YRKESHÖGSKOLAN NOVIA

Definition and Development of the Internal Guideline to Support the Transition to Model-Based Definition

MBD – Model-Based Definition

Joel Linde

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DEGREE THESIS

Author: Joel Linde
Degree Programme and place of study: Mechanical and Production Engineering, Vasa
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Supervisor(s): Kenneth Ehrström (Novia), Franco Cavressi (Wärtsilä)

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Abstract

This thesis is written on behalf of Wärtsilä, a global leading company in innovation technologies and lifecycle solutions. The business is mainly focused on energy and engine solutions for marine and powerplant use.

To keep a leading position in the global competition, new technologies and methods need to be researched and taken into use if possible advantages in a method are found. Several market-leading companies have fallen out of the competition because of not adapting to the latest technology. For a company that has billions of Euros in revenue, even less than 1% saving makes up to enormous amount of money.

Therefore, the method to design in Model Based Definition was requested to be researched by Wärtsilä. This way of designing can be used to save time, ensure more quality, and be more applicable to smarter manufacturing technology. MBD is exceptionally suitable for smaller production batches and more production variants, since the possible reduction in design time.

This thesis work resulted in a design guide on the information needed for designing in MBD and it is meant to be used internally only for Wärtsilä's own use.

Language: English
Key Words: Model-Based-Definition (MBD), Product-Manufacturing-Information (PMI), Design Guide

EXAMENSARBETE

Författare: Joel Linde
Utbildning och ort: Maskin- och produktionsteknik, Vasa
Inriktning: Drifts- och energiteknik
Handledare: Kenneth Ehrström (Novia), Franco Cavressi (Wärtsilä)

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Abstrakt

Detta examensarbete är skrivet på begäran av Wärtsilä, ett världsledande företag inom innovationsteknik och hållbarhetslösningar. Verksamheten är främst inriktad på energi- och motorlösningar för marin och kraftverks sektorn

För att behålla en ledande position i en global konkurrens behöver nya tekniker och metoder undersökas och tas i bruk om möjliga fördelar hittas. Det har funnits många marknadsledande företag som fallit på grund av att man inte anpassat sig till den senaste tekniken. För ett företag med en omsättning i miljardklass kan en besparing på mindre än 1% gör upp stora summor.

Därför begärde Wärtsilä att metoden att designa i Model-Based Definition skulle undersökas. Detta sätt att designa kan användas för att spara tid, säkerställa kvaliteten och bli tillämpad i smartare tillverkningstekniker. MBD är exceptionellt lämpligt för mindre produktionsenheter med flera olika varianter av produkten, eftersom metoden möjliggör kortare designtid.

Detta examensarbete resulterade i en design-guide med information som behövs att designa i MBD, design-guiden är menad att enbart användas internat för Wärtsilä anställda.

Språk: Svenska
Nyckelord: Model-Based-Definition (MBD), Product-Manufacturing-Information (PMI), Design Guide

OPINNÄYTETYÖ

Tekijä: Joel Linde
Koulutus ja paikkakunta: Kone- ja tuotantotekniikka, Vasa
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Ohjaaja(t): Kenneth Ehrström (Novia), Franco Cavressi (Wärtsilä)

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Tiivistelmä

Tämä opinnäytetyö on kirjoitettu Wärtsilän, joka on maailman johtava innovaatioteknologian ja kestävän kehityksen ratkaisujen yritys, pyynnöstä. Liiketoiminta keskittyy ensisijaisesti meri- ja voimalaitossektori energia- ja moottoriratkaisuihin.

Johtavan aseman säilyttämiseksi globaalissa kilpailussa tulee uusia teknologioita ja menetelmiä tutkia ja ottaa käyttöön, mikäli mahdollisia etuja löytyy. On ollut monia markkinajohtavia yrityksiä, jotka ovat pudonneet, koska eivät ole mukautuneet uusimpaan teknologiaan. Miljardien liikevaihdon omaavalle yritykselle alla prosentin säästökin kompensoi suuria summia.

Siksi Wärtsilä pyysi selvittämään Model-Based Definition. Sillä voidaan säästää aikaa, varmistaa laatua ja soveltaa älykkäämpiin valmistustekniikoihin. MBD soveltuu erinomaisesti pienempiin tuotantoyksiköihin, joissa on useita eri muunnelmia tuotteessa, koska menetelmä mahdollistaa lyhyemmän designe-ajan.

Opinnäytetyön tuluksena syntyi design guidein, joka sisältää MBD:n suunnitteluun tarvittavat tiedot, suunnitteluopas on tarkoitettu vain Wärtsilän työtekijöiden sisäiseen käyttöön

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Kieli:
Avainsanat: Model-Based-Definition (MBD), Product-Manufacturing-Information (PMI), Design Guide

Table of Content

Abbreviations

Table 1

MBD	**Model-Based Definition**
PMI	**Product Manufacturing Information**
CAD	**Computer-Aided Design**
TDP	**Technical Data Package**
SSoT	**Single Source of Truth**
TED	**Theoretical Exact Dimensions**
CAM	**Computer Aided Manufacturing**
DPD	**Digital Product Definition**
IoT	**Internet of Things**
RAD	**Reduced Annotation Drawing**
2D	**Two Dimensional**
3D	**Three Dimensional**
CPS	**Cyber-Physical Systems**
AI	**Artificial Intelligence**

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1 Introduction

Modern design and production chains make it possible to utilize Model Based Definitions. MBD is a way to create 3D models that contain all the needed data to define a component. The MBD 3D CAD model will include dimensions, orientations, tolerances, surface roughness, material specifications, stampings, and component information. The resulting model file can then be transferred directly to the machinery at the manufacturer and be read by the machine to manufacture the MBD-designed component.

Today Wärtsilä uses a design system that includes two parts, first, the designer creates a 3D model of the component. The designer uses specific dimensions to create the 3D model. A 2D drawing with views of the model is made from the 3D model, and all the manufacturing information is added to the drawing. These files are then used by the manufacturer to manufacture the component.

The transition to MBD reduces the risk of human errors, since using only one reliable source of truth with the manufacturing information. To efficiently use MBD in the manufacturing process it requires machinery and smart systems that can read the files and manufacture the components. There is an ongoing transition in the industry to smarter systems, and utilization of AI to further improve productivity, and avoid errors and mistakes.

1.1 Background

Wärtsilä is a company operating on a global scale in more than 68 countries. To keep up with the global competition there is a need to keep up with the latest way of working, otherwise, there is a risk of falling behind the competition. Since a large part of Wärtsiläs work involves design work, there is a need to research if new ways of designing can be useful and if there is a possibility to adapt it to the design-engineers way of working.

This resulted in that Wärtsilä wanting to do research in Model-Based Definition if there is a possibility and a good way to implement MBD for the way of working for Wärtsilä

engineers. To do this implementation, there is a need for a design guide on how to create an MBD design, that describes the steps and information needed.

The first step was to look at what possibilities MBD can bring with it, and if the effort to change the way of designing is worth to be changed.

MBD is the new and modern way to design components, the reason for Wärtsilä to make this change is to stay competitive in the global market considering factors such as performance, innovation, quality, and personalization. In a project, time is critical, delays and prolonged construction time is expensive and can create time constraints in other projects. (Boucher, 2017) has researched how time is spent while designing. The conclusion of the research showed that 33% (*figure 1*) of the designing time is spent on creating and making changes to the 2D drawing. Since the 3D model already includes most of the needed information, a second 2D drawing of it can be considered a waste of time. To save this time, MBD can be used. Model-Based Definition (MBD) uses a 3D CAD model where the Product and Manufacturing information (PMI) is embedded into the 3D model. The embedded information can include geometric dimensions, surface finish, and material specifications. This 3D CAD model with all the documentation supports downstream processes such as supply processes, manufacturing, analysis, and inspection. By implementing MBD, companies are looking for a way to improve the use of engineering time.

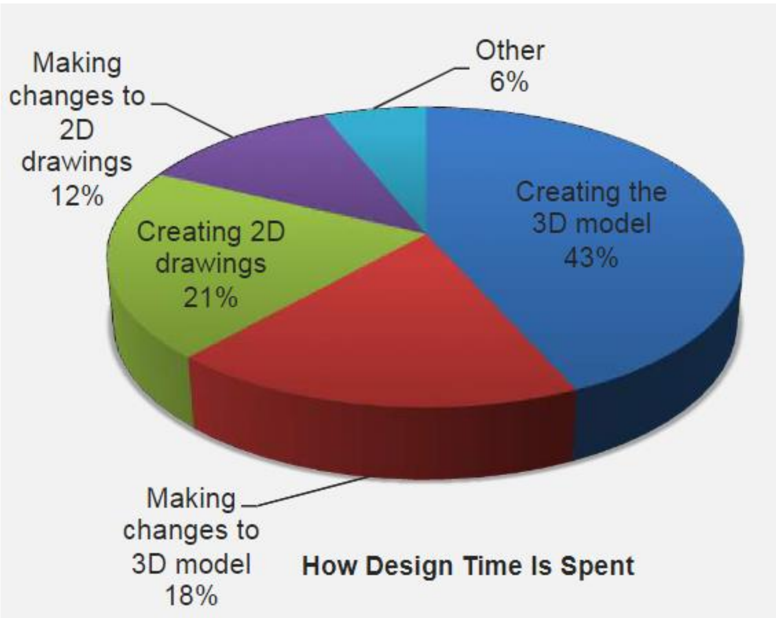

Figure 1, How time is spent when designing **(Boucher, 2017)**

Some Large companies like Boeing have made a successful transition to Full 3D-based engineering (MBD), however, other companies have been less successful in their attempts and kept on to their old way of working. Studies done by *Deloitte study on digital manufacturing"* concluded that there is a possibility to improve quality up to 35% and at the same time reduce cost by 20-30% (*figure 2*). This possibility of quality improvement and cost reduction gives an advantage to companies that succeed to make the transition to MBD. Because of the advantage, there is limited information released by the companies on how to make the transition successful.

The studies done by (Laaper & Kiefer, 2020) show possible saving opportunities in specific areas and why MBD is important to implement for a more success full manufacturing process.

Improved asset efficiency (10-20%)	**Improved quality (10-35%)**	**Reduced cost (20-30%)**
• Optimized capacity • Asset utilization • Changeover time • Down time	• Scrap rates • Fill rates • Yield • Lead Times	• Labor cost • Sourcing cost • Inventory levels • Maintenance cost • Warranty cost

Figure 2, Areas with saving opportunities **(Laaper & Kiefer, 2020)**

1.2 Purpose

The purpose of my thesis was to define and develop the information needed to support the internal transition to Model based definition for Wärtsilä.

1.3 Goal

The goal of this thesis work was to write a design guide that can be used internally by Wärtsilä designers. The document will explain the way and rules on how to create a PMI-equipped 3D model. To reach the information needed for the design guide, we needed to research information about MBD, create example cases (in 3D models), find applicable international standards, and communicate with design experts at Wärtsilä.

1.4 Demarcation

My thesis project was to write the design guide as part of the Model-Based Definition project. This included finding and describing the standards needed for designers to fulfill MBD implementation, how to create MBD models and assemblies, how to create and apply PMI, and how to export the files. My role was to document and put together the information and decisions we found through our research and studies to create a design guide for other designers. Since MBD is still in early adoption face worldwide, we knew that we would not have access to a lot of material to base our study on, this meant that we needed to find and create our own material to base the design guide on.

During project execution, the target for the design guide changed as our team got a deeper understanding of MBD. The focus changed from assemblies & models to mainly focusing on finding appropriate standards that should be followed during the implementation of MBD models, how to create PMI views to 3D models in NX and what to include in a specific PMI view, how to apply PMI to 3D model, how to create RAD (Reduced Annotation Drawing), how to export model and how to use/create JT2Go.

We decided to leave out assemblies and the checkmate tool, focusing on only models for the first revision.

1.5 Company Description

Wärtsilä is a Finish global leader in innovation technology and lifecycle solutions for the marine and energy market. Wärtsilä is operating on a global scale in over 68 countries and has a team of 17,000 employees.

The main product from Wärtsilä is medium-speed diesel & gas engines, used by the marine and stationary energy sector. My position at Wärtsilä is in the R&D section for marine as a design engineer on the W31 engine. 2015 Wärtsilä won an achievement for the Wärtsilä 31 engine, Guinness world record appointed the W31 the most efficient 4-stroke diesel engine in the world.

Wärtsiläs is not a mass producer or seller of parts and only manufactures parts for engines in production or for service use, therefore the production consists of smaller batches.

Wärtsiläs is not a mass producer or seller of parts and only manufactures parts for engines in production or for service use, therefore the production consists of smaller batches. Engine products are made to last for a long lifetime, so quality is a crucial part of production. The production is focused to be made for different engine variants, there for MBD can be utilized for the production to make it more efficient.

Also, a large part of Wärtsiläs business consists of service and upgrades. These services are often different from engine to engine, and therefore smaller production since parts are often specific to engines. There for MBD could be used in a lot of ways to make production more efficient.

Figure 3, Wärtsilä logo **(Wärtsilä , u.d.)**

1.6 Disposition

Chapter 1, includes an introduction of Model-Based Definition, the background that led to this project, the purpose of the project, the goal of my thesis, and an introduction of the company I wrote the thesis for

Chapter 2, includes the theory, design, tools, and changes in the industry that makes MBD useful. What standards were used in the Model-Based Definition Design Guide, and another company that utilizes MBD

Chapter 3, includes the method used to create this design guide

Chapter 4, includes parts of the result, but because of confidentially restrictions, detailed information regarding Wärtsiläs design guide is left out.

Chapter 5, includes a discussion of my view of writing this thesis.

2 Previous Research and Theory

Previous research done by (Ruemler, Zimmerman, Hartman, Hedberg, & Feeny, 2016), describes the strategy for Model Based Definition (MBD). The idea about MBD is to use a 3D model where all Production Manufacturing Information is stored in the CAD file and moved away from the 2D drawing. The transition to MBD can establish a single source of truth (SSOT) in form of a 3D CAD file if all the necessary PMI is entered directly into the 3D model instead of a paper-based drawing. The 2D drawing has been and, in some cases, still is the primary carrier of product definition used for manufacturing, but through the years CAD has become more and more the standard to use for product-definition source by engineers. However, Model Based Definition is still in the early adoption phase worldwide but is gaining popularity due to the benefits and advantages MBD brings with it. Since information placed in the 2D drawing is already used to define the CAD file it seems unnecessary to reproduce the same data in another file. Errors when reproducing data can be reduced when fewer files and unnecessary design time is reduced. The survey result shows that the idea of 3D CAD is accepted by the industry but a full transition to MBD without any 2D drawing drawings is commonly seen as too big of a risk.

2.1 Industry 4.0

Industries have gone through different types of industrial revolutions, in short, there have been three major industrial revolutions and now the fourth is ongoing. (i-SCOOP, u.d.)

- Industry 1.0, the first industrial revolution. During the first revolution, the focus was on labor-assisted manufacturing, with the introduction of water and steam-powered mechanical machines to manufacturing.

- Industry 2.0, the second industrial revolution. Introduction of electricity in manufacturing facilities. This allowed a way for mass production by electrical machinery and the invention of the production line.

- Industry 3.0, the third industrial revolution. By Implementing electronics and computer technology in manufacturing. A programmable Logic Controller (PLC) could be used to automate the production line.

- Industry 4.0, the fourth industrial revolution refers to the ongoing transition to digitalization and advanced robotics in manufacturing. By using the Internet of Things (IoT), Artificial Intelligence (AI), Smart manufacturing, real-time data, and Cyber-Physical Systems (CPS). Industries can analyze the data and streamline production to improve processes.

2.2 Industry 4.0 / Smart Manufacturing

By transitioning to a smarter manufacturing system (*figure 4*) that includes machine learning, data analytics, 3D printing, IoT, and other technological improvements, it is possible to reduce the dependence on personal decisions when manufacturing. By connecting the information through IoT it is possible to have a source of information that is trustable and not dependent on anyone without the knowledge, this can reduce errors in the manufacturing process. Implementation of a smart manufacturing system with IoT and Cyber-Physical Systems (CPS) can be used to make data-driven decisions in the manufacturing process. The connections between machinery allow Machine-to-Machine communication, the data given from a machine can be read and tracked by other machines in the factory process. The information collected is analyzed and the factory process adapts to make the best of the production line.

Figure 4, Industry 4.0 **(Buchberger, 2021)**

2.3 Product Manufacturing Information

The model-Based definition is the latest revolution in product development and manufacturing. The theory behind the change is to include and provide all the product manufacturing information data in the 3D CAD model, this makes the external 2D drawing with the added PMI data unnecessary.

The PMI data added to the MBD 3D CAD file depends on the component.

PMI data that could be added to MBD 3D model

- Dimensions and tolerances
- Geometrical Product Specification
- Surface roughness
- Zero Point Definition
- Markings
- Tightening Torque

These are just a few of all the existing PMI:s that could be added.

2.4 Standards

The design guide is based on international standards. Some standards are parallel with minor differences and can be used for specific cases depending on specific requirements.

In *table 2* are listed the standards that are relevant to the design guide

Table 2

Standards	Name of the standard (GPS) = Geometrical Product Specification (TPD) = Technical Data Package
ASME Y14.41-2012	Digital Product Definition Data Practices
ISO 16792:2015	Technical product documentation – Digital product definition data practices
MIL-STD-31000B:2018	IL-STD-31000B, Military Standard: Technical Data Package
ISO 1101:2017	Geometrical Product Specification (GPS)
AS9100	Quality Systems
EN ISO 22081:2021	Geometrical Product Specification (GPS)
ISO 17450-1:2011	Geometrical Product Specification (GPS) – General concepts – pt1: Model for Geometrical specification and verification
ISO 5459: 2017	Geometrical Product Specification (GPS) – Geometrical Tolerancing – Datums and datum systems

2.4.1 ISO 22081

Standard that is used to define and interpret the general geometrical & general size specifications according to ISO 8015:2011. MBD design is based on ISO 22081 standard.

This standard is used to define general product specifications standards. This includes general geometrical specifications and general size specifications that can be used in a Technical Product Document (TPD) with the less individual specification. Since many geometrical features use individual specification that is similar or identical, general specifications can be applied (ISO-22081, 2021).

2.4.2 ISO 17450-1

Standard that provides a model for geometrical specifications, and verification & defines the corresponding concepts.

This standard is used to define the fundamental concepts of GPS systems. This includes the GPS language to verify features, rules, and characteristics to be used in designing, manufacturing, or verification. This standard provides a complete symbology language to indicate GPS specifications. (ISO-17450-1, 2011)

2.4.3 ISO 5459

Standard that provides terminology, rules, and methodology for indication and understanding of datums and datum systems in the technical product documentation.

This standard is used to specify terminology, rules, and methodology to indicate and understand datum and datum systems in the technical product documentation. Datums are used to locate or orient tolerance zones (ISO-5459, 2011)

2.4.4 ISO 1101

Standard that defines the symbol language for the geometrical specification of workpieces and the rules for its interpretation (ISO-1101, 2011)

2.4.5 MIL-STD-31000B

Standard that defines the requirements for a technical data package (TDP) and related data management products.

The Technical Data Package (TDP) is used to provide an authoritative technical description for an item. TDP could include data like models, drawings, associated lists, specifications, standards, quality assurance, provision software, and documentation packaging details. (MIL-STD-31000B, 2018)

2.4.6 ISO 16792

Standard that defines requirements for the preparation, revision, and presentation of digital product definition data.

It specifies what requirements are needed for digital product definition data, this supports 3D models only and 3D models with a 2D drawing. A digital Product Definition data set includes annotations, attributes, and the CAD design model. (ISO-16792, 2021)

2.4.7 ASME Y14.41

Standard that establishes requirements and reference documents applicable to the preparation and revision of digital product definition data. (ASME-Y14.41, 2019)

2.5 Single Source of Truth

The reliability of the source/file is critical to avoid mistakes that can cause problems and extra costs. Using a single file containing all the information (SSoT), ensures that the file given to the manufacturer includes the relevant data. Without MBD there are two Sources of Truth, one source includes the 3D model, and the other source is the 2D drawing with Production Manufacturing Information. This means that information needed to manufacture the product is stored in two separate places. This makes the possibility for errors when product information is taken from different places and inserted into a machine. With MBD all the product information is included in the 3D CAD model, which leads to a Single Source of Truth.

2.6 Designing In 2 Dimensional & 3 Dimensional

For mechanical design and manufacturing, CAD files are commonly used. There are two common ways of designing for manufacturing, 2D, and 3D (*figure 5*). The traditional way of designing was simple drawings on paper without any computer-assisted programs, this made 2D drawing on one plane the way to do designs. This method is still in use today, often used combined with a 3D-designed model and a 2D drawing with views and measurements (PMI). With the evolution and application of computers in engineering, designing 3D models where the most efficient and logical way of designing. This made it possible to make a visual component with specific measurements and production manufacturing information into the model, the model can then be rotated on any of the axis (x, z and y) to visualize the workpiece.

By looking at the differences between 2D and 3D, there are many advantages to using 3D over 2D.

- 3D CAD improves production quality and technical content. In modern mechanical production facilities, advanced design methods are used to insure and improve quality, optimization, stress analysis, and motion simulation.

- Reduces design time and improves efficiency. With a 3D-designed component the model can be visualized and reconstructed accordingly to changes in structure size and parametric changes when a structure is changed other related structures can change as well to the redesigned component without the need to change all views. This makes the design work more efficient.

- 3D design promotes CAD/CAM integration. By designing in 3D, the 3D model can realize the integration of CAD to CAM, this means that 3D CAD technology can understand and support the process from product design and obtain the information for the manufacturing process. If the machinery can read and make an integration between the 3D CAD to the CAM file, it is possible to ensure that the component created by the machinery is consistent with the design.

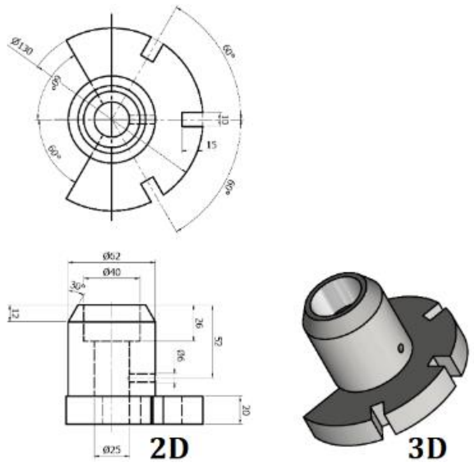

Figure 5, 3D view of part and 2D views of part
(CNCLATHING, 2020)

2.6.1 2 Dimensional Views

2D CAD is a two-dimensional Computer-Aided Design used to define and display views of a model with height and length (*figure 6*). Since 2D only uses two axis in one plane (X and Y) depth is not possible to project. 2D views present the model from different angles usually top, bottom, front, back, and sides, depending on the design of the component. The information added to the drawing is critical for the manufacturer to be able to manufacture the component. 2D CAD used in manufacturing design collects measurements and definitions of geometric elements of points, lengths, diameters, radiuses, and arcs. Drawings are made on one plane file or paper and need to be understandable from the dimensions to manufacture.

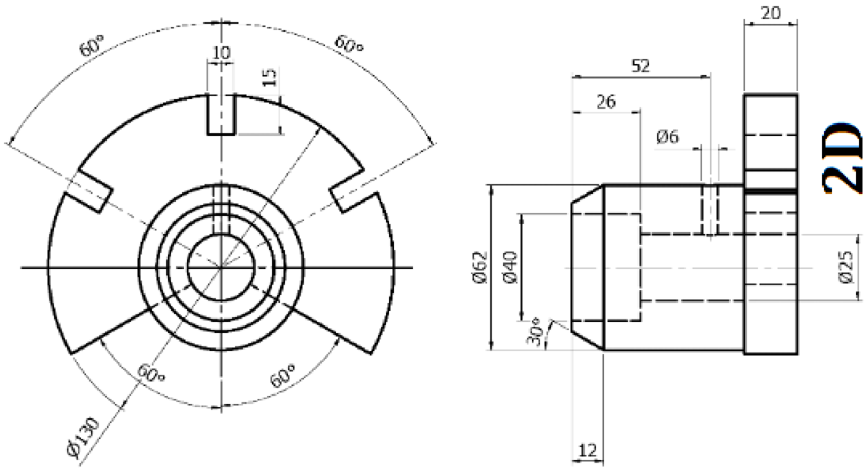

Figure 6, Views in 2D **(CNCLATHING, 2020)**

2.6.2 3 Dimensional Views

3D CAD is a three-dimensional Computer-Aided Design that defines and displays a whole component with length, width, and depth (*figure 7*). 3D CAD is the 3D model of a component that represents the total and actual shape of the component. Included in the model are the measurements and geometry of the faces, points, and lines. With a 3D model, it is possible to see and understand how the final product is presented and should be manufactured.

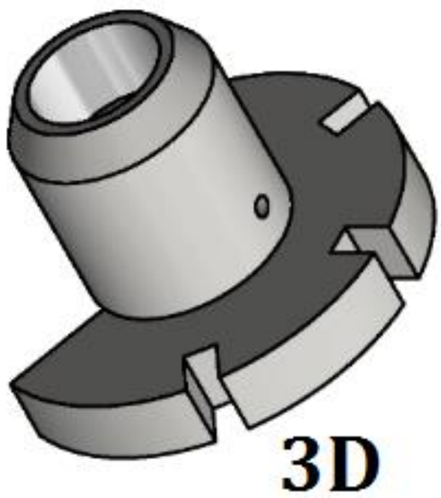

Figure 7, 3D model **(CNCLATHING, 2020)**

2.7 SIEMENS NX

The tool we used to design and create MBD models was (SIEMENS NX, u.d.), which is a CAD software used to design 3D models and create 2D drawings. Siemens NX supports Model Based Definition by having tools that complete digital definitions of a component designed in 3D (*figure 8*).

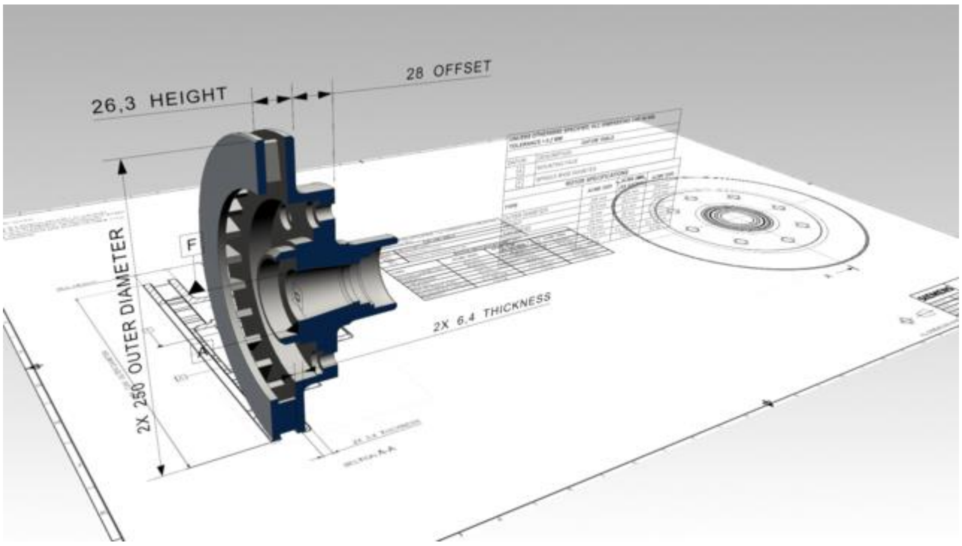

Figure 8, MBD in NX **(SIEMENS NX, u.d.)**

2.8 MBD in Boeing

Boeing is the world’s largest aerospace company and leading manufacturer of commercial jetliners, defence, space, and security systems. They have implemented Model Based Definition (MBD) for their suppliers to follow according to the Boeings Assessor Task Guide for “Digital Product Definition/Model Based Definition Checklist”

The task guide created by Boeing is made for their suppliers. This document is split into 4 sections so suppliers can follow the requirements needed. The sections are defined as followed (Boeing, 2010).

- Section A of the checklist is used to perform a basic Digital Product Definition (DPD) capability verification.
- Section B is used to perform Model Based Definition (MBD) capability verification.
- Section C is used for Coordinate Measurement System (CMS) capability verification.
- Section D is used to perform Plotter Capability verification.

Boeing uses the Assessor Task Guide as a Model-Based Definition Checklist and document D6-51991 (QUALITY ASSURANCE STANDARDS FOR DIGITAL PRODUCT DEFINITION AT BOEING SUPPLIERS) as information on what standards and requirements are needed to design and manufacture for Boeing. By making these guidelines and quality-assured standards documents, Boeing can inform and let their suppliers reach the requirements set by Boeing.

A more comprehensive description of Boeings task guide can be found (Boeing, 2010)

3 Method

Summer of 2021 I started working as a design trainee for the Wärtsiläs department of R&D for the W31 engine. After the summer I continued a 25 h/week contract and was offered a position to be a member and thesis writer in a new team my manager started. I was given the task to write the design guide for the project.

To get the decisions and results to the design guide we needed to work together to solve the problems. We had a goal that we wanted to reach, **MBD "full 3D based engineering"**, and from that goal started the study on how to reach it. Since we as a team had to find the way and plan for Wärtsiläs application to MBD we started to study material from standards, other companies, and MBD studies available.

By creating example MBD models we were able to identify problems and situations that we needed to sort out. By showing examples to design experts within Wärtsilä, decisions were then taken on how to continue with the design.

Our plan for Model Based Definition is targeted to be reached before 2024, but the whole transition could take much longer. The plan is divided into three groups, starting with the Acquisition of know-how and continuing with distribution and futureproofing (*figure 9*).

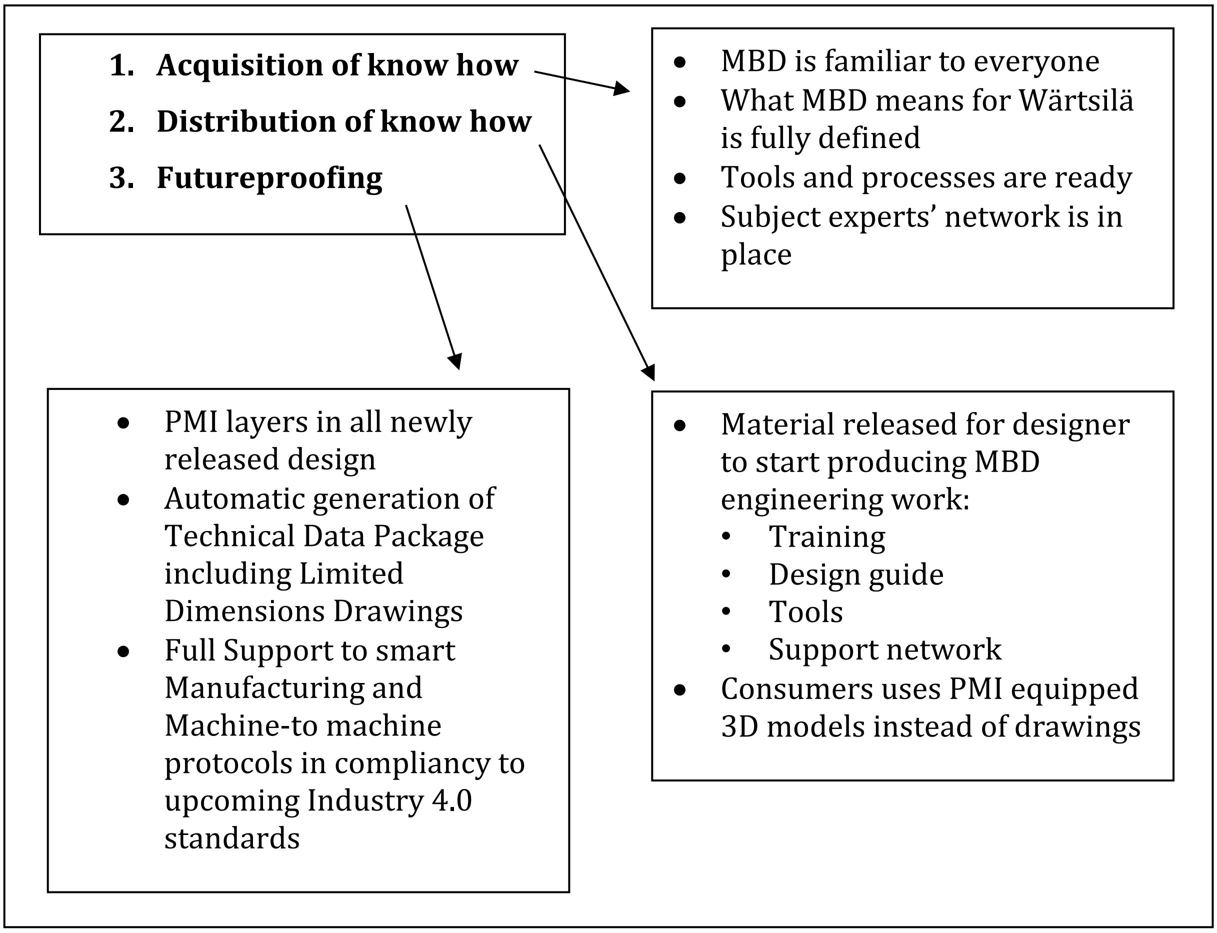

Figure 9, Model Based Definition Plan

4 Result

The purpose of the design guide is to be used as a guideline for designers and experts, on how to create a Model-Based Definition design.

The result was published on 26.08.2022 to Wärtsilä Marine Solution Engines Technology as a Design Guide for Model Based Definition in Engineering Innovation and Advanced Concepts. The design guide is to be published for internal use only and cannot be distributed outside of the Wärtsilä organization. Because of that important and specific information has been left out of the result.

Design is based on standard (ISO-22081, 2021) PMI is given to separate views under model views in NX. These views shall include specific Product Manufacturing Information determined by the view.

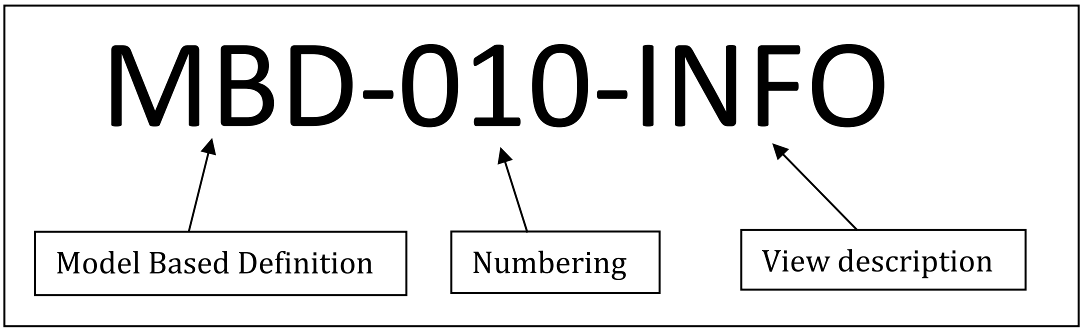

Figure 10, MBD view names

The PMI-equipped model will be released as part of a Technical Data Package (TDP). A TDP is a data package that includes the technical design such as the PMI-equipped 3D model and the manufacturing information needed for the manufacturing of the component. In our case, the TDP will include the PMI-equipped model and a Reduced Annotation Drawing (RAD).

For the 3D model, there will be a support document to complete the model. This document is a reduced drawing since all the Product Manufacturing Information that would be put into the 2D drawing is now included in the 3D model. The Reduced Annotation Drawing will therefore include less information and only show one view (*figure 10*) with main dimensions to easily check the size of the component.

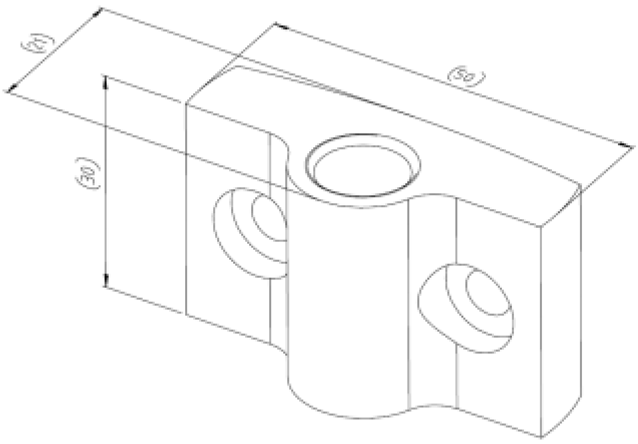

Figure 11, Isometric view to use in RAD

4.1 Example of how to create an MBD-PMI view

All annotations should be placed in dedicated PMI views. Each PMI views is to contain (dimensions) annotations on the plane perpendicular to the view line of the site

PMI views are created in the view node on Part Navigator

1. First, the appropriate standard view is made the work view and not re-oriented

Figure 12, Standard model views in part navigator

2. Click mouse button 2 (MB2) on the Model Views line in Part Navigator and choose Add View

3. Enter a name for the new view, using the format “MBD-###-Description” (Running number and view description)

Figure 13, New work view with name according to *figure 10*

4. Add the PMI views to the “Model Views” list by clicking the mouse button (MB2) on the Model Views line in Part Navigator and save the arrangement.

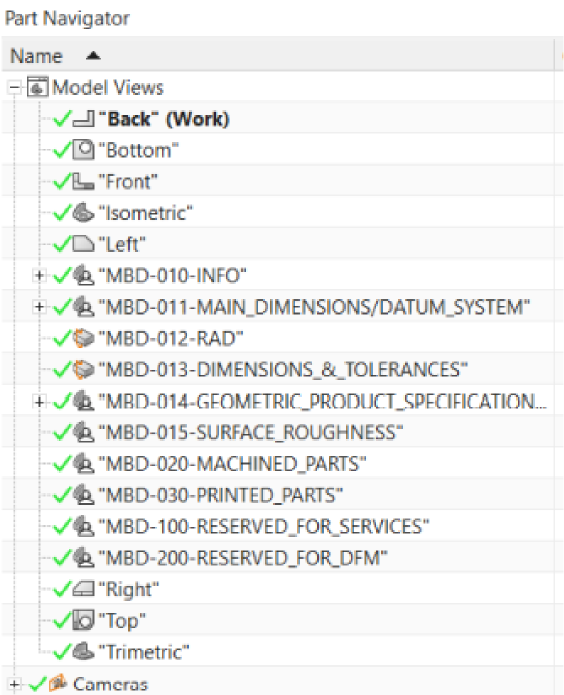

Figure 14, Part navigator with example model view names

4.2 PMI annotations

Dimensions, surface roughness, and other PMI annotations to the model views are added from the PMI ribbon.

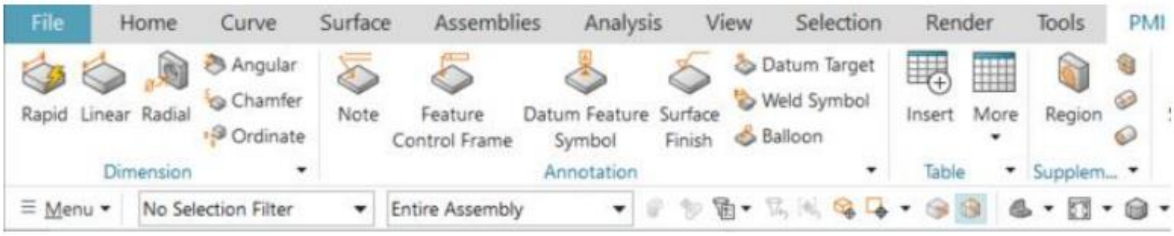

Figure 15, NX command ribbon

4.3 Example of how to create a Surface Roughness PMI annotation

1. First, create a View for Surface roughness "MBD-###-SURFACE_ROUGHNESS"
2. Make the New View Work View, by double-clicking on the view

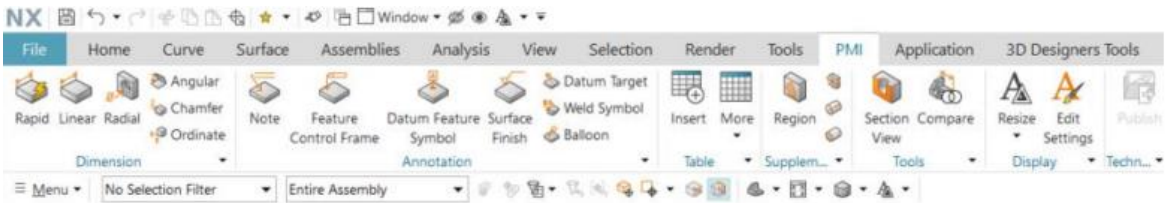

Figure 16, PMI options in NX

3. Place the Surface Finish symbol in the position where it should be shown related to the model presentation, then select all similar surfaces that are defined to have the same surface roughness value and enter the specific values

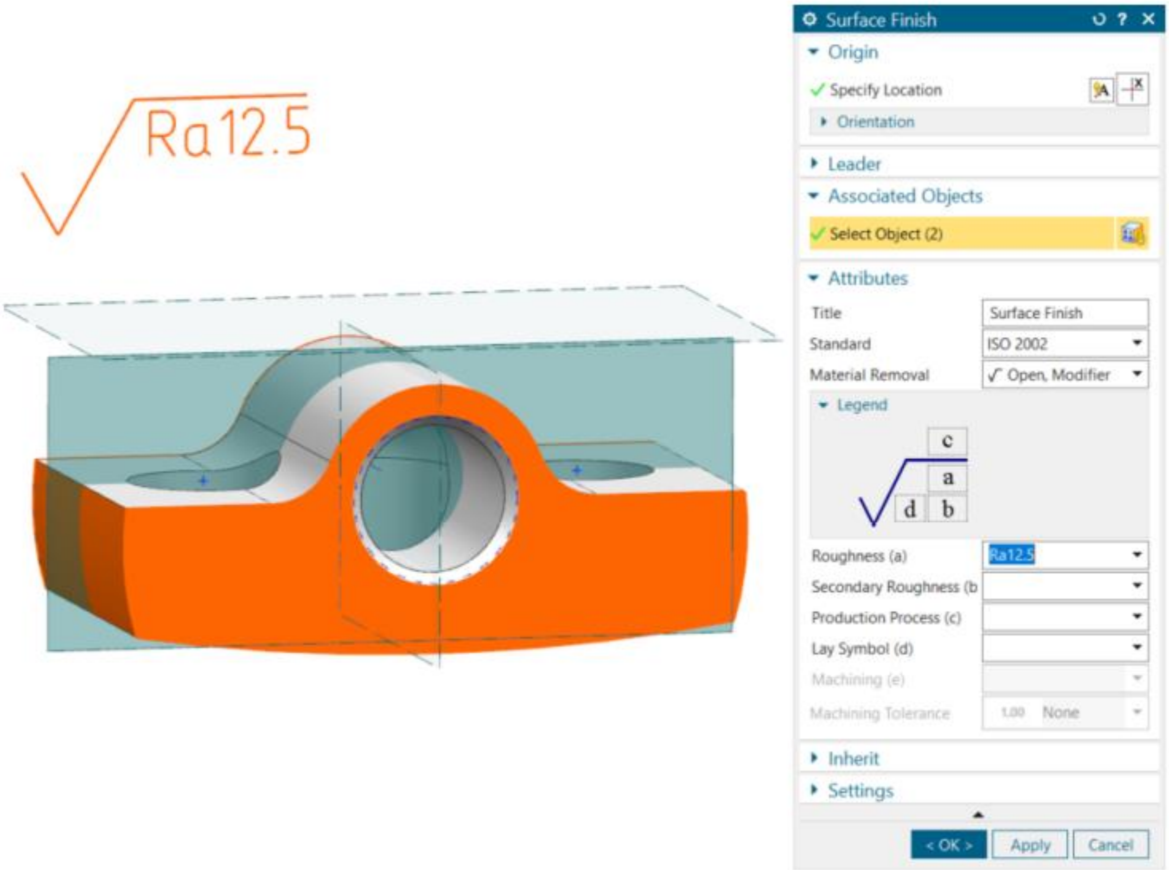

Figure 17, Applications of Surface Finish in MBD

4. Model with added PMI annotations, surfaces affected with specific surface roughness is highlighted when an annotation is affected

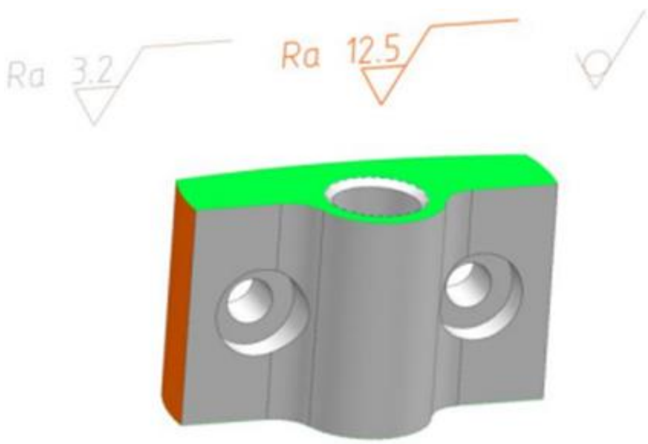

Figure 18, Example model with PMI annotations

Design is based on standard (ISO-22081, 2021), (ISO-5459, 2011) & (ISO-17450-1, 2011) where zero point is determined by datum systems. There are usually three datums given, A, B & C (*figure 19*), and the intersection point of the three datum planes determines the measuring/machining zero point.

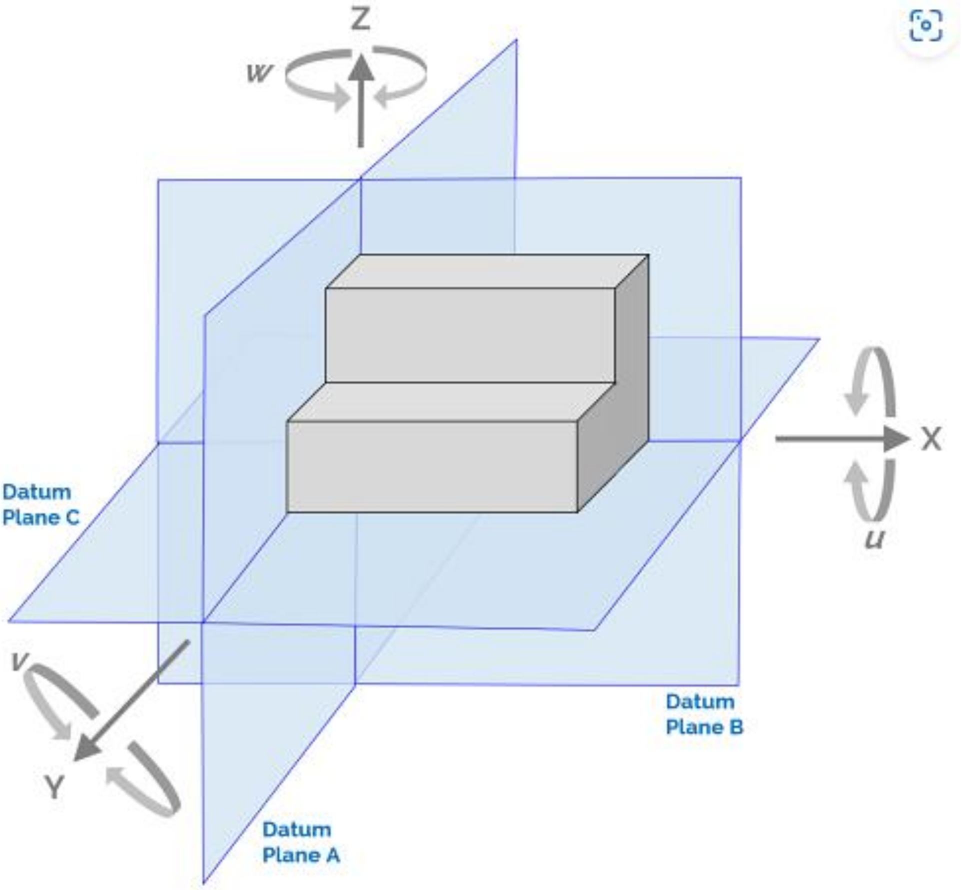

Figure 19, Example on Datum A, B & C **(Enventive, u.d.)**

4.4 The design Guide

The design guide is to be used internally only, there for it cannot be released for this thesis document. This shows only the overall subjects used in the design guide.

1. Introduction
   The design guide written for Wärtsilä starts with an introduction of the design guide and introduction plan for Model-Based Definition. Also, the relevant standard to use when designing in MBD is listed.

2. Design
   The design part describes how to use MBD, what support documents are needed and how to create them.

   What information to place in specific MBD view and how to sort them.

   How to create PMI views in NX, and how the information, dimension, annotations, or markings should look and be placed into the views.

   Information on specific Manufacturing Technologies, machined, sheet metal, casted, welded, or 3D printed parts

3. Exports
   Information on how to export parts, how to create the files and how to prepare models for export

4. APPROVAL PROCESSES FOR MBD OBJECTS
   What to consider when approving MBD objects

5. JT2Go
   Siemens software 3D viewer

6. ABBREVIATIONS
7. REVISIONS

The rest of the project results regarding Wärtsiläs transition MBD is not included in the scope of this work.

5 Discussion

The design guide is now released to Wärtsilä but not taken fully into use, since there is still ongoing research for MBD in certain areas. For example, assemblies, and tools are still under development to fulfill the design guide. During the time the design guide was written, new situations and how to solve it was needed to take into mind, and some had to be left out for now.

For example, there is an NX tool called checkmate that was investigated on how to include it for MBD. The tool could be used to place certain requirements that need to be fulfilled in a specific MBD view before finishing a design. This tool can be used to reduce checking time and avoid errors.

5.1 Challenges

There were some challenges that occurred during the time I was writing the design guide. Since we as a team had to figure out the best way to go, changes in our steps needed to be made during the way we got more information. These changes that we had to do, could affect the earlier decisions we had taken, which lead to some rethinking. There the plan for the content in the design guide changed during the project was ongoing, when a better solution was found.

5.2 Final words

This way of working for this thesis was new to me, and I found it educational and interesting. Starting with limited information and having to do research and testing on how to continue with the project was interesting. When looking back at it now, I enjoyed and learned a lot throughout this project.

I especially want to thank Franco Cavressi, my supervisor from Wärtsilä, for assigning me this project and guiding me through the writing of this design guide and thesis work. Also, I want to send a big thank you to Kenneth Ehrström my supervisor from Novia, and my teammates Fredrik Roos and Heikki Laaksonen.

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