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DESIGNING THE CONFIGURATION OF A MODULAR SLOW TURNING DEVICE

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DESIGNING THE CONFIGURATION OF A MODULAR SLOW TURNING DEVICE

The purpose of this Bachelor’s thesis was to improve the slow turning device in the engines by changing the usage of the device from pneumatic to electromechanic, and to give suggestions on how to improve the engine configurations.

This thesis contains information about the essential subjects of the project and the basic information about the parts and models used in the project. This thesis was commissioned by Wärtsilä.

Because of Wärtsilä’s product portfolio and different engine configurations, there are many different slow turning modules This creates a workload and slows down designing and inspecting the changes made in the area near the slow turning device.

The project was necessary because the pneumatic slow turning device had had some durability issues. Also the electromechanic device is more user-friendly and safer. The project changed the engine configuration so that there is only one module on the specific engine size and type.

The change to the engine configurations has not been implemented yet because the slow turning devices are at prototype stage being tested and validated.

KEYWORDS:

slow turning, turning device, module, modularization

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MODULAARISEN HIDASPYÖRITYSLAITTEEN KOKOONPANON SUUNNITTELU

Tämä opinnäytetyö ja siihen liittyvät havainnot ovat tehty Wärtsilälle.Opinnäytetyössä käydään läpi projektin keskeiset osat ja perusteet projektiin liittyvistä osista, sekä malleista.

Projektin tarkoituksena oli parantaa hidaspyörityslaitteen toimintaa muuttamalla sen käyttöä pneumaattisesta elektromekaaniseksi ja samalla antaa parannusehdotuksia nykyisiin moottorikonfiguraatioihin.

Wärtsilän tuoteportfolion ja erilaisten moottorikofiguraatioiden vuoksi on olemassa monta erilaista hidaspyörityslaitekokoonpanoa ja tämän vuoksi muutoksien suunnitteluun ja tarkistamiseen käytetään paljon aikaa.

Projekti on tarpeellinen, koska pneumaattisella hidaspyörityslaiteella on ollut ongelmia kestävyyden kanssa, elektromekaaninen hidaspyörityslaite on myös turvallisempi ja helppokäyttöisempi.

Projektissa muutettiin moottorikonfiguraatiota, jotta saatiin yksi hidaspyörityslaitemoduuli käyttöön muutoksen alla olleisiin moottorikokoihin ja –tyyppeihin.

Muutosta ei ole vielä tapahtunut, koska hidaspyörityslaitteet ovat prototyyppi tasolla testauksessa ja validoinnissa.

ASIASANAT:

hidaspyöritys, hidaspyörityslaite, moduuli, modulointi

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List of abbreviations and definitions

Modularity	The existence of systems constructed from modules.
Component sharing	Sharing the same component between the different products.
Component swapping	Sharing the frame and by changing a component creating different modules.
Sectional modularity	Modules sharing same interfaces.
Cut-to-fit modularity	Sharing same types of components, but by changing for example the length of a column to obtain different end products.
Bus modularity	Sharing the platform and by changing or adding components creating different modules.
Flywheel 0-point	When the number 1 piston is at top dead center.
TDC	Top Dead Center, the upmost position of the piston.
TBA	To Be Announced.
X-axis	Horizontal axis, when looking towards the flywheel.
Y-axis	Vertical axis, when looking towards the flywheel.
Z-axis	Depth axis, when looking towards the flywheel.
NO-valve	Normally Open valve
NC-valve	Normally Closed valve
TD	Turning Device
EM	Electric Motor
SA	Start Air

1 INTRODUCTION

In recent years there have been several cases of bent connecting rods in several types of engines. These incidents have created doubt against the reliability of the pneumatic slow turning function used in Wärtsilä 4-stroke liquid and gas fuel engines.

At the beginning of the year 2011 a product improvement project was initiated to improve the slow turning function. The project was started by conducting research in the engine laboratory. According to the lab results, it is possible that the pneumatic slow turning used is not able to give alarm about the liquid in the compression chamber, as it was intended.

The hydraulic lock was detected by rotating the engine slowly. Slow turning was to be electromechanic with a turning device. Several variables were monitored during slow turning. If something abnormal was detected, a slow turning failure was given.

Turning device development was completed in co-operation with Katsa - a partner with a long experience in designing and delivering turning devices to Wärtsilä engines. A new main start valve without the slow turning circuit was developed. The target was to test a DN 50 size valve. The new main starting valve was developed in co-operation with Seitz.

By making the slow turning function electromechanic, the pneumatic slow turning function in the main starting valve would become obsolete. Components related to pneumatic slow turning were removed from the engine.

To be able to change the slow turning function from pneumatic to electromechanic the engine configuration will have to go through some changes. The changes made to the engine configuration should be made keeping the modular thinking perspective in mind. (Passila 2012.)

2 PRODUCT DESCRIPTION

Because at the moment Wärtsilä is using pneumatic slow turning which has had some durability issues and the technology of pneumatic slow turning is becoming obsolete, Wärtsilä has started to research for new ways to do the slow turning on the engines. One of these new ways is the electromechanic slow turning.

The electromechanic slow turning has many benefits over the pneumatic slow turning. Because the slow turning is done using a frequency converter to drive the slow turning device, the slow turning function is more accurate. Also, with the electromechanic slow turning the data and measurements received from the engine are more reliable and accurate and it is more practical when driven remotely. This is because the electromechanic slow turning function is controlled from the frequency converter and from the converter you can change the speed of the slow turning function if needed. For example, you get an alarm from the engine and with the electromechanic slow turning function you can have the precise point of the pistons where the alarm was given. Also, it is easier to control the electromechanic slow turning because you drive it from the frequency converter which has a control interface on it.

2.1 Slow turning

Slow turning is an automatic procedure where the engine is rotated slowly for a couple of revolutions without any fuel injection activated. Slow turning ensures that the engine can rotate freely and any faults in rotation can be checked. Slow turning is conducted both periodically for standby engines and during the start sequence.

2.2 Start air system

All engines, independent of the number of cylinders, are started by compressed air. The maximum pressure is 30 bar, while the minimum pressure before a start is 18 bar. The start is performed by injecting compressed air directly into the cylinder.

However, four cylinder engines intended for automatic start, W20, and the old types of SG and DF engines are provided with a pneumatic starting motor that operates the engine by means of a gear ring in the flywheel. Also this system requires an air pressure of 30 bar for starting.

The starting air is produced by air compressors in the starting air unit. The starting air is stored in starting air bottles until it is used for starting the engines.

The starting air compressor unit consists of one or two air cooled compressors, one working and one stand-by, and for big plants more than 2 starting air compressors can be needed. Both are electrically driven. However, one compressor can be diesel-driven and is then used as an emergency unit. This should be avoided and a better solution for a black start is to have the black start generator dimensioned also for the electric starting air compressor. The electrically driven compressor is used in all other cases.

Both compressors are of the same size and built on the same frame as a unit. The air outlet from the compressors is always connected in parallel. Vibration dampers are mounted between the compressor unit and the floor.

The starting air unit is also equipped with connections for the instrument air system. This is working as a backup line for the instrument air system in cases where the instrument air compressor fails. The pressure is controlled by a pressure reducer. On the next page, a picture of a double starting air compressor unit can be seen.

Picture 1. A starting air compressor.

2.3 The test laboratory engine

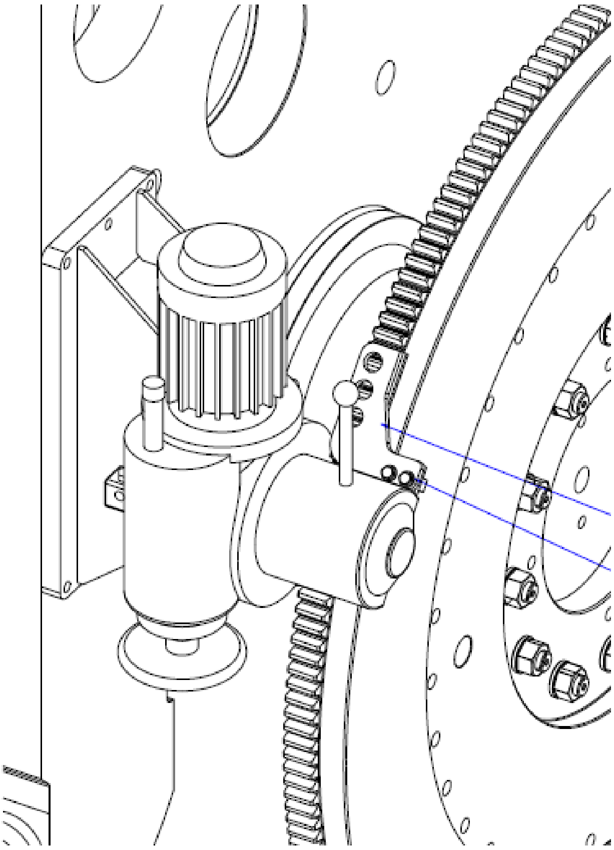
The engine which was selected to test the electromechanic slow turning function needed to undergo some changes in the engine configuration.

The first change was the starting air valve, because the start air valve had the pneumatic slow turning function integrated into it and it was no longer needed so there would be a new start air valve without the slow turning function. Because the new start air valve had smaller pipe size than the previous engine configuration, the starting air pipe needed to be modified accordingly. Also, the internal starting air schematic needed to be upgraded to have the electromechanic slow turning function in it.

The second change was to design a new fixing plate for the new slow turning device, and to design a fixing for the solenoid valves and for the start blocking valve. Because the new slow turning device was bigger in size than the previous one, it needed a new fixing for the ruler of the zero- point of the flywheel.

The third change was to design a new fixing for the frequency converter, which makes the electromechanic slow turning possible. This fixing became a new module added to the engine configuration.

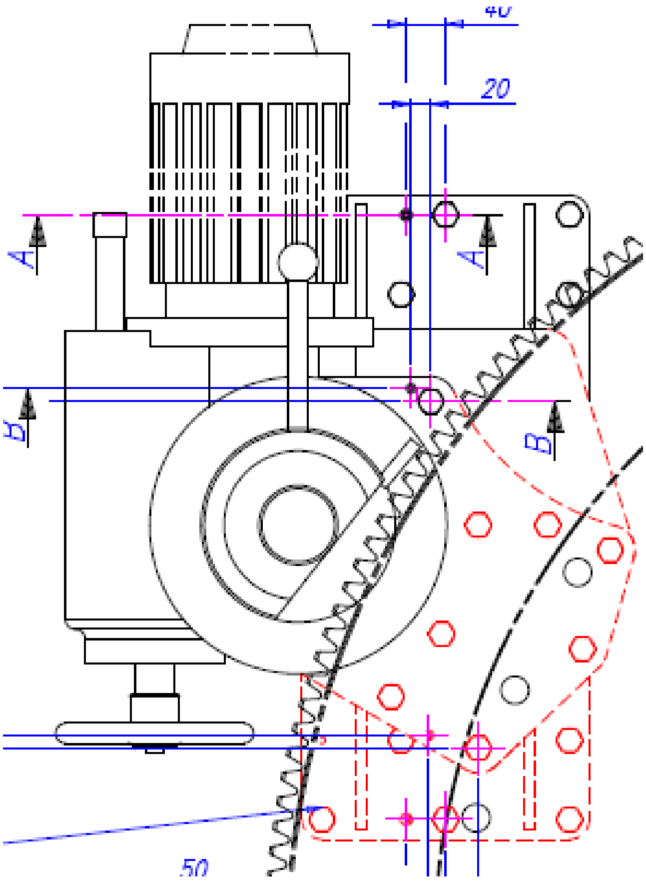
Below pictures and drawings can be seen from the current configuration of the test engine in question. There are also explanations on the changes needed in the engine.



Picture 2. The current slow turning device with pneumatic slow turning function.

In Picture 2 you can see the current slow turning device. This slow turning device has a pneumatic slow turning function and it is controlled by pressurized air and driven by an electric motor. The turning device has a handle for manually moving the turning gear to contact with the flywheel and to take it off contact with the flywheel (On and Off positions), and a hand wheel on the bottom to rotate the turning gear manually. The turning device also has a ruler to point out the 0-point of the flywheel (TDC, Top Dead Center of the cylinder 1) and the position of the crankshaft in general.

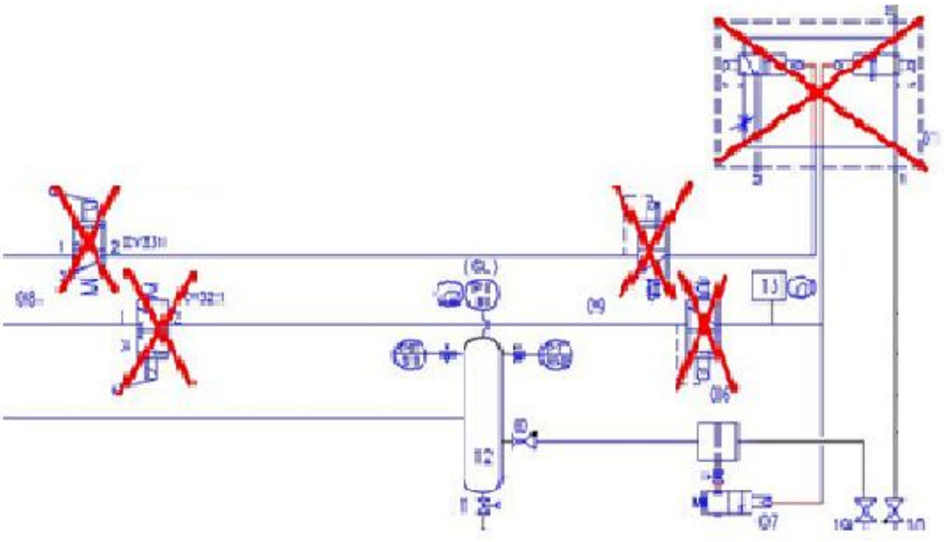
The slow turning device was attached to the engine block with a fixing plate, which did not fit with the new turning device, so a new one must be designed.



Drawing 1. The current slow turning device.

The current slow turning device is fixed with a fixing plate to the engine block. Above you can see how it is fixed. As you can see, the turning device has a mounting point which is on an angle when compared with the fixing plate.

This turning device is smaller and in different position than the upcoming turning device, so a new fixing plate had to be designed for the new turning device. A new position for it had to be determined because the new turning device is bigger in all directions.



Drawing 2. The current starting air schematics.

In drawing 2 you can see the current starting air schematics in use in the test engine now. The crossed-out areas need to be replaced.

The valves that need replacing are:

08: 3/2 solenoid controlled valves for starting and slow turning

09: Current blocking valve of turning gear

01: Main starting valve

Because the electromechanic slow turning was to be used, the solenoid controlled valves for slow turning were obsolete and needed to be removed. The current blocking valve of the turning device was changed to a new one and in a different place in the schematic. The last thing to be changed was the main starting valve with a new model.

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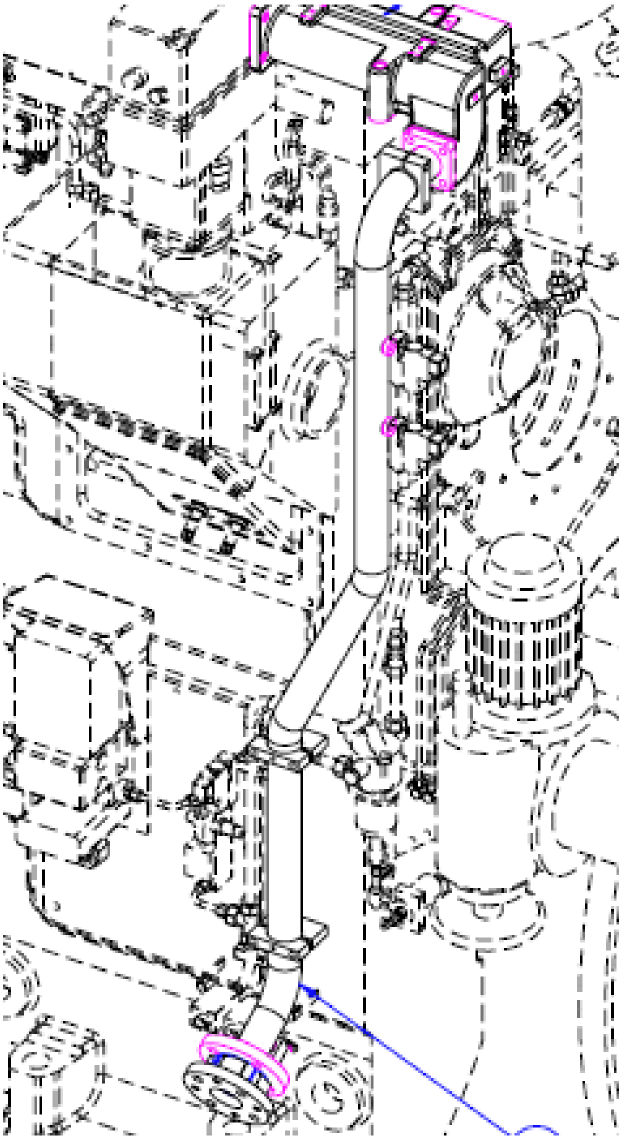
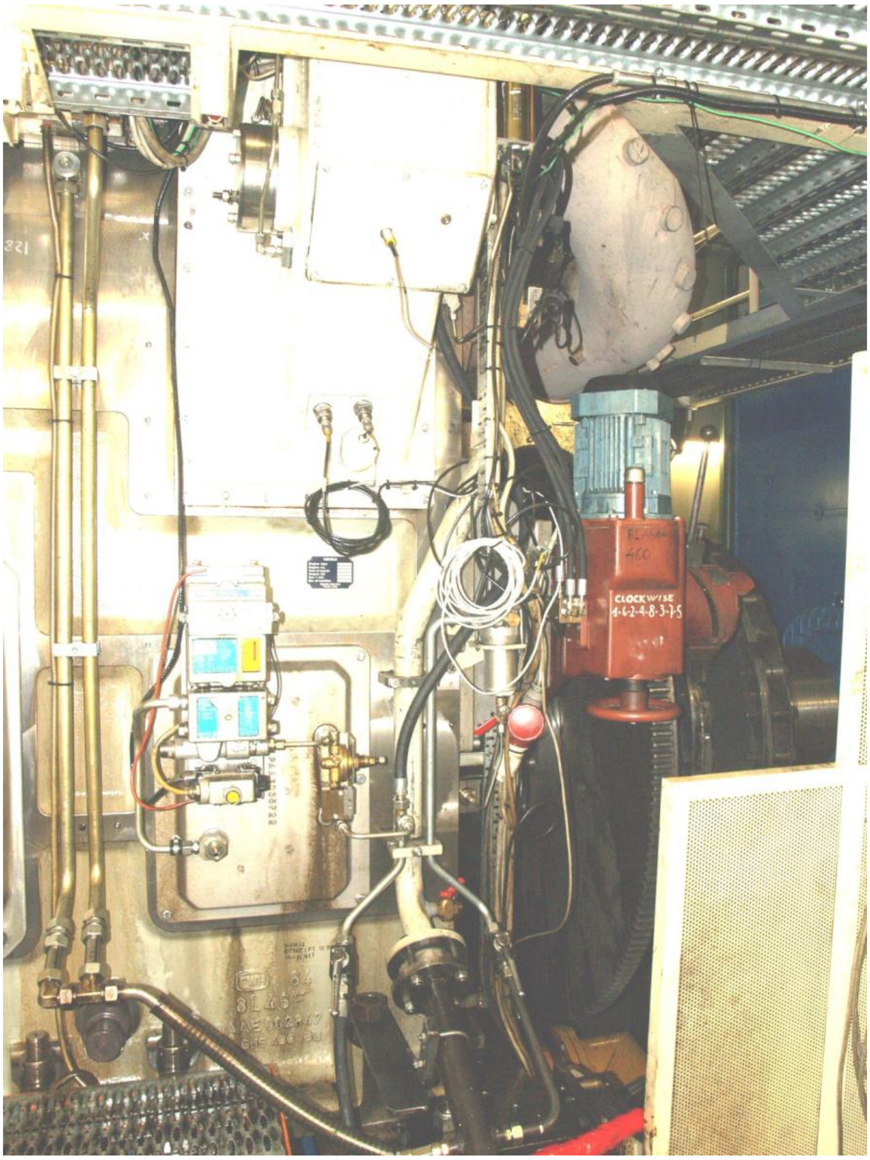


Picture 3. The starting air piping currently in use.

This is one of the modules that was replaced and merged with the starting air system module.

The starting air pipe module here has a simple starting air pipe leading from the starting air compressor (from the bottom of the picture, the round flange) to the main starting valve on top of the engine. The starting air pipe is fixed to the engine block with two fixing clamps.



Picture 4. The starting air pipe and the current slow turning device.

This picture is taken from the current setup of the modules in the laboratory. Here you can see the starting air pipe coming from the starting air compressor and connecting to the starting air pipe module in the engine.

This will also give a clearer picture of the true condition of the engine and the real placement of the modules.

3 MODULARIZATION

Modularization is a design of a system using modules. The modules contain parts and they are also called assemblies. These modules can be constructed from submodules. Modular thinking offers some important advantages over the older monolithic approach. For example, it makes the modules easier to assemble, repair and upgrade.

A monolithic approach means to design something from a single piece rather than from a number of different parts. A good example of a monolithic approach is a statue carved from a single piece of marble. (Karlsson 2008.)

Modular design can include a monolithic approach. A good example of this is the engine block which is used as a framework to design the modules into.

Modularity is a concept that has proved to be useful in many different fields of manufacturing and design. These fields range from brain science to industrial engineering.

In other words, modules are parts of a larger system that are connected together but can work independently if needed. The larger system itself, here the engine block, provides the framework to connect the modules onto. (Clark & Kim & Baldwin & Carliss 1999, 45.)

3.1 Modularization examples

Modular homes are houses that are divided into multiple modules, or sections. Modular houses are manufactured in, for example the supplier’s factory and not on the intended building site. The modules are then shipped to the intended building site and assembled together into a single building using a crane.

> *Modular design in cars*; many car manufacturers make a basic model from a car to sell it at a little cheaper price. You can, however, buy upgrades to these basic cars, for example with a more powerful engine. The basic car model is here just a frame and by switching the engine module to it you can manufacture the car with the same chassis and steering and put a different engine module onto it. (Karlsson. 2008.)

3.2 The benefits of modularization & standardisation

The main benefit of modularization, from design perspective, comes from the reduced time of design due to the re-use of existing drawings and calculations. Modular assemblies also benefit from reduced assembly time due to the familiar setup and modular assemblies are designed to be easy to fit.

When designing a module, designers try to use the same or similar parts in new assemblies than in the older assemblies. This is called standardization. Standardization greatly decreases the assembly time and it reduces the number of different spare parts in stock as well as the need to manufacture new parts only for the assembly in question.

The procurement phase of the design is faster due to the fact that there is little or no need to buy newly designed parts for the assembly, but to use parts in stock or to order the standard parts. This procedure also helps the sales department to calculate the price of manufacturing the parts and the price of the assembly due to the fact of using the standard parts in the assembly.

With modularized assemblies, the transport of the assembly and the parts is easier because the size of the assembly is known more accurately and the needed maintenance is easier due to the re-use of service procedures. . (Karlsson, J. 2008.)

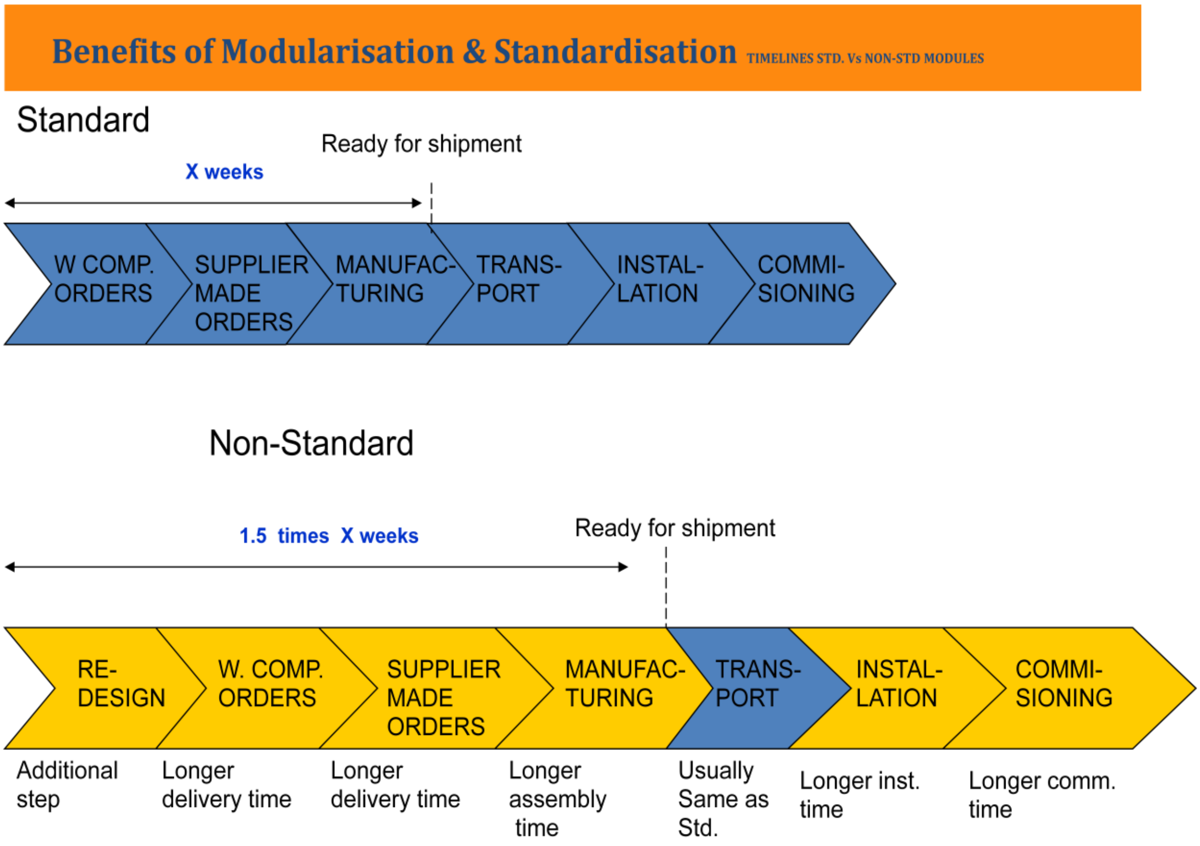


Figure 1. The benefits of modularisation & standardisation (Karlsson 2011).

4 THE DESIGN PROCESS OF THE SLOW TURNING TEST CONFIGURATION

The design process starts by studying the engine configuration and obtaining a clear picture of the necessary changes in the configuration. The next stage is to start a so called “mapping out” process. This is an important stage where you reserve enough room in the engine for the new parts or for the parts you change.

After these steps, you are ready to start sketching the new parts and placing them correctly in the 3D model. The design is completed with I-deas 3D modeling software. The same software is used to make the drawings of the models. After making a prototype of the models they will be stress calculated by an employee in the Wärtsilä simulation department.

The design is completed in cooperation with the supervising test engineer in Italy. There are weekly meetings with the test engineer and other supervisors, where the progress of the design is viewed.

The information on the parts in the engine configuration can be found in Wärtsilä’s internal engine configuration registry.

4.1 Design stages

This particular design process is quite difficult when considering that the engine in question is a test engine and has gone through some changes over the years of which some changes have not been properly documented. Therefore most of the designing is based on photographs of the engine and drawings that must be up-to-date.

Also, it will prove difficult to use as small number of parts or new parts as possible in the design and placement of the new frequency converter on the engine. The new frequency converter will have to be close to the main electric cabinet of the engine and there is not much room at that point.

A so called *bottom-up* perspective is used when designing these parts. The bottom-up perspective means that the engine is analyzed and to use as many existing parts and modules as possible that are currently installed onto the engine. With this analysis, the product architecture and the components that are re-used can be identified. It is then possible to check whether some parts from the old modules can be combined with the new design or the new modules can be designed around the old ones. (Ong & Nee & Andrew & Xu 2008, 100.)

The design will have to meet the requirements stated in Wärtsilä’s internal Design Assurance guidelines made specifically for this product. (Bottos 2013.)

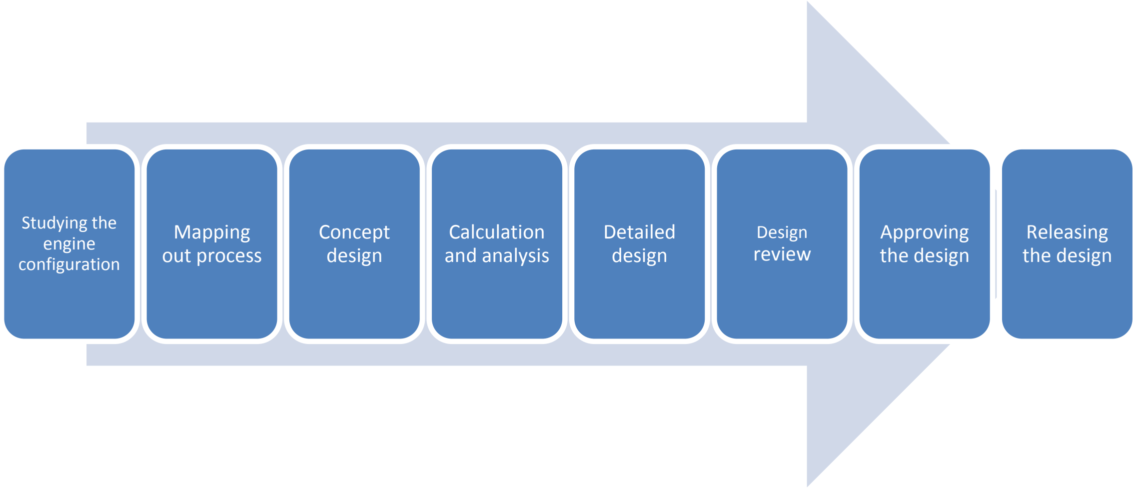


Figure 2. The design process

From Figure 2 you can see the steps of the design from start to finish. As mentioned earlier the design work begins with the studying of the engine configuration. The engine configuration can be found in the internal engine registry at Wärtsilä. The studying of the engine configuration is largely placing the parts in use today to the engine 3D model and confirming with the test engine supervisor that the models are the right ones.

The “mapping out” process is making sure that the new design will have enough room to fit in the engine. At this point, you also reserve enough room for the new parts. This is completed for example, by using solid 3D cubes on the model with the size of the new parts. When using 3D cubes, it makes sure that you have more than enough room to sketch your parts.

The concept design phase is the actual modeling of the parts. In this stage, you make the first draft of the new parts. The next task is to place these parts in the 3D model in the right position and start constructing modules from them. This phase can take more time than one would imagine. This phase can also bring up some new problems in the parts.

After you have the first draft of the parts you send them to the simulation department for stress calculations. They will give you feedback of your design and if it needs changes in for example the size of a supporting structure of a part. The next part is revising the parts if necessary. The simulation department will give recommendations on how to revise the parts to pass the stress calculations.

After the parts are in the right position and the modules are ready, they will be sent along with the technical drawings to the approver of the design.

If the design is approved by the supervisor and there is nothing on the design that needs to be re-designed, then the design is released. When the design is released, other Wärtsilä’s personnel can view it and it is ready to be ordered. (Childs 2003, 17-19.) (Poelman & Keyson, D. 2008, 24.)

4.2 The target of the design

The main target for the new design is to reduce the number of modules in the engine configuration and to make the new modules with a small number of parts in them. The design will have to pass stress calculations conducted by the simulation department of Wärtsilä.

The task is to design a modular engine configuration for the slow turning device testing engine. This is completed in cooperation with other Wärtsilä employees at Italy Trieste laboratory site and R&D Turku site.

The product has to be made using the smallest number of parts possible in assemblies or modules. Also, new modules are added to the engine configuration. The time limit for the design was 3 months.

When designing these modules, the modular way of thinking has to be kept in mind. The design work and drawings are completed using I-deas 3D-modeling software. The finished models and drawings are then sent to the TeamCenter program, where they are usable and viewable by everyone included in the project.

5 DESIGN SOLUTIONS FOR THE SLOW TURNING ENGINE CONFIGURATION

After the design process, modules were constructed from the parts and placed in the right position in the engine.

Even though the task was to design the modules for the test engine, the production engine of this size was cross-referenced for every part and module. This was done so that when the slow turning device and the starting air modules are placed in production engines, the modules only need some minor changes and a revision of the drawings and models.

When designing the new modules for the engine, they were designed to be modular so that three modules are delivered which include the slow turning device module, the starting air module and the frequency converter module. The modules are ready to be shipped to the laboratory engine site and they will be installed the modules into the engine. The modules are designed in a way that only the current parts can be removed from the engine and the new modules installed in it, similar to a converter kit.

The new turning device is more user-friendly and durable than the old turning device.

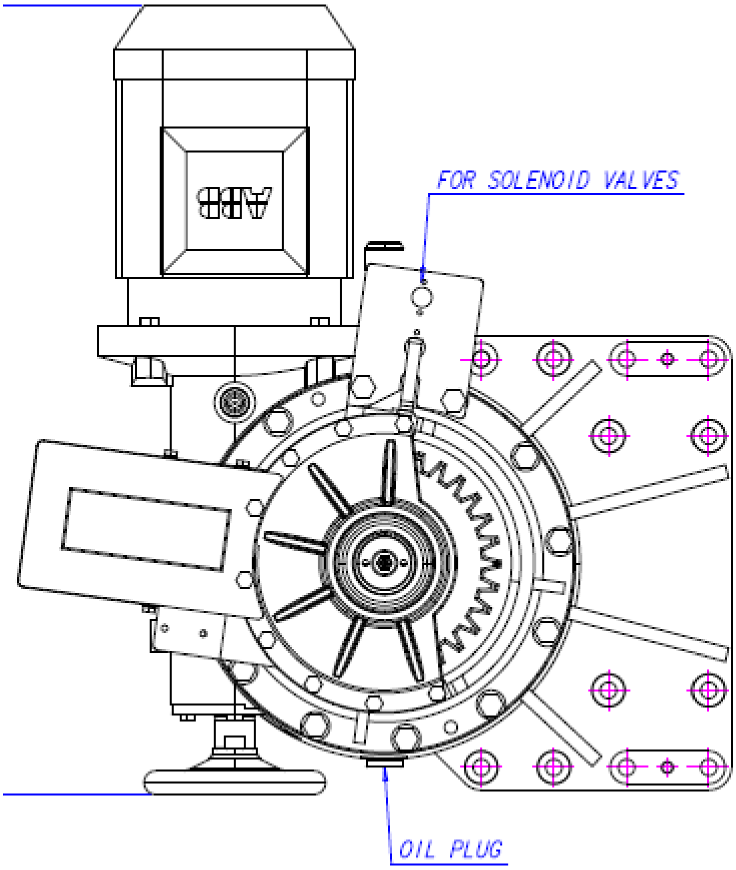
The modular way of thinking is better than the old monolithic way of thinking. The greatest difference came, from design perspective, from the amount of documentation and design work. For example, if you want to find a specific flange, you can find it easier now because the modules are divided from one main module to so called ”sub modules”, so you only have to know one module number to find everything connected to it.

5.1 The electromechanic slow turning device

The new electromechanic slow turning device is different in size and placement than the old one. The new slow turning device is also more powerful and durable than the old one according to the calculations conducted by the engine experts of this component.

The new slow turning device is also controlled by pneumatic air via two solenoid valves positioned on top of the gear pinion housing. There is a blocking valve detecting the position of the gear; it is located on the side of the pinion housing. The blocking valve is 3/2 special valve, what makes the valve special is the fact that it can be installed NO or NC (Normally Open or Normally Closed). The valve detects the arm of the cylinder that moves the turning gear.

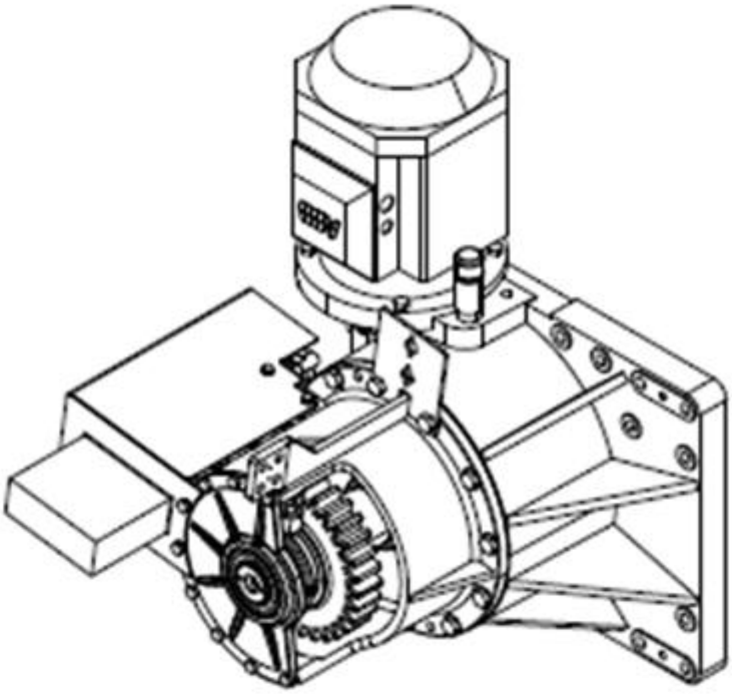
In the following there are some pictures from the design of the new slow turning device and some explanations of the reasoning behind the design.



Drawing 3. Drawing of the new slow turning device.

Here you can see the placement of the control solenoid valves that control the cylinder of the turning gear. Below the cylinder cover (the left side of the pinion housing) you can see the fixing place for the new blocking valve. This valve detects the position of the turning gear.

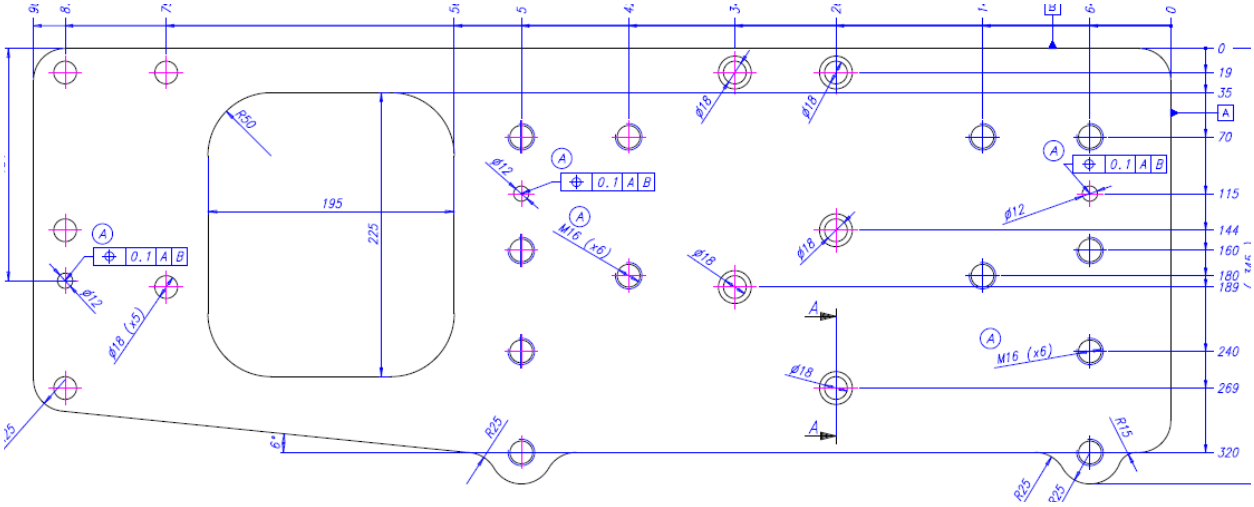
The turning device is driven by an electric motor and controlled by two control solenoids. This turning device also has a wheel on the bottom for manual use.



Picture 5. Isometric drawing of the new slow turning device.

This gives a more detailed picture of the new turning device. As you can see, this turning device is bulkier than the old turning device. You can also see that the new turning device has a different kind of fixing point. Therefore, a new fixing plate for it (Drawing 4) had to be designed.

Also you can see the placement of the fixing for the ruler (Drawing 6) without the actual ruler fixing.



Drawing 4. The fixing plate for the slow turning device.

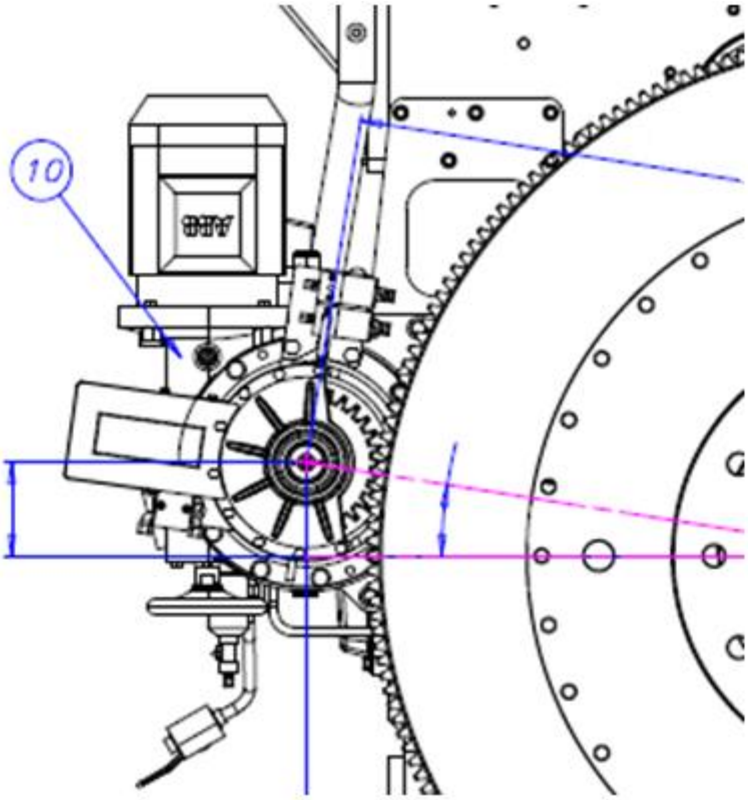
Drawing 4 shows the new fixing plate for the new slow turning device.

The requirement for the slow turning device position on the X-Y-Z axis was not given as the only requirement was to have the centerline of the turning device at 1000 millimeter distance from the centerline of the crankshaft. This distance was to ensure that the gear had a good contact with the flywheel.

A good position was found for the slow turning device in the engine. The design task was difficult because the engine block had threaded holes from the previous setup and new ones could not be drilled.

The slow turning device is fixed to this fixing plate onto the threaded holes you can see from the picture above. There are positioning pin holes in the fixing plate. The fixing plate is fixed to the engine block through the free holes using screws.

The big rectangular hole on the fixing plate is designed only to save some weight. The fixing plate is stiff by design as unnecessary material was eliminated.



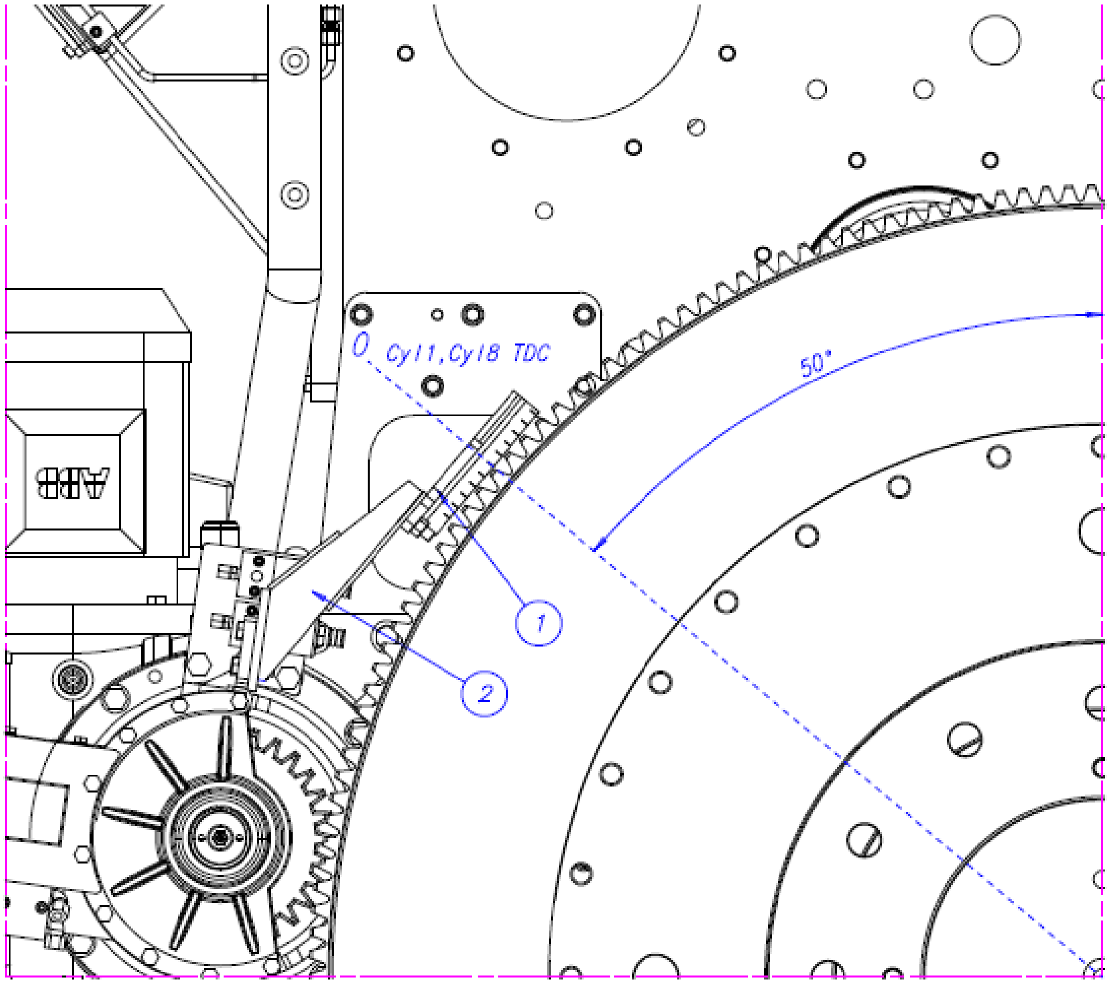
Drawing 5. The new slow turning device.

In Drawing 5, you can see the new slow turning device and its placement.

The requirement for the placement of the new slow turning device was only that it had to have 1000-millimeter distance between the middle of the axle of the pinion gear and the middle of the crankshaft of the engine. A new fixing plate (Drawing 4) was designed for the turning device to meet the requirement.

Also you can see two solenoid valves on top of the pinion housing; they will control the gear to contact and off contact the flywheel (On and Off positions).

The slow turning device also has a manual control lever for the gear, but it is underneath the covers you see on the left side of the pinion housing.



Drawing 6. Drawing on the new fixing for the ruler of the 0-point of the flywheel.

In Drawing 6, you can see the new fixing (in the picture numbered as 2) designed for the fixing of the ruler. The ruler shows the 0-point of the flywheel, which is the TDC (Top Dead Center) of the piston 1. The ruler (in the picture numbered as 1) is the same ruler that was used previously in the engine.

The reason for this new fixing is that the laboratory did not have the time nor the manpower to remove the flywheel and move the position of the 0-point. The 0-point is stamped on the flywheel.

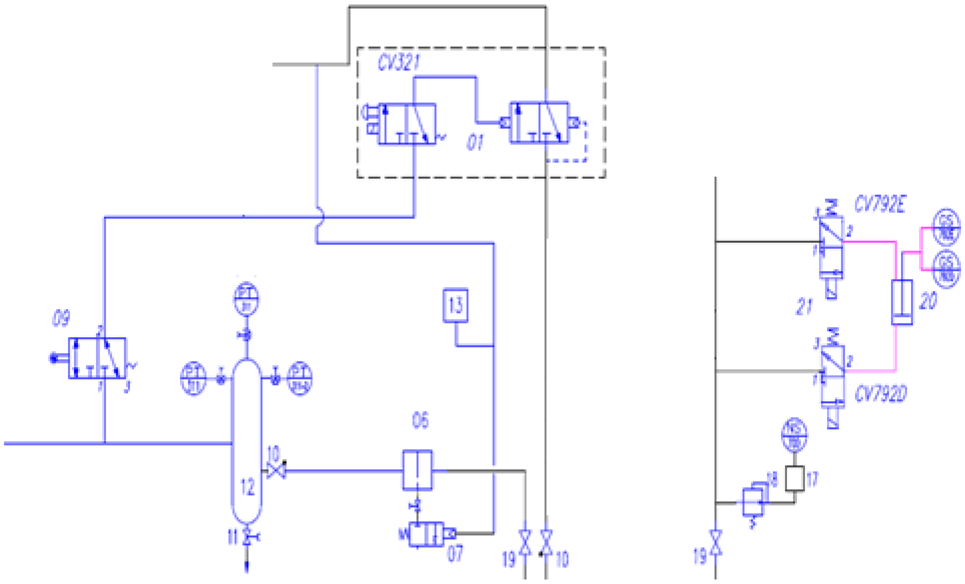
5.2 Design of the start air system

The starting air system has undergone some major changes. The greatest change in it is the removal of the old main starting valve and introducing a new one.

The start air system was completed co-operating with Wärtsilä’s engine expert of pneumatic systems. The design was approved by him with guidance and help in the start air schematic and how to make the drawings up to standard.

The new start air system features the new slow turning device, the new main starting valve, a new blocking valve and the new control solenoid valves that control the slow turning device.

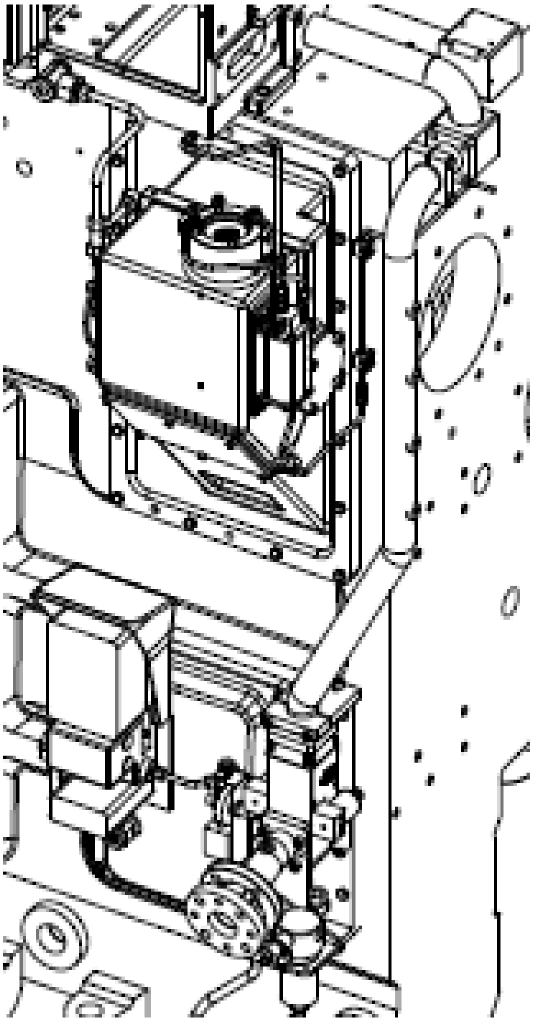
In the following there are some pictures from the design of the new slow turning device and some explanations of the reasoning behind the design.



Drawing 7. The new starting air schematic.

The new schematic now has a solenoid controlled starting air valve (CV321, part 01), a new blocking valve for the turning gear (part 09) and two slow turning solenoid valves were removed. Also, this schematic has two new solenoid valves that control the slow turning device (CV792E and CV792D, parts 21) and a slow turning gear engaging cylinder (part 20).

Two slow turning solenoid valves were removed because the new slow turning device uses electromechanic slow turning that is driven with a new frequency converter.

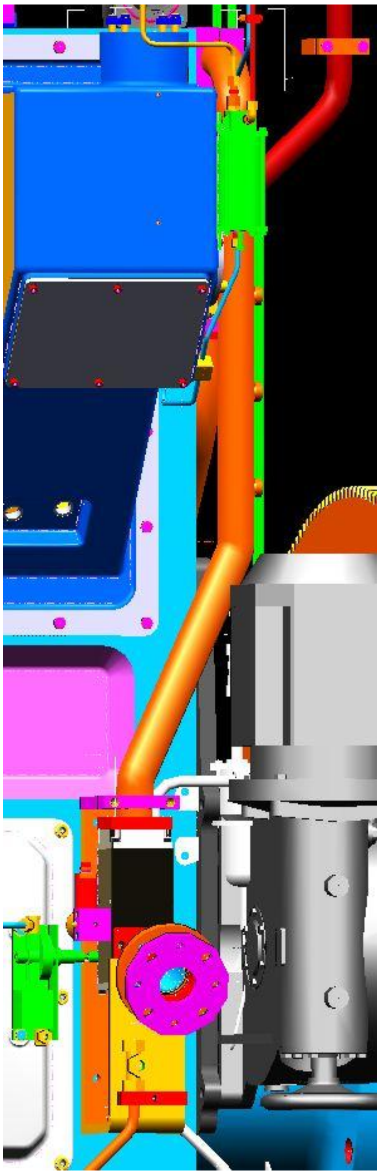


Picture 6. The new starting air system module.

This is the new module which combined two old and different modules.

Here you can see the whole module without the slow turning device in place. This module now has the new starting air valve in place. A new housing was made for it using the same holes in the engine block that had the previous piping clamps attached to them. The position of the incoming starting air from the starting air compressors is at the same spot.

Also, the new starting air pipe has two more places for different sensors.



Picture 7. The starting air module.

In Picture 7, you can see the finished starting air module. The X-Y-Z positions of the incoming start air from the starting air compressors are the same than in the old setup.

The test laboratory uses hoses instead of small diameter pipes. So there was no need to use design time to determine and design the small diameter pipes.

5.3 Frequency converter

The frequency converter was a new module to be introduced in the engine configuration. The frequency converter will be used to drive the slow turning device.

The frequency converter had to be close to the main electric cabinet and not collide with any of the wiring. Also the frequency converter fixing structure had to be as stiff as possible to withstand all of the vibrations. The structure will have vibration dampers, so the vibrations will not break the frequency converter. One part of the laboratory test is to test the durability of the frequency converter.

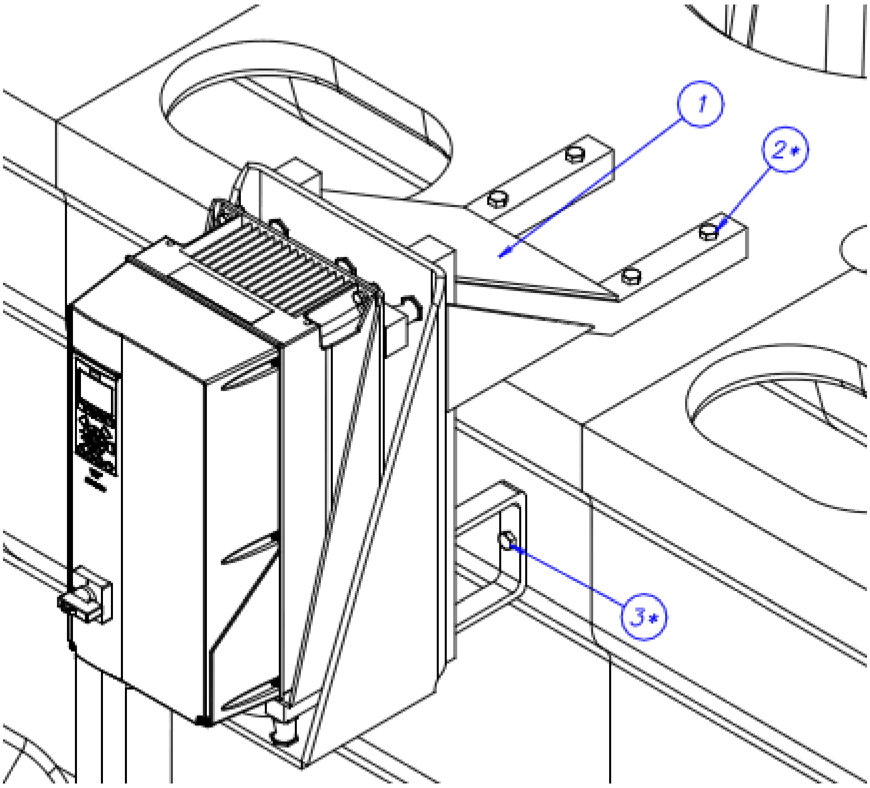
Many different solutions existed for the fixing structure and they were presented to the test engine supervisor. In the end, one of the proposals for the fixing structure was taken into use. The reason was that it was stiffer than the other proposals and that it was the easiest one to fix in the engine.

In the following there are some pictures from the design of the new slow turning device and some explanations of the reasoning behind the design.

Picture 8. The main electric cabinet of the test engine.

The aim was to find a good position for the fixing of the frequency converter, because the frequency converter had to be close to the main cabinet and, as you can see, there is not much room there.

After some consulting with co-workers and presenting of ideas for the supervisors a fixing (Drawing 8 and Picture 9) was developed that will not collide with any wires or pipes or the floor.



Picture 9. Picture of the fixing of the frequency converter to the engine block.

Here you can see how the whole fixing structure (part 1) and frequency converter are fixed to the engine block.

The fixing is made by bending sheet metal and welding the corners, after this the bigger sheet metal part is welded to the parts that are fixed to the engine block. Between the two sheet metal parts there are vibration dampers to protect the converter.

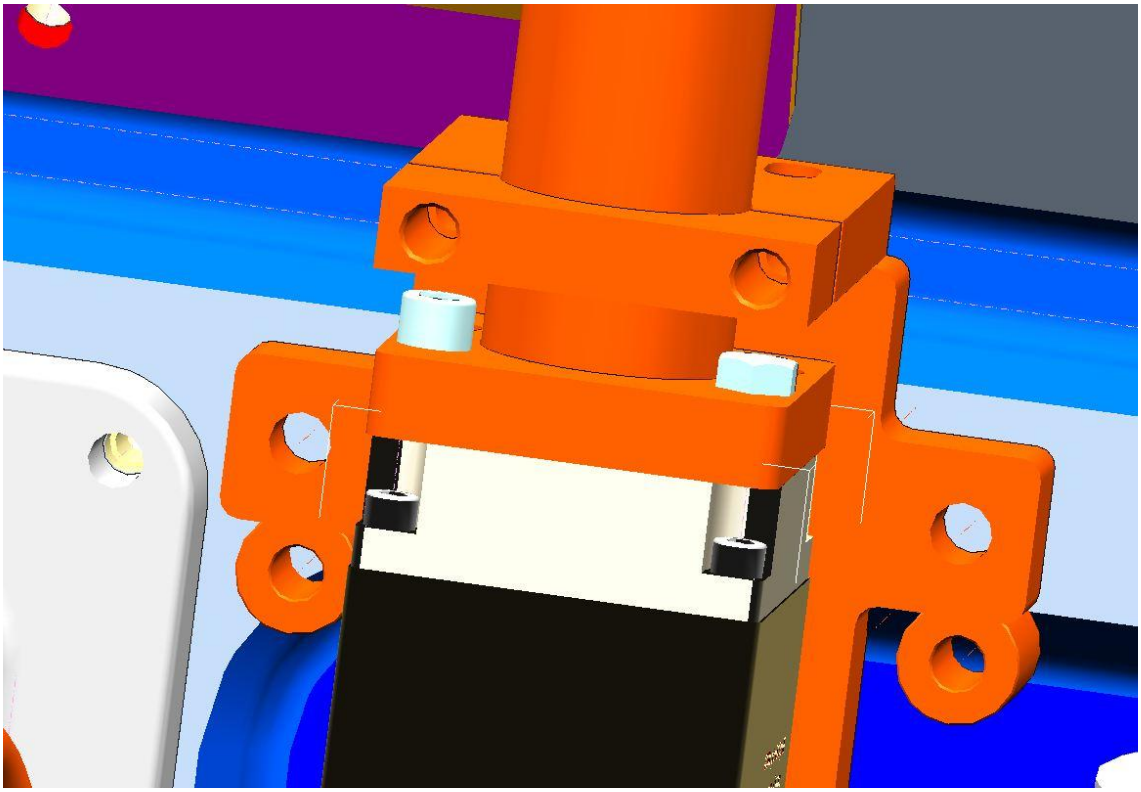
The requirement for the fixing was to be as stiff and durable as possible and then have the vibration dampers remove the vibrations and other stresses.

The position of this is close to the main cabinet and the fixing does not collide with anything.

The fixing structure is fixed to the engine using screws and bolts (parts 2* and 3*); the holes for these are drilled on site.

5.4 Finishing the design

After designing all of the parts and modules everything was checked to find any faults. After addressing some minor faults the design was sent to the approval process and then released.



Picture 10. Screws on the main starting valve.

On checking everything it was noticed that the main starting valve cannot be fixed using hexagon head screws. As you can see from Picture 10 there is not enough room to use a wrench to tighten them to proper torque. So instead socket head screws were used.

5.5 Summary of the design

After the design was released to the system it was time to determine if the target of the design was met. Here you can see two tables of the engine configuration changes and explanations of them.

TURNING DEVICES	6 - 8L	9L	12 - 20V
Turning device	Variant TD1	Variant TD2	Variant TD3
ELECTRIC MOTOR	6 - 8L	9L	12 - 20V
380 V, 50 Hz, 2.2 kW	Variant EM1		
380 V, 60 Hz, 2.2 kW	Variant EM2		
400 V, 50 Hz, 2.2 kW	Variant EM3		
400 V, 60 Hz, 2.2 kW			
440 V, 50 Hz, 2.6 kW			
440 V, 60 Hz, 2.6 kW	Variant EM4		
690 V, 50 Hz, 2.2 kW	Variant EM5		
690 V, 60 Hz, 2.2 kW	Variant EM6		
380 V, 50 Hz, 5.5 kW		Variant EM7	Variant EM7
380 V, 60 Hz, 5.5 kW			
400 V, 50 Hz, 5.5 kW			
400 V, 60 Hz, 5.5 kW			
440 V, 60 Hz, 6.3 kW			
440 V, 60 Hz, 6.3 kW		Variant EM8	Variant EM8
690 V, 50 Hz, 6.3 kW		Variant EM9	Variant EM9
690 V, 60 Hz, 6.3 kW		Variant EM10	Variant EM10
690 V, 60 Hz, 5.5 kW		Variant EM11	Variant EM11
START AIR	6 - 8L	9L	12 - 20V
Starting air pipe (on driving end)	Variant SA1	Variant SA1	Variant SA2
Starting air system (on driving end)	Variant SA3	Variant SA3	Variant SA3

Table 1. The current number of different turning device configurations in use.

As you can see from Table 1, there are many different possible configurations in use today in the engine. This makes the design more difficult for the future parts.

There are many unnecessary parts in the configuration, for example the inline engine alone has different configurations for six to eight cylinder engines and for nine cylinder engines, and in these two different main configurations there are more different possibilities. There are 6 possible different variants in the 6-8 cylinder engine configurations, 5 possible different variants in the 9 cylinder engine configuration and in the V-engine has 5 different possible variants. Also, the start air has two different modules, one for the starting air system and one for the starting air pipe.

TURNING DEVICES	6 - 9L	12 - 20V
Katsa	Variant TD1	
Katsa		Variant TD2
ELECTRIC MOTOR	6 - 9L	12 - 20V
ABB 3.5kW	Variant EM1	
ABB 11kW		Variant EM2
START AIR	6 - 9L	12 - 20V
New start air	Variant SA1	
New start air		Variant SA2

Table 2. The targeted number of turning device configurations.

In Table 2, you can see that the number of different configurations for the engine is reduced. As you can see there are only 2 different main configurations for the engine, one for the inline engines and one for the V-engines. The starting air system has only one module which includes the starting air pipe. Also, there will be less electric motors in the configuration, because the 3.5kW electric motor has enough power to be able to be used in all of the inline engines and the 11kW electric motor is sufficient for the V-engines. The new turning device will be powerful enough to be used in all of the inline engines, so there will be only one module both for V-engines and inline engines. This is easier for future design projects and the service department.

6 DESIGN REVIEW

The target of this design was to make a modular engine configuration for the slow turning device with the smallest number of parts in them. The parts were to withstand all of the stresses from the engine. The time limit for was three months.

The number of the modules in the test engine was reduced and replaced them with three major modules. These modules are constructed using the smallest number of parts in them. Therefore the service and the assembly of the upcoming test is easier. Because the amount of documentation is reduced, it is easier to re-design and check the modules and parts if needed.

When designing these parts, it had to be considered that they should withstand all of the stresses and vibrations from the engine itself. The vibration and stress calculations passed, so the parts will withstand all of the stresses and vibrations. The calculations were made by a Wärtsilä employee in the simulation department.

In the design work, a production engine of this size and type was crossreferenced for every part and module. The modules are almost ready to be installed in the production engines of this size and type. All they need is minor changes and a revision of the drawings and models to be used.

The new electromechanic slow turning function is better than the old pneumatic slow turning. The electromechanic slow turning phase is more accurate and easier to take measurements from and receive alarms. According to the lab results, it is possible that pneumatic slow turning in use today is not able to give an alarm about liquid in the compression chamber whereas the new electromechanic driven slow turning function can give these alarms.

In this product the modular way of thinking was difficult to keep in mind. However, the new modules have smaller number of parts and are constructed to be three major modules which can be installed in the engine in a way that a conversion kit works.

What also proved difficult was to stay within the time limit. This was every part had to be designed by the author, only screws, bolts and pins were standard. But the design was ready and released with the time limit of three months.

The slow turning device is installed and being tested at the moment at Italy Trieste laboratory site. They will test not only the new technology, but how much stress the design can withstand. The tests will show if the design work is successful. Some of the design would have been different if there had been more time or the engine in question would had been a production engine.

First of all, the fixing plate is not necessary in production engines, and it was only done to this test engine. This is because when we move to the production engine design phase, the engine block will have new holes drilled onto it and the slow turning device will be fixed onto them. So, the fixing plate will not be necessary in the future.

Secondly, the fixing for the ruler of the 0-point in the flywheel is not necessary. The design was done because the amount of work and manhours that goes into taking the flywheel off the engine and installing it again is too much. There was no time to do that.

Thirdly, there is the fixing of the frequency converter as the design of it does not please the eye. The only requirement for it was to be stiff enough and to test the vibration dampers and how much stress the frequency converter can withstand. The fixing does all of that and a little more.

7 SUMMARY

This project was about designing a new modular slow turning engine configuration. The design had to be made to withstand all of the stresses from the engine using the smallest number of parts in the modules. There was also a time limit of 3 months to finish the product.

The new modules were successfully designed for the test engine in Italy Trieste site laboratory. The modules are made keeping the modular thinking persperctive in mind and the drawings were made for every part and module. They are released and ready to be used or redesigned if needed.

All of the requirements were met and tasks were successfull. The parts were confirmed to be durable enough by the simulation department in Wärtsilä and the time limit was long enough to design all of the modules.

This project taught a lot of design and the starting systems and pneumatics. Also, the project taught about the starting sequences of the engine and of the slow turning function.

A lot was learnt about co-operating with other engineers to lighten the workload and to have tips about design in general. The weekly meetings taught more about working in a foreign language with people from all around the world.

ACKNOWLEDGEMENTS

Overall I enjoyed my time designing these parts and models for the test engine. The co-operation with other people when designing was great and I enjoyed the style of working in Wärtsilä. The weekly meetings gave me so much new information on design in general and some new tips and ways of thinking when designing new parts.

I want to thank Wärtsilä and all of my co-workers in R&D and all the people that were involved in this project.

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