pak.

1.4.1 Subgoals

To be able to achieve the main goal some studies are performed. The current methods used at Tetra Pak when developing a new machine has to be examined and understood For the purpose of using virtual simulation as a tool in the development phase, the possibility to easily construct simulation models from CAD drawings will be investigated. The possibility to use data from the virtual model for generating state charts and PLC-code is also a vital part. As a final part a 3D model will be created that is good enough to be used in software verification. A virtual controller will be constructed in order to run the virtual test rig.

1.4.2 Exclusions

There will be a few exclusions in the project.

- Exception handling will not be included in the virtual machine.
- The process flow will not be optimized.

1.5 Computer used during project

	Dell OPTIPLEX 740
CPU:	AMD Athlon 64 X2 Dual Core 5000+, 2.61GHz
Memory:	2GB RAM
Graphics:	NVIDIA Quadro FX 550

1.6 Structure of the Report

In this first chapter an introduction to the thesis and the problem is given. In section two are some information about how the work is done at Tetra Pak when a machine is developed. Section three gives a short description about simulation followed by section four describes the different simulation software solutions and the possibilities to convert existing CAD-data to them.

Section five through seven gives the result and a discussion followed by a conclusion in section eight.

2 Tetra Pak

This section will give a short description on how the development of a new machine is accomplished at Tetra Pak today. Tetra Pak uses a method called the V-Model.

The V-Model is a tool developed for project management and project planning. It is meant to be a guide when planning and execute development projects, defining what results are to be achieved and the approach for developing the results. The V-model is also used to define who is to do what and when.[5]

The objective of the V-Model is to:

- Minimization of project risks
- Improvement and guarantee of quality
- Reduction of total cost over entire project and system life
- Improvement of communication between all stakeholders [5]

Limitation of the V-model

The organization and execution of operation, maintenance, repair and disposal of the system are not covered by the V-Model. However, planning and preparation of a concept for these tasks are regulated in the V-Model.

2.1 The V-model at Tetra Pak

Figure 3 shows the V-model used at system engineering at Tetra Pak.

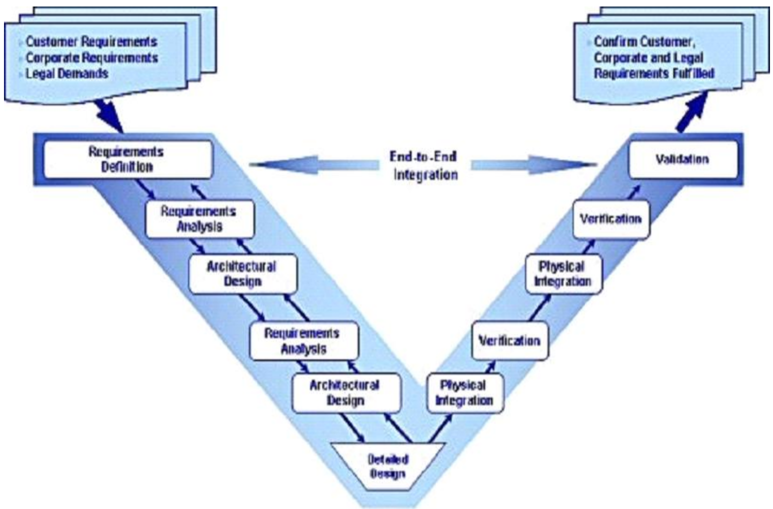


Figure 3: The V-Model used at system engineering at Tetra Pak. [3]

To better understand this V-Model it helps to examine Figure 4 which comes from The International Council on Systems Engineering (INCOSE). A detailed description on the V-model and its use at Tetra Pak will follow.

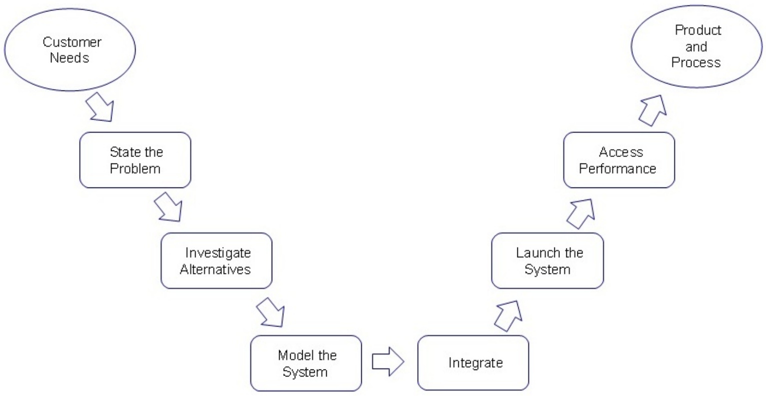


Figure 4: A V-Model from INCOSE. [3]

- **Costumer needs:**
  A stakeholder, a costumer or an internal project, has a need for something to be done, this could be an external or internal stakeholder.
- **State the problem:**
  The need is examined and analysed, and together with the stakeholder a set of requirements are defined. The requirements are reformulated as non technology bound problems in order to avoid getting trapped in "old solutions".
- **Investigate Alternatives:**
  Various solutions to the problems are suggested, examined, and rated on their chance of success.
- **Model the system:**
  The "best" solutions are modelled. Mechanical design use Pro/Engineer, more information on Pro/Engineer can be found in Section 2.2 to draw the blueprints and simulate for reachability, clearance, durability, and fatigue. In parallel with this the code and equipment needed for controlling the solution is developed and examined.
- **Integrate:**
  A physical prototype is constructed and the mechanical and software solutions are integrated and tested together. Alterations are done and errors are corrected.
- **Launch the system:**
  All the various solutions are combined and tested so that they function togeather as meant.
- **Access performance:**
  The result is compared to the stated problems to see if the solution is good enough.

- **Product and Process:**
  The need from the stakeholder is fulfilled and the product is delivered to the stakeholder.

At each of these step there are toll-gates where the project is re-evaluated and a decision on whether to continue or not has to be made.

2.2 Pro/ENGINEER

Pro/ENGINEER[6], or Creo/Elements as it will be called in the future, is a 3D CAD tool developed by PTC. Pro/ENGINEER uses the GRANITE modelling and interoperability kernel developed by PTC. The GRANITE kernel includes CAD translators for a lot of other standards. Applications built on GRANITE can read Pro/ENGINEER files, as well as other standard formats of CAD programs, including IGES, STEP, VDA-FS, ACIS SAT, Parasolid, and JT. Pro/ENGINEER also allows for data exchange with CATIA V4 and CATIA V5, and it supports 3D geometry, topology, color, long names and show/no show attribute transfer[7]. In Pro/ENGINEER it is also possible to do analysis and simulations on durability, heat and motion performance and simulate non-linear deformations.

Pro/ENGINEER Wildfire 5.0 is the version that is used at Tetra Pak today.

2.2.1 Shrinkwrap

In many cases will large assemblies be static or the movements are such that the assembly will move as one unit. To reduce the calculations in the simulation it can be a good idea to reduce this assemblies to single parts instead. This is possible by using shrinkwrap in Pro/ENGINNER.

A Shrinkwrap feature is a collection of surfaces and datums that represents the exterior shape of a model[8]. It is possible to shrinkwrap a part, a skeleton, or an assembly. When shrinkwrapping an assembly it is possible to choose which components that will be included in the shrinkwrap. By default, all components will be included. The shrinkwrap enables an accurate and lightweight representation of an assembly. A shrinkwrap model will always be a part. There is a possibility to choose the level on the shrinkwrap from 0 to 10, where 10 is the highest and will contain the most details.

There are three different ways to build the shrinkwrap model. In Figure 5 is an illustration where some of the differences can be seen.

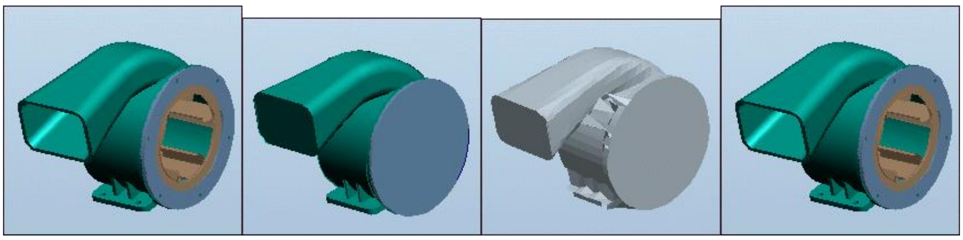
Surface Subset
A surface subset Shrinkwrap model is a single part, composed of a collection of surfaces and datum features, that represents the external surfaces of a reference

model. The quality of the collected surfaces can be adjusted by the user. A higher quality level will increase the amount of surfaces included in the shrinkwrap. It is possible to exclude surfaces to reduce the model size or add surfaces to get a better representation of the source model, as shown in Figure 5b.

The surface subset is the fastest Shrinkwrap method and results in the smallest model size. Each surface collected from the exterior of the original design is copied into the Shrinkwrap model. Colors are retained. Creating a surface subset Shrinkwrap model produces external Copy Geometry features.

Faceted Solid
A faceted solid Shrinkwrap model provides an approximate visual representation of the original model. It is a single solid model, representing all external surfaces, with additional surfaces added to bridge gaps and complete the solid. One can adjust the quality level of the collected surfaces. Higher quality increases both the accuracy of the representation and the size of the output file. No colors are retained as shown in Figure 5c. Creating a faceted solid Shrinkwrap model produces an external Copy Geometry feature and a protrusion.

Merged Solid
A merged solid Shrinkwrap model provides a very accurate solid representation of the original model. The system merges external components from the reference assembly model into a single part representing the solid geometry in all collected components. The system creates the exported Shrinkwrap model by merging and copying components from the reference model into the Shrinkwrap model. When a merged solid Shrinkwrap model has an enclosed cavity, the system fills it with solid geometry. Colors are retained. Creating a merged solid Shrinkwrap model produces an external Copy Geometry feature and a protrusion. The merged solid shrinkwrap can be seen in Figure 5d.



(a) The original assembly *(b) Surface Subset* *(c) Faceted Subset* *(d) Merged Solid*

Figure 5: Example of an assembly shrinkwrapped in the three different ways. The shrinkwrapping is done at level 5 quality.[8]

2.3 Motion control of packaging machine at Tetra Pak

At Tetra Pak, all the packaging machines are built with cyclic operations[3], complex motion patterns and relatively short cycle times. Cyclic operations means most events and motions are made in a cyclic flow and repeated in the same order as long as no exceptions are happening.

There is always an eagerness to shorten the cycle time to increase production rate. Therefore the cycle times are often as short as technically feasible. By using cyclic operations instead of event based operations it is possible to keep the signals for the PLC to a small number. Since the response times for the I/O handling is essential for the cycle time it is good to keep the logical events to a minimum.

Tetra Pak previously used a motion control managed by a mechanical shaft controlling all parts of the machine by cam wheels and indexing gearboxes. To the left in Figure 6 are the main motor, also called the master. The machine was essentially controlled by controlling the speed of this motor. The position of the motor was read by an encoder and fed to the PLC and triggered all I/O events that depended on the position.

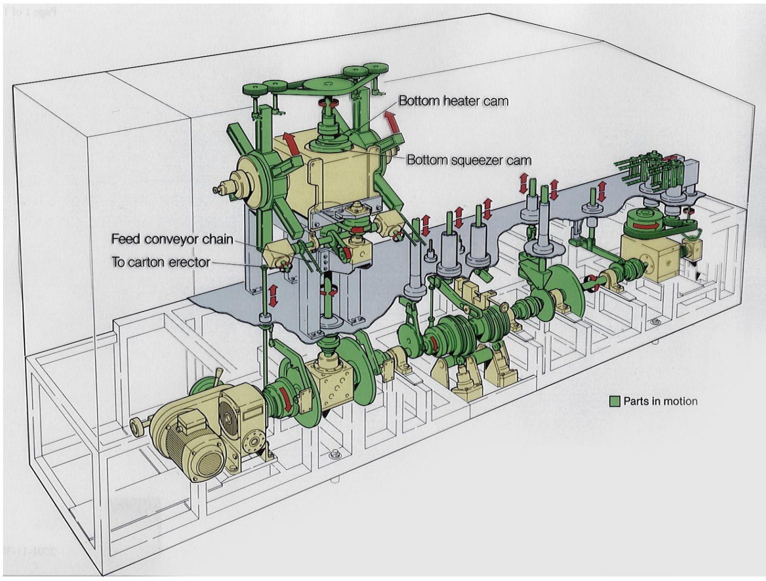


Figure 6: A Packaging machine from Tetra Pak using cam wheels for motion control.[3]

The cyclic operations are still used even if servo motors are introduced to control the motions. The difference is that the cyclic periodicity is now defined in the software instead of the mechanics. See Figure 7.

The cams are described using mathematical models. All motions are usually a matter of one dimension motions in a packaging machine. The need arise to coordinate

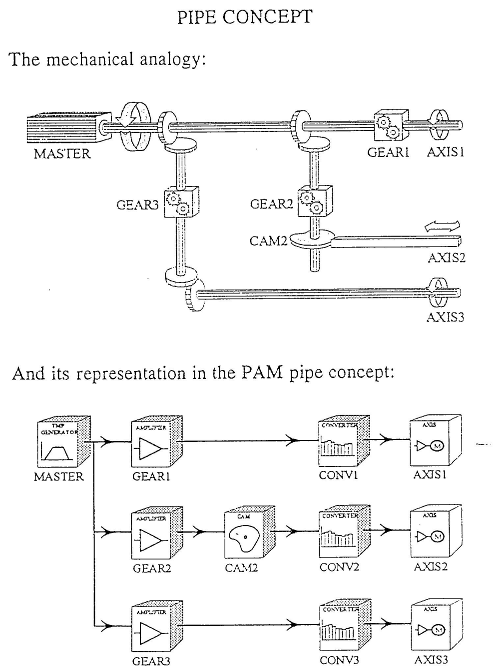


Figure 7: Illustration on the analogy between the old mechanical system and the motion control used today.[3]

more than one motor for a machine function is usually due to several tools acting on a single package simultaneously.

There are lots of possibilities to control the machines in this way compared to the old mechanical system. The control of events outside the cyclic operations are also easier to take care of. The exception handling and parts that might not be moving for a complete cycle is examples of tasks that will be easier to control with this method. Another advantage is that it will be easier to test the control code for every single part separately this may and the adjustments when some parts are out of sync could be ynchronised in the software instead of changing the mechanics which can be time consuming.

2.4 Tetra Rex 28(TR/28)

The TR/28[9] is a filling machine for chilled products with a high capacity and high performance. It has a best-in-class hygiene. It is designed to use different sizes of the packages in a range of 237ml to 1,136ml and has a capacity of 14,000 packages per hour. The filling machine has a proven efficiency of at least 94% on a wide range of products. The filling accuracy is at ± 1 gram per litre.

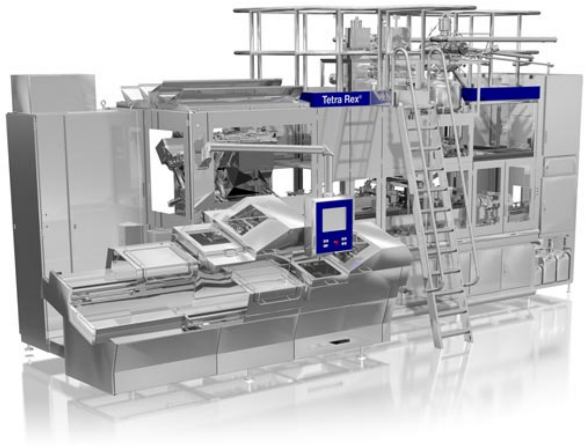


Figure 8: The Tetra Rex 28.[9]

The machine has four production lines running in parallel. Two lines shares the same conveyor belt that steps two packages in each cycle. Every other package belonging to the different lines. This can be seen in Figure 9. Every operation on the packages are done in pair. For example is two packages lifted to the nozzles and filled at the same time.

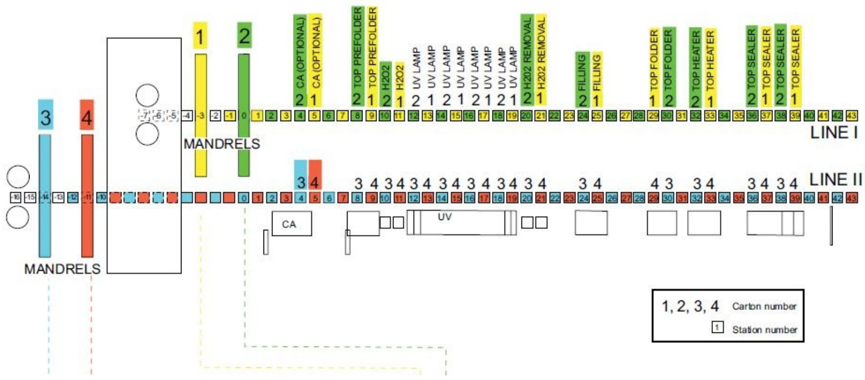


Figure 9: The concept of how the four lines are separated in the TR/28 filling machine.[3]

3 Simulation

Simulation is an imitation of something real. This is a rather wide concept. In this context simulation is the virtual representation of a physical manufacturing machine. The increased complexity of the machine tools and manufacturing systems together with increased demand on fast deliveries has made the introduction of simulation software a necessity for many company. The aim is to make the simulation as lifelike as possible.[1]

3.1 Software in the loop

In Software-in-the-loop (SiL) there only exists software in the control loop, hence the name[10]. Everything is simulated like components and control algorithms. Design specifications and performance measures etc. can be obtained without real-time requirements[11].

3.2 Hardware in the loop

Hardware-in-the-loop (HiL) simulation has a real controller compared to the simulated one in SiL. This technique is used in the development and test of complex real-time embedded systems[12]. To minimize the TTM there is no time to wait for a prototype in order to test the control system. Many times there are control systems developed in parallel with the plant and simulations are done on a simulated plant, controlled with the real control system.

HiL simulation is a key step in the process of developing human factors. The next step is to include the HMI and test the control algorithm together with the Humans in what sometimes is called man-in-the-loop simulation or usability test.

4 Simulation software solutions

Simulation software solutions from five developers are described in this section. One software solution from each developer gets the most attention: DELMIA[13], 3DCreate [14], Process Simulate[15], TrySim[16] and FlexSim[17] are simulation software solutions that enable to create virtual models of the manufacturing systems. The ability to reuse "old" models are also improved by using a simulation tool.

One of the most important aspect for the different tools is that the time spent on building the virtual models need to be as short as possible. One way to minimize the time to develop the models is to be able to import the CAD-files from the existing CAD-tool used at Tetra Pak to the simulation tools. One of the aspect that the authors look into is the possibility to import files from Pro/ENGINEER Wildfire 5.0[6] to the different simulation software solutions and what information are included in the conversion to the different simulation tools. The more data that is included in the translation from Pro/ENGINEER to the simulation software, the less work needs to be done in building the virtual model.

Another aspect that is important for the further research work is the possibility to extract information on state and control information for the possibility to optimize the process. The optimization is both on minimizing the cycle time and to avoid deadlocks. The vision is to use this optimized state charts to generate control code.

4.1 DASSAULT SYSTÈMES

Dassault Systèmes (DS)[18] offers PLM, CAD and simulation solutions for numerous industrial branches including Automotive and Transportation, Costumer Packaged Goods and Life Sciences. The simulation tool from DS is DELMIA[13], and it offers solutions from process planning to complete definition of production facility and equipment. It is possible to do virtual commissioning with DELMIA and validate the control code before going into production. DELMIA also supports HiL.

It is possible to generate a XML representation of the job[20] in DELMIA. The XML file is customizable and what information is extracted and how it appears is stated by the user. All of the details can be extracted. DELMIA uses the same file format as CATIA which is the CAD program offered from DS.

DELMIA Smart Device Builder is in the DELMIA V6 Portfolio and enables the possibility to use Lifelike Conveyor. It makes it possible to create conveyor sections that utilize belt, roller, or smooth surfaces. Realistic dynamic solvers provide a lifelike experience to how items will move along the conveyor and the behaviour that will happen when items on the conveyor collide with each other. This life-

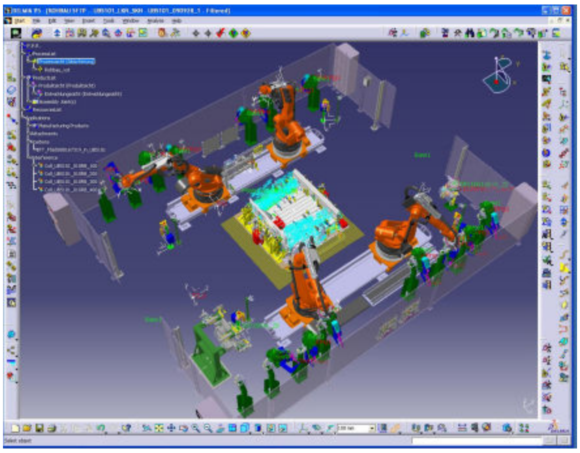


Figure 10: DELMIA[19]

like conveyor behaviour allows the user to experience in a virtual environment how conveyor designs and part-transport plans will impact execution of process plans on the shop floor.

4.2 Visual Components

Visual Components[21] is a 3D-simulation software developer. It was a team of simulation experts that founded the company in 1999. They saw the opportunity to bring simulation into the mainstream by developing a reusable concept for simulation models. The founders had found valuable insight in the future of production simulation tools after working with the development of Deneb Robotics (Former name of DELMIA).

Visual Component's software suite consists of four software solutions packages[22].

4.2.1 3DRealize

This is a tool for making layout proposals to generate working modules or production systems. Sales people and application engineers is the most suited users. They can analyse, demonstrate, and present different layouts for suppliers and customers. The discrete event simulation engine drives production flow based on component parameters that have an effect on the material flow and processing times. Standard routing rules and statistical analysis tools are available to analyse different production scenarios.[23]

4.2.2 3DRealize R

3DRealize R enhances the capabilities of 3DRealize with the ability to model a complex robot based workcell.

4.2.3 3DSimulate

3DSimulate is the newest member of the Visual Components product family with in-built statistics and reporting tools. It is a multi-purpose simulation and visualization tool with extensive built-in tools for statistical analysis of production systems and machinery. It offers layout designers an integrated tool with in-built reports and interface for communicating with external systems.

4.2.4 3DCreate

3DCreate is the component model and application authoring tool used to build and publish 3D simulation components, layouts and new 3D simulation based applications. Starting with existing engineering 3D CAD data, the model geometry is optimised for display on standard computers. Easy to use Plug-and-play connection interfaces are added along with realistic behaviours to result in a lightweight parametric based simulation model that can represent an entire product family. In a single package the user gains access to a material flow discrete event simulation engine, robotic kinematic modelling services. The possibility to write scripts in Python and use the Microsoft COM interfaces provide flexibility to extend the product family to meet specific developer needs.[23]

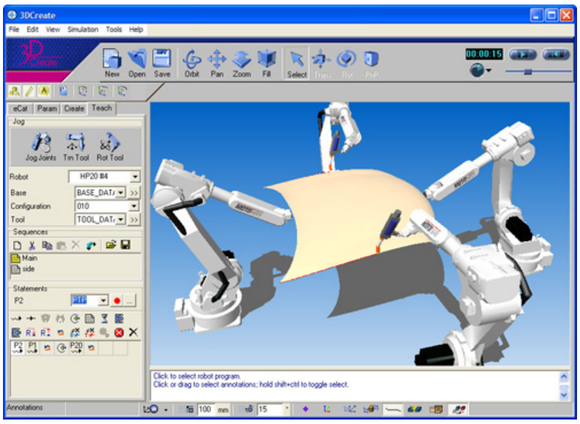


Figure 11: 3DCreate[24]

4.2.5 3DAutomate

3DAutomate will be the new flagship from Visual Components containing all the functions of 3DCreate and some new features such as Automatic Path generation and Offline Programming tools[25]. It will also be better on massive models. 3DAutomate is still in development. One license for the Beta version is available at the Department of Product and production development(PPU) at Chalmers University of Technology.

4.2.6 Python

Python is a high-level programming language[26] whose design is made for easy reading of the code. Python aims to combine "remarkable power with very clear syntax", and its standard library is large and comprehensive.

Python supports multiple programming paradigms, primarily but not limited to object-oriented, imperative and, to a lesser extent, functional programming styles. Like other dynamic languages, Python is often used as a scripting language. It is the language used for writing scripts in 3DCreate an 3DAutomate. The use in non-scripting contexts is also wide spread.

Python are available for many platforms, and Python programs can be packaged into stand-alone executable code for many systems using various tools.

4.2.7 PLC Add-On

Visual Components has a PLC Add-On available for 3DSimulate and 3DCreate.

The PLC Add-On allows the connection to a programmable logic controller and other industrial devices by using a compliant OPC server/client connection. A Beckhoff specific connection enables communication to Beckhoff's TwinCat system. A generic connection is also available for Siemens S7. More vendor specific connections can be configured using the standard plug-in architecture over the Visual Components API. This gives the possibility to test the model with HiL described in Section 3.2.

4.3 Siemens PLM Software

Tecnomatix has a comprehensive range of digital manufacturing solutions that connects all manufacturing disciplines including product development[27], from process layout and design to simulation and validation, and execution of manufacturing. Tecnomatix is based on the open PLM foundation called Teamcenter's manufacturing platform. Among the tools that Tecnomatix offers are Process Simulate that will be evaluated in this thesis. Process Simulate is a suite of tools that consists of Process Simulate Human, Process Simulate Weld, Process Simulate Robotics and Process Simulate Assembler. The 3D process design and simulation is based on JT[28] visualization standard in Process Simulate. Read more about JT in Section 4.6.6. To get access to the JT-files it has to be placed in either a .COJT or .CO folder and placed in a library in the project[29]. .CO is the file format used by ROBCAD which is the precursor to Process Simulate. According to Johan Nordling at Siemens Industry Software AB it is possible to save the kinematics in a PLMXML-file after it has been redefined in Process Simulate. This means that the kinematics don't have to be defined after every update of the JT-file. In Tecnomatix it is possible to import CAD-files from Pro/ENGINEER, CATIA V5, NX and many more by using CAD Translators. In version 9.1.1 and later it is possible to import Pro/ENGINEER Wildfire 4 files.

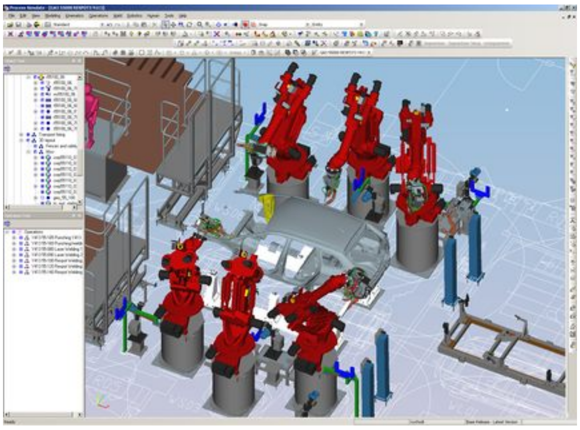


Figure 12: Process Simulate[19]

Process Simulate use XML-files to store all types of structured information, and to enclose or encapsulate information in order to pass it between different computing systems which otherwise would be unable to communicate.[30]

Using Process Simulate Commissioning[31] makes it possible to integrate the mechanical and electrical discipline in the real commissioning of a production zone/cell. It enables the possibility to generate a PLC-code. This PLC-code can then be used on a real PLC hardware connected to the virtual environment using OPC in a HiL-simulation.

4.4 Cephalos GmbH

TrySim is a simulation tool where it is possible to simulate at an I/O level of the controller[16]. After constructing a 2D or 3D model of the special purpose machine it is possible to run simulations to verify the controller. The software supports numerous interfaces including MPI to Siemens S7, TCP/IP (ethernet), S7-PLCSIM or even write your own drivers for a costume made interface. With TrySim you can verify the code prior to building physical prototypes, and can via the interfaces run HiL and verify subsystems prior to assemble.

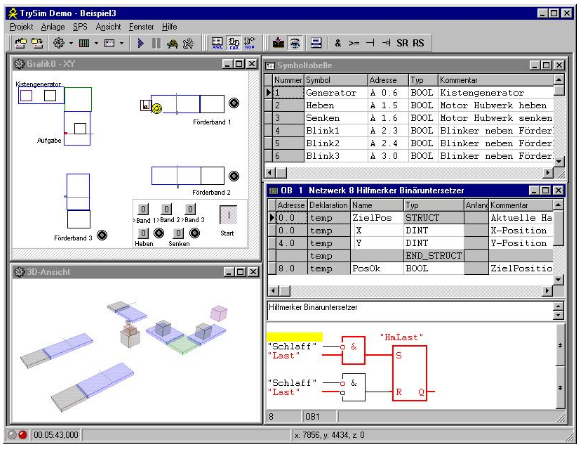


Figure 13: TrySim[32]

In the graphical simulation it is possible to have both a really simple 3D view and 2D views as can be seen in Figure 13.

4.5 Flexsim Software Products, Inc.

FlexSim[17] is a process simulation software. Models of systems are created in 3D and assembled by drag and drop. In FlexSim it is possible to import input data for different processes by taking data collected from the real world and turn it into mathematical formulas that drives the simulation. FlexSim supports SiL and HiL but one has to create the logic for this oneself in order to enable the communication needed. This can be done via TCP/IP, DLL or by converting the FlexSim model into C++ and write the logic directly. Lars-Olof Leven at Rejlers Ingenjörer AB recommends TCP/IP or DLL for this.

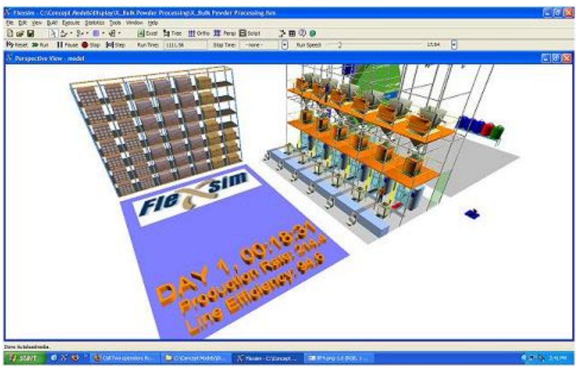


Figure 14: FlexSim[33]

4.6 How to transfer CAD models to simulation tools

In order to construct a model for simulation it is interesting to know if it is possible to reuse the designs that are already created in various 3D CAD tools, and for the purpose of this thesis the possibility to reuse designs made with PTC Pro/ENGINEER or Creo Elements/Pro is in focus.

However, due to various implementation choices and specific data models used by each CAD actor on the market, MultiCad direct solutions cannot guarantee that produced data perfectly matches original data at anytime in every possible situation.[34]

4.6.1 Pro/ENGINEER

Pro/Engineer itself has a tool for enabling the transfer from CAD models to simulation tools. It is possible to save the design in different file formats. Formats that are of interest and supported are STEP, JT, CATIA V4 and CATIA V5, IGES. However there is a need for an interface and a license to the actual interface, if required to export to CATIA V4, CATIA V5 or JT[8]. The limitation of the translated files from Pro/ENGINEER to CATIA V5 are accessible only on CATIA V5 release 16,17 and 18. By default only the boundary representations are exported. Pro/ENGINEER has the possibility to export into three different CATIA V5 file formats.

- **CATPart**
  This is the file extension used for every component in CATIA and DELMIA. It contain information about geometry and topology.
- **CATProduct**
  It is an assembly consisting of CATParts and/or other CATProducts
- **CATIA V5 CGR**
  CGR is the triangulated format used as the visualization format of CATIA V5. It is a very light format and it is possible to do approximate measurement. It is also possible to get access to all the basic Digital MockUp(DMU) functionalities.

4.6.2 MultiCAx plug-in for DELMIA

In order to use CAD files in DELMIA there exists a plug-in called MultiCAx. This add-on is used to import 3D data from I-DEAS, Pro/ENGINEER, SolidEdge, Inventor, SolidWorks, DELMIA D5, CATIA V4, CATIA V5 and various other formats (IGES, STEP, STL, SLP, OBJ Wavefront, VRML, I-DEAS IFF). [35]

When importing an assembly from Pro/ENGINEER using MultiCAx, the assembly hierarchy will be converted to product structure and retain the relative positions. There is an option to include simplified representations and part instances if they are present. The kinematic will not be imported since no other attributes than hierarchy, positions, and colours of the geometry are imported.[34]

When using MultiCAx PD or P Plug-in for importing Pro/ENGINEER part geometry, it will convert all solid bodies belonging to visible layers in the Pro/ENGINEER part into the CATIA Graphical Representation(CGR)-facet form, with user specified tessellation parameters. There is also an option to import the parts in CATPart data format, with full support for exact geometry. Coordinate systems can also be retrieved in the generated CGR and CATPart files. All user attributes defined in the original part will be stored in the CATProduct or CATPart document.

The use of batch conversion will directly generate the CATProduct documents for the imported assemblies, and the parts included in the assembly will be converted to CGR or CATPart. During this conversion, all information about the assembly structure, geometrical information and original links are all transferred into the V5 format. All length units will be converted to millimetres both for parts and assemblies when using batch conversion. There are some attributes not supported when using batch conversion.

- Assembly-level colours
- Pure wire frame data and coordsys
- Text and annotations
- Cable elements
- Parts and sub-assemblies residing in invisible layers

When importing Pro/ENGINEER to DELMIA V5 there are three different file formats to save in depending on how the imported data will be used. The possibly formats are

- CGR
- CGR with canonical information
- CATPart

All of these formats give access to the part user attributes and they all have their own advantages and limitations.

CGR is the very light file format mentioned in Section 4.6.1.

CGR with canonical information gives the possibility for exact measurement and exact snapping.

CATPart is a standard V5 CATPart which is locked. It can be used as any other CATPart with the exception that it will not be possible to modify it since it is locked. It is only possible to reference it.

After the conversion, a link to the original file will be stored. This link will make it possible to determine if the imported files are up to date compare with the original files.

There is an update batch function that is used to initiate the associative mode. It operates on the V5 data and updates the structure or geometry if there is any changes done on the original file in Pro/ENGINEER. The associativity schema can be seen in Figure 15. The associative mode is on by default.

- If one of the parts in an assembly is modified in Pro/ENGINEER, the update batch can be run on the CATProduct so that the specific part is reconverted and the geometry in the V5-file is up to date compared with the Pro/ENGINEER part.
- If it is only the assembly structure that has been changed in Pro/ENGINEER, then it is possible to run the batch on the CATProduct so the assembly file is reconverted and the V5 product will be updated.

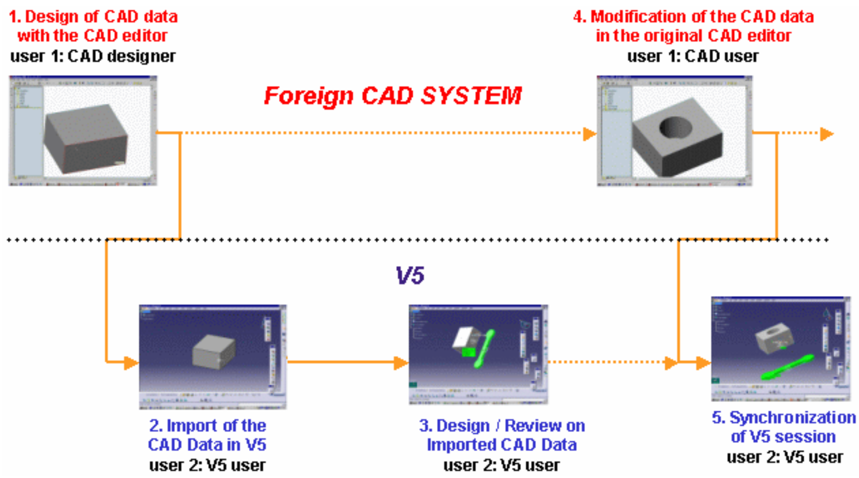


Figure 15: Schema of the parallel between the CAD system and V5. Step 3 corresponds to the modification or review of imported CAD data in V5. [34]

By using the associative mode, the user is guaranteed to maintain a synchronization with structure and/or geometry changes. It is possible to turn off the batch and thereby disable the synchronization between the V5 data and the original data from Pro/ENGINEER.

4.6.3 Polytrans Exporter Add-On for 3DCreate

The Polytrans Exporter Add-on from Visual Components adds the ability to import a wide variety of geometry formats, including SolidWorks, STEP, Pro/ENGINEER and IGES. It provides an interface to Okino's[36] Polytrans CAD import/export software. According to Robert Lansdale, CTO & Product Manager at Okino Computer Graphics, it is possible to do a 1:1 conversion without any data losses from Pro/ENGINEER to 3DCreate using the Polytrans add-on.

4.6.4 IGES

Initial Graphics Exchange Specifications (IGES) was created in 1979 after a meeting with the Society of Manufacturing Engineers where the difficulties using different CAD systems where adressed. The National Bureau of Standards and several companies including Boeing, General Electrics and Applicon and Gerber put together a task force in order to find a common file system. The result was IGES, an ASCII based representation of a CAD design[37]. IGES became an ANSI standard in 1980 and there are still files available in the IGES-format. When STEP was introduced in 1994 the interest for IGES declined and the last version, 5.3, was released in 1996[38]. The IGES files consists of entities, and each entity is categorized as geometry and non-geometry. A geometrical entity contains information on physical shape: Points, curves, solids and relations. Non geographical entities gives characteristics and definition for single o groups of entities and defines and instances groups of entities.[37]

4.6.5 STEP

The Standard for the Exchange of Product Model Data (STEP), is a comprehensive ISO standard (ISO 10303) that describes how to represent and exchange digital product information[39]. The ISO-standard has several Application Protocols (AP)[40]. *AP 203 - Configuration Controlled 3D Designs of Mechanical Parts and Assemblies* is the one used for mechanical parts and assemblies. It has six groups of shape representations of a part:

- advanced boundary representation
- faceted boundary representation
- manifold surfaces with topology
- geometrically bounded surface and wireframe geometry
- wireframe with topology
- constructive solid geometry in three-dimensions

Often many systems are used to manage technical product data in design and manufacturing. All system have their own data formats which means that same information has to be entered once for every system leading to redundancy and errors. This problem is significant for the manufacturing industry since they often use a more complex design data like 3D. STEP can be used to transfer data between CAD, CAM, CAE and even to a CNC-machine using STEP-NC. See Figure 16 for a visual description of how STEP can be used.

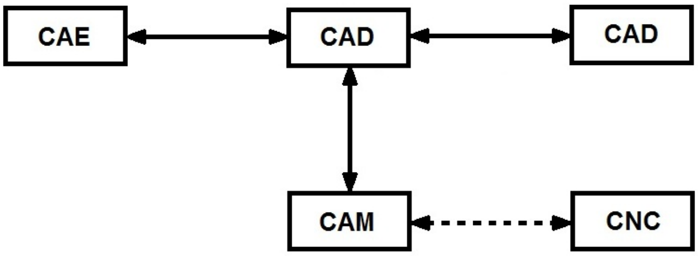


Figure 16: A flow chart for how STEP(line) and STEP-NC(dashed) can be used to transfer data between different systems.

4.6.6 JT file format

JT is the file format used across all Siemens PLM Software and is used as the long term data archival format across all of Siemens[41]. The file format are used in product lifecycle management (PLM) software programs by engineers and other professionals that need to analyze the geometry of complex products. The structure of the format and associated software makes it possible to load, shade and manipulate an extremely large number of components in real-time. All major 3D CAD formats are supported which make it possible to make any combination in a JT assembly. This has led to the term "multi-CAD".

JT is a mature and lightweight file format which make it ideal for internet collaboration. With the growing globalization there is a growing need for companies to have the resources available wherever they are in the world. This gives an advantage to a lightweight file format as JT since files in the size of ~1-10% of a CAD file is easier to send.

JT has a widespread use in the automobile and aerospace industries. It is equally suitable for all manufacturing industry applications.

It is possible to save a wide range of engineering data in the JT data model. It can be very lightweight or it can be quite rich. Data that can be saved in the JT-file format are[41]:

- Product Structure - assembly, part, instance
- Facet - polygon, polygon set
- Lighting - light set, point light, infinite light
- Textures
- Precise Geometry and Topology - point, curve, surface, face, loop, edge, vertex
- Boundary representation
- Geometry Primitives - box, cylinder, pyramid, sphere
- Product Manufacturing Information
- Attributes / Properties - text, integer, float, date, layers
- Meta data - property filters, transforms, bounding box definitions

4.6.7 Datakit

Datakit offer four solutions for CAD data exchange[42]. A whole set of CAD data is possible to read. Both parts and assemblies are well recovered thanks to matching with the original data hierarchy.

Two of them provides the possibility to transfer Pro/ENGINEER files to CATIA format and ROBCAD format. They also provides the possibility to convert into STEP and JT, but that is no solution that will be used in this case since it is possible to save into this file formats within Pro/ENGINEER.

Cross Manager is a stand alone software that convert files between different CAD formats. It is just to select a CAD file in the software for convert it automatically in the format needed. In Table 1 it is possible to see what versions and file extensions that are supported. All geometric entities can be converted into nurbs (curves and surfaces)

Software	Version	file format
Pro/ENGINEER	2000i to wf5	.prt .xpr .asm .xas
CATIA V5	R14	.CATPart .CATProduct
ROBCAD	All versions	.rf

Table 1: Supported versions and file extensions for the different formats when using Cross Manager. (This is for reading from Pro/ENGINEER and write to one of the other.)

CrossXpert is an efficient tool to exchange data between different CAD software. It can be done without sacrificing any of the integrity or completeness of their original geometry and topology. CrossXpert is also possible to use for analyzing and repairing models. Supported versions and file formats can be seen in Table 1.

4.6.8 Translation Technologies (TTI)

TTI[43] is listed as a software partner to PTC and provides tools for translating CAD data.

Acc-u-trans is a tool for CAD data translation between some of the leading CAD solution like CATIA, Pro/ENGINER and Unigraphics. They have also developed Mirror Model Comparator (MMC) that allows the user to verify translation by comparing the original and translated model.

Unfortunately no recent activity from the company has been detected. The latest update of the webpage seems to be an update at "TTI in the news"[44] from March 2007 when TTI was mentioned in an article in Manufacturing Engineering[45]. Attempts to get in contact with the company by e-mail has failed since they have all bounced. PTC has not been able to get in contact with them either according to Petter Frieberg at PTC.

4.6.9 Parasolid

Parasolid is a geometric modelling kernel[46], that can be licensed by other companies for use in their 3D computer graphics software products. Parasolid files contains 3D solids and/or surface data. Parasolid offer Translator toolkits for converting data between Parasolid and other CAD formats, including, IGES, STEP, Pro/ENGINEER, CATIA V4 and CATIA V5. They also offer Parasolid Bodyshop, a specialized tool for boosting the success of 3D data exchange by cleaning and repairing imported models.

Pro/ENGINEER is licensed to use the Parasolid kernel and can export solids, surfaces, part density, colors and component structures. All this exported data will be saved in Parasolids own text file format .x_t[8].

4.6.10 Elysium

Elysium is a software partner with PTC, Dassault Systèmes and Siemens PLM Software. They develops and markets interoperability solutions for the global PLM market[47]. The translation solution CADporter currently supports data exchange among CATIA, DELMIA, Pro/ENGINEER, JT, Parasolid, and UGS NX. CADporter will make geometry-based translation that corrects the resolution of the topology differences between the systems. It also includes healing of models from different tolerances and trim curves with surfaces.

4.6.11 Theorem Solution

Theorem Solution provides a tool called CADverter[48] for direct CAD to CAD translation. The interesting solution for this thesis is Pro/ENGINEER ↔ CATIA V5. It reads and writes data from CATIA V5 and Pro/ENGINEER and all geometry can be converted. Assembly data can also be mapped between the two systems.

5 Software selection

Two of the software solutions was eliminated early in the process. TrySim seems to be a very useful tool for SiL/HiL simulation, but since the need to access information for further research is one of the fundamental functions desired in the software and no information on the abilities to do this is available, hence it was not suitable. FlexSim proved to be a process flow simulation software and is used to simulate the flow of products in factories, warehouses, etc, and therefore was eliminated. When it came to the choice between DELMIA, Process Simulate and 3DCreate it seems that 3DCreate would be a good choice due to the low learning threshold, but it was also discarded since no information about the ability to access data that can be used for generating state charts or PLC-code could be found. The search for information was made in several databases accessed via Chalmers Library. Questions was also sent directly to Visual Components via both their support and a PhD-student at PPU. One last try was even to ask JH Engineering who used to be a reseller for Visual Components, but any answer was never sent to the authors. The choice was now narrowed down to two products, DELMIA and Process Simulate, both with the ability to access the information needed for generating state charts or PLC-code, and both capable of creating controllable, moving simulations.

DELMIA can with the MultiCAx add-on convert a Pro/ENGINEER file directly and then use it as a DELMIA component that retains a link to the original file and easily updated if the original file is changed in Pro/ENGINEER. It is possible to translate the files to JT in Pro/ENGINEER, which can be used in Process Simulate. The kinematics can then be created in Process Simulate and stored in a separate file (plmxml). This means that the kinematics don't need to be redone every time a new revision of the JT-file is made. As long as the changes in the JT-file does not compromise the kinematics. Since Tetra Pak expressed their displeasure of using a method that causes extra work for the designers and need of keeping dual editions of all CAD data, it might even risk causing contradicting file versions. Due to all this knowledge, the choice of simulation software fell on DELMIA and the work of building a virtual model of the filling station of TR/28 could be initiated.

6 Building the model

For the construction of the virtual machine it has been decided that the TR/28 will be modelled and simulated in DELMIA.

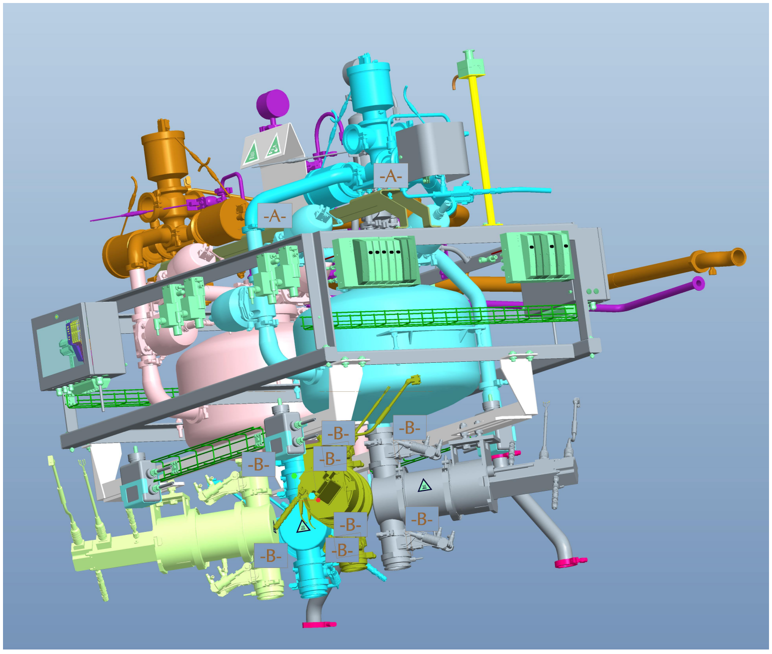
6.1 The Graphical Model

For the construction of the model, Tetra Pak supplied the CAD blueprints of the four components that the filling station of the TR/28 contains of.

An upper filler
Which stores and handles the distribution of the fluid. See Figure 17a.

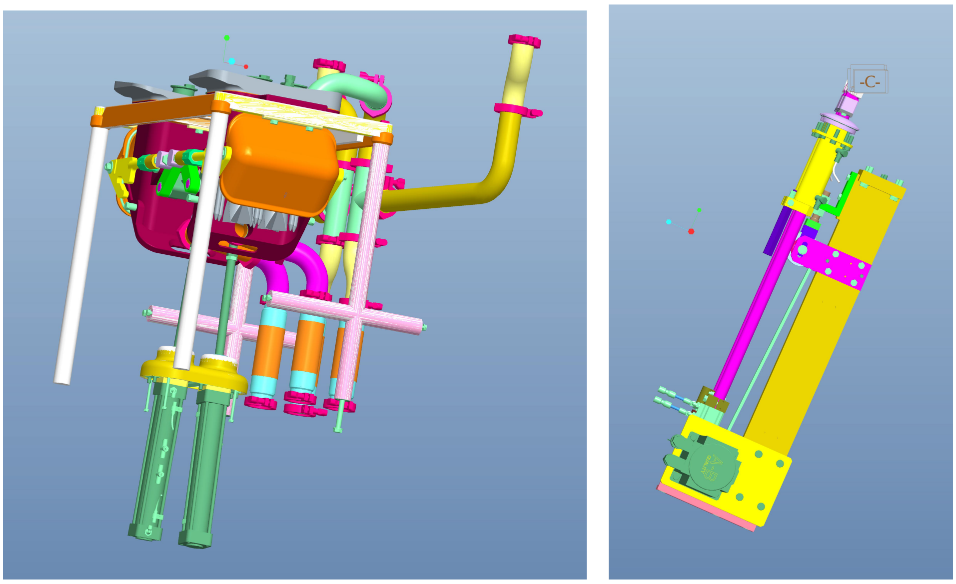
A cleaning box
This includes the filling nozzles and guides for the cartons. The nozzles are inside a box that can be closed. The box is closed when cleaning the machine. See Figure 17b.

Two carton lifters
It basically is two assemblies that are mirrored to each other. They lift the cartons to a position close to the filling nozzles and the cartons are filled on the way down. See Figure 17c.



(a) Upper Filler

Figure 17: The components of the TR/28 filling station



(b) Cleaning Box *(c) Lifter*

Figure 17: The components of the TR/28 filling station

DELMIA were the choice of simulation software as mentioned in Section 5 and the choice for conversion fell on MultiCAx, but there were some issues to get the right version of DELMIA and MultiCAx. The access to MultiCAx was available early in the process, but it later turned out that the version that was available was not compatible with the version of Pro/ENGINEER used at Tetra Pak. According to staff at Dassault Systèmes is MultiCAx V5R20 with SP5 which is the release required to be able to convert the files from Pro/ENGINEER wf 5.0. The required version of DELMIA was distributed to the authors, but unfortunately was not MultiCAx included. Since the lack of right version of MultiCAx some other solution had to be taken. In this case, the choice was STEP, since it is an open standard supported by both Pro/ENGINEER and DELMIA.

6.1.1 Pro/ENGINEER

The static parts of the filling station were simplified by using shrinkwrap to make the simulation of the model as simple as possible. To maintain as high level of detail as possible, a decision was made to use Merge solid shrinkwrap with as high level as possible. The Merge solid with high levels did take a lot of time and caused Pro/ENGINEER to crash since the computer ran to out of memory. The lower levels of the merged solid shrinkwrap lost many of the details and did not give a satisfying result. A solid merge shrinkwrap at level 1 of the cleaning box can be seen in Figure 18 and compare it to the original file in Figure 17b. Merged solid was possible to use when the largest assemblies was split up in smaller ones, but unfortunately those files were not possible to open upp in DELMIA after STEP. Once again, the reason was the lack of memory on the computer used during the project. Due to all problem with merge solid, some other method had to be tested or the assemblies would have to be split up in even smaller parts and then assembled in DELMIA. In that case some of benefits of shrinkwrap would be lost. Surface Subset was the next method to try out. At level 10, a shrinkwrap with high level of detail was generated in just a few minutes. Prior to the shrinkwrapping all hidden components were removed. The reason for this was that when the STEP conversion was made, all invisible parts became visible. The STEP-files were then opened in DELMIA.

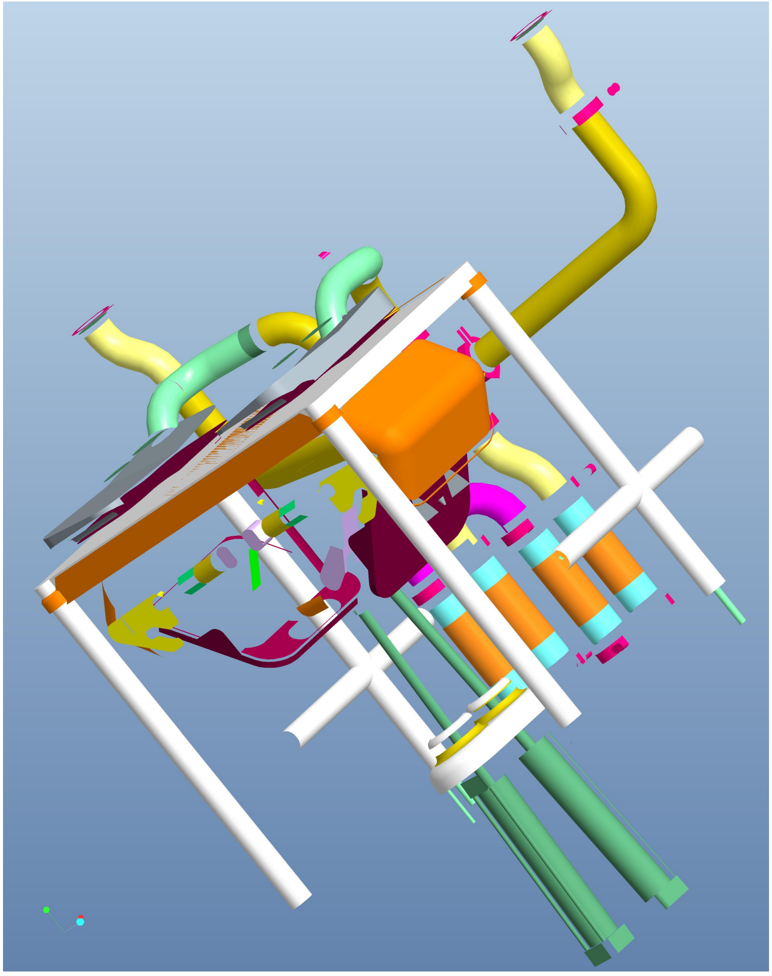


Figure 18: A merged solid shrinkwrap at level 1 on the cleaning box.

The two carton lifters were given some thought and a slight regrouping of the parts that were supposed to move were made to facilitate the adding of kinematics in DELMIA. They were converted directly using the STEP method since the idea is that some of the part will be moving.

6.2 The logic of the model

Since the idea is to create a virtual rig that can be used in the generation and validation of PLC code it is important to know what inputs and outputs there will be on the physical rig and emulate these in the virtual environment. Looking at the components provided from Tetra Pak, there are four valves on the Upper Filler that releases the fluid through the nozzles inside the Cleaning Box. When the packages is in place, the valves will open and fluid are flowing through the nozzles. The cleaning box can be closed which enables the possibility to clean the nozzles. The Carton Lifters grab a carton and lifts it into position in the cleaning box, then lowers as the carton is filled and releases the carton when reaching the bottom. For a PLC to control these actions signals are needed for the different components and in DELMIA internal logic that based on these signals have to be defined in order to perform the tasks. For the Carton lifters, movements have to be defined as well.

6.2.1 DELMIA

In DELMIA the STEP files was opened and saved as a CATParts or CATProducts. The two carton lifters were fitted with joints to allow movement and assigned internal logic in order to enable controlled simulation. Control signals for this can be grab/release carton, extend/retract lifter.

The Cleaning Box was fitted with sensors that can detect if a carton is present or not and therefore inform if the filling shall commence or not when the carton is lowered. It was decided not to add the kinematics for closing the box for cleaning mode since the rig will be used to test the filling process and therefore it would be a waste of time to model functions not necessary. A cylindrical "Lamp" was also added to indicate if the filling is done or not since we have no actual fluid representation, this one is also coordinated with logic to enable changing of colour, blue for default and green for filling. Control signals are the signals to fill, and the sensor data from indicating if a carton is present or not.

A sample of the internal logic for a lifter can be seen in Figure 19.

6.3 Assembly of the rig

Since it was found that the Upper Filler really don't add any vital information to the test rig, its one function being represented by a light indicator it was decided to not include it in the test rig to reduce the load on the computer. In order to move the cartons to the carton lifter in a way that resembles the real machine a simple conveyor was created in DELMIA. All these components together with a representation of a carton was assembled in one product and can be seen in Figure 20.

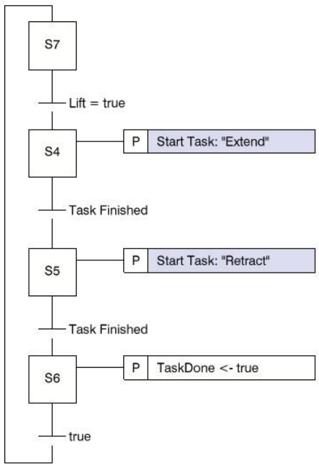


Figure 19: The internal logic of a Carton Lifter

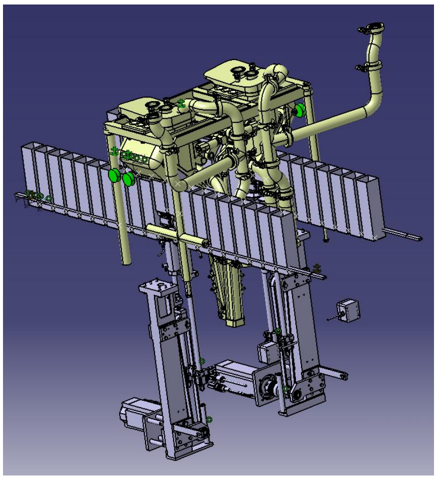


Figure 20: The Virtual Test Rig

6.4 Controlling the rig

Because there was no time to create a controller for the rig, some small changes to the internal logic of the components were made in order to create a simulation that performed all the tasks automatically, however no concern to a master PLC was taken when doing this.

7 Discussion

The goal to simulate the entire TR/28 was altered into start working on simulate only the filling station of TR/28. Additional parts of the machine would be added if time permitted it. The change was made in consultation with the supervisor at both Chalmers and Tetra Pak. Due to difficulties to find the necessary information needed to reach a good decision on which method of CAD-translation and simulation that can fit best into the organization of Tetra Pak and in the future research work, there were no time to add other parts of the machine.

As mentioned in Section 6.1.1 the Carton Lifter had some of its sub assemblies regrouped prior to the transfer to DELMIA. During this regrouping it was found that the design thinking when creating assemblies that are to be reused for constructing a test rig could benefit from an overview. No logic to the order in which the subcomponents were placed in the assemblies could be distinguished. Components that are supposed move were mixed in the same sub assembly as components that are supposed to be static. The same was found in the cleaning box, where there also were hidden items that became visible when doing the STEP conversion. The extra components were easily removed however. This shows that extra thought has to be put into the early design work. A few moments spent considering the grouping of components can end up saving a lot of time further down the road. By building the assemblies with all parts that will be moving together in one sub assembly, it will be a lot easier to define the motions. Instead of define motions on every single part it is possible to assign the motion on the assembly.

The Upper Filler was the part that confused the most though. No intuitive way of connecting the cleaning box and the upper filler was found. After some examining of the blueprints it was noticed that one of the pipes was going straight through another component in an incorrect manner. After readjusting the pipe the upper filler and the cleaning box had common connection points.

The use of STEP as a mean for file import/export was not the one that was supposed to be used. The idea was to have a quick way of importing the designs using the MultiCAx add-on. MultiCAx seemed very promising considering the fact that a connection to the original Pro/ENGINEER file is maintained and changes done in Pro/ENGINEER can be automatically updated into DELMIA.

7.1 DELMIA

DELMIA has a high learning threshold with help files of varying quality. For some tasks it was very easy to learn how to do it and see how it could be implemented when building the virtual machine. Other help sections were very informative on how to use the particular tool on previously created objects, but no information on how such objects were created. The search engine needs to be improved upon and the overall encoding on the html based help system needs an overhaul. There exist no actual tutorials for DELMIA and no open training material available for learning DELMIA, from the experience of the authors. In the help files are there a number of smaller training tasks to do with associated training files. Without any good tutoring and guidance it will take a lot of time to learn DELMIA from the help files as it is huge and has lot of information.

Working in DELMIA, once a task was understood was relatively easy. Defining internal logic for smart devices such as the carton lifters was easily done. The connection to a controller was smooth and simple. It was tried to use delays for the cyclic behaviour of the conveyor and the lifter since no time to design an actual controller was available. This turned out to be a bad idea since no consideration had been taken to the time it takes for the internal logic to step forward, instead some logic was included to indicate when some particular task was finished and the next one can be executed.

7.2 3DCreate

As mentioned in Section 5, no information needed to know what the possibilities are there in 3DCreate to access the data about states and control information that can be used to create a state chart and even control code. The possibilities to access the data about the machine states is of most interest for the research work which is the joint project between Chalmers and Tetra Pak that this thesis is a part of. There might not be any native tools in 3DCreate to extract the desired data for generating state charts, but it is possible to write your own functions through COM API. This means that there are probably the possibilities to define your own function which then can extract the information needed to obtain all the states in the process. It is of great interest for further work in the research to obtain this state chart and use them to optimize the process by minimizing the cycle time and make the process non-blocking by synthesising with a supervisor.

On the Visual Components website, there are some tutorials to download to get an overview on how the program works. These exercises were carried out to get some knowledge about what possibilities are available in the program. Although there were few exercises and they were at a quite low level, it gave an idea of what kind of potential there is in the program. It seems to have significantly lower threshold to learn than with DELMIA. During the tutorials we learned that in 3DCreate it is possible to define inputs and outputs on all parts for were the products will be transported. During the assemble it is possible to use this inputs and outputs and enable a snap function which makes it easy to place the parts where this kind of ports are defined.

Before any tutorials could be done in 3DCreate, some problems with licenses were encountered. A 14 days trial were acquired from Visual Components after some time. No reply were given on the request of extension until end of thesis. A license were later acquired from PPU. Unfortunately the license for polytrans add-on was not available in the version provided by PPU and as the response from Visual Components is not reasonable, it was decided not to continue to work with this solution. And hence, no work were done with this add-on to confirm if it is possible to do a 1:1 conversion without any data losses stated by Robert Lansdale at Okino Computer Graphics. Previous thesis work have attempted to use the add-on but since that research is four years old it might be of interest to find out what improvements have been done.

Information from PPU - Visual Components is also developing a new software called 3DAutomate with more possibilities. According to the Research assistant at PPU that have a beta version of 3DAutomate to work with for evaluation, this program will make Visual Components more competitive to major developers of software for Virtual commissioning like Dassault Systèmes and Siemens PLM Software. However 3DAutomate will probably be a light version compared to DELMIA and Process Simulate.

7.3 Process Simulate

Even if there is quite many tutorials available for Process Simulate where very little work was done with Process Simulate. This based on the stated reluctance from Tetra Pak to use Process Simulate due to the risk of getting conflicting file versions. However, the fact that it is possible to save kinematic definitions in a separate file and therefore eliminate the need of redefining it every time a minor change is made to the JT file does speak well for Process Simulate. Process Simulate do also have an open API which make it possible to extract the data about states and control information. This data can then be used to generate a control code for an optimized process.

7.4 Source criticism

Many of the sources used in this thesis is from the software developers own Web sites. Since they only take up all the positive characteristics, it has been very difficult to get any information of possible weaknesses. To get an objective view on some of the software, some consultations were made with users of the software.

8 Conclusion

Since the integration of mechanical and software engineering is done on a physical model there is an opportunity to take a step into the virtual world of engineering and start by integrating the modules in a simulation tool and detect erroneous behaviour. This would allow for alteration to be made prior to building the physical prototypes. Some thought have to be devoted during the mechanical design phase so that parts that are supposed to be moving together in an assembly are grouped into separate sub-assemblies.

No opportunities to convert more than the graphical representation and measurements were found when transferring the CAD files from Pro/ENGINEER to any of the investigated simulation tools. When it comes to the two that known to be capable of extracting the data on states a model can occupy, they both have different advantages. DELMIA has its advantage in that the MultiCAx add-on retains a link to the original Pro/ENGINEER file and therefore changes made in Pro/ENGINEER can be updated into DELMIA. Process Simulate however can save the kinematics in a separate file and thus saving effort when alterations are made in Pro/ENGINEER. If 3DCreate is capable of extracting the state information it might also be a useful tool due to the fact that it is relatively easy to use.

9 Future work

- Like mentioned in the report there were no chance to try out MultiCAx for translation of the CAD-files to DELMIA. When the issues with software and licenses for the required version of MultiCAx is solved, it is recommend that some test could be done to see how well the link between Pro/ENGINEER and DELMIA works using MultiCAx.

- Examine the exact procedure to extract data from DELMIA for generating state charts.

- No confirmation on the possibilities to extract data from 3DCreate and 3DAutomate or to write your own functions using the COM API were found so a continued work to find information about this would be good, it is believed that 3DCreate is a software with a sufficient smaller threshold compared with DELMIA. A study on 3DAutomate would be sufficient since we belive it would be a good solution for Tetra Pak if there is possibilities to extract data for generating state charts.

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