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CATALYTIC ELEMENT TIGHTENING SYSTEM

Concept Designs for Wärtsilä NOR SCR-Reactors

School of Technology
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ABSTRACT

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This thesis was made for Wärtsilä Catalyst systems Technology team. The research focuses on the catalytic element tightening system of Wärtsilä's NOR SCR-reactors. The objective of this study was to identify possible areas of improvement in design with concept designs derived from theoretical studies.

The comprehensive study starts with system and legislation research. The SCR-reactor needs to be compliant with international legislation while being a maintainable entity. The study was made using the existing product as a guideline and a starting point. Information to support the study was gathered by an in-depth product analysis and interviewing those who have knowledge on operating the system.

The study achieves good well-rounded knowledge of areas to improve. The most important observations focus on friction, tolerances, and mechanisms. The findings lead to concept designs aimed at reducing the effect of friction and tolerances and simplifying mechanisms. The concept designs are aiming to balance variables and provide most efficient design to improve on.

Keywords Concept, SCR, NOx, catalytic and design

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TIIVISTELMÄ

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Opinnäytetyö on tehty Wärtsilän Catalyst systemsin Technology-tiimille. Työn päämääränä oli tutkia Wärtsilän NOR SCR -reaktoreiden katalyyttielementtien kiristysjärjestelmää ja saadun tiedon perusteella luoda konseptimalleja tuotteen kehittämiseen.

Tutkimustyön taustoja haettiin järjestelmää koskevasta lainsäädännöstä, tuoteanalyysistä sekä järjestelmän kanssa työskennelleiden henkilöiden kokemuksista ja havainnoista. Pohjana analyysille ja rakenteille käytettiin olemassa olevaa tuotetta ja sen ominaisuuksia.

Tutkimus saavuttaa laajan yleistiedon tuotteesta ja sen ominaisuuksista. Selväksi käyvät tuotteen haasteet kuten vallitsevat kitkat ja toleranssien vaikutukset. Tutkimuksen perusteella luotiin konseptisuunnitelmat, joiden päämääränä on kehittää tuotetta entistä toimivampaan suuntaan.

Avainsanat konsepti, SCR, NOx, katalyyttinen ja suunnitelma

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1 INTRODUCTION

Wärtsilä is one of the major maritime and powerplant engine manufacturers. All engines produce emissions and there is global legislation to control allowed emission limits. Selective catalytic reduction (SCR) is one of the most efficient and common ways to reduce emissions to approved levels. This thesis focuses on the element tightening system of Wärtsilä's NOR SCR reactors.

In the current design there is an area requiring attention. Mainly the tightening systems lack of feedback to the user performing the element installation. This has been found to cause catalytic element damages due to overtightening. In other cases, the lack of tightening has also caused element damages and or malfunctions in operation. The goal is to improve the current element tightening system and design new concepts which are beneficial for future designs of Wärtsilä's NOR reactor development. This thesis does not aim to design and develop a finalized product. The main focus is on concept designs and ideas providing fresh out of the box ideas for further improvement.

The main guidelines for improved and a totally new design concept are as follows:

- ease of use
- lessen install deviations made by users.
- can be produced using common machine shop technology.
- out of box approach

The long-run goal of this thesis is to provide groundwork and new ideas to improve future iteration of element tightening system of the NOR products, and with that reduce the numbers of system malfunctions and damaged elements. Thus, the overall quality, customer satisfaction and fluency of installation and service will be improved.

2 SCR TEHCNOLOGY AND LEGISLATION

SCR is an emission treatment system for internal combustion engines. The task of the SCR system is to reduce nitrogen oxides which are biproducts of fuels burning process in an internal combustion engine. The common term for these nitrogen oxides is NOx. For the most part the burning process creates nitrogen monoxide (NO) which oxidises into harmful nitrogen dioxide (NO_2) due to ozone in the atmosphere. Nitrogen oxides have many adverse effects, which creates a need for legislation to reduce amounts released into the atmosphere. The property of nitrogen oxides to react with water forms acids, which, when they reach the ground, among other things, acidify waterways and soil. In terms of health effects, nitrogen oxides are also harmful. The effect on health is mainly seen in the tissues of the respiratory tract. Above all, children and those suffering from respiratory diseases are very susceptible to these health problems. /1/.

Because of all the harm produced by nitrogen oxides, permissible limits have been set for them as part of several different emission legislations. One of the most significant global emission legislations for shipping is the emission classification system of the International Maritime Organization (IMO), which is commonly referred to Tier I-III (for example IMO Tier II). Examples of regional emission classification system includes the European Union’s Euro Stage system and United States Environmental Protection Agency’s EPA Tier system. Land-based traffic and stationary combustion engines (for example, generators and power plants) also have their own emission classification systems. /2/.

Using the IMO Tier system as an example. IMO Tier I was enacted in 1997 regarding the emission limits of ships commissioned from January 2000. In 2008, both IMO Tier II and IMO Tier III were enacted, which entered into force in July 2010. Therefore, from July 2010 all new engines had to meet the requirements of the IMO Tier II emission legislation as well as the requirements of the IMO Tier III emission legislation for those ships that operate in the specified IMO Tier III areas.

Along with the legislation at that time, a legislation also came into force according to which ships built before 2000 also had to meet the IMO Tier I emission classification. To achieve the IMO Tier III classification, different exhaust gas aftertreatment methods such as SCR systems can be used to achieve that. /2/.

2.1 General SCR Reactor Structure and Operating Principle

The SCR system is an entity formed by several components together, the purpose of which is to reduce NOx emissions from the exhaust gases. The main components of the system are the injection and mixing unit and the reactor, which contains the catalytic elements. The operation is based on the nitrogen oxides-reducing effect in a reagent injected into the exhaust gases, usually a urea solution, which in enhanced by running the mixture through the catalyst. Usually, the surface of the catalyst element is doped with a catalytically active noble metal alloy coating. The most common is platinum (Pt) and rhodium (Rh), whose task is to create an efficient environment for the reduction process. Vanadium (V2 O5) is the most common active ingredient in marine engines. /3/.

The structure of the reactor is determined by the size of the reactor. The size of the reactor, on the other hand, is determined by the NOx reduction performance and backpressure set for it and the size of the engine supplying it with exhaust gas. The structure of the reactor is significantly affected by its size and installation location. In principle, it makes sense to implement a small reactor as one whole, so to speak, an integrated entity with the catalyst. An example of the described solution is a car’s catalytic converter. The structure of the car and the layout of the structures offers the possibility of a compact reactor due to the relatively small displacement of the engine. This, combined with the very straightforward structure of the exhaust gas system, enables easy installation. Comparatively, the engine size in a ship is many times larger than a car engine. The engine is located on the lowest deck of the ship and the exhaust gas system passes through the upper decks for up to several tens of meters. The combination of variables determines that it is generally not logistically, structurally, or installation-wise profitable of even possible to work with an integrated reactor unit. In this case, the best solution is to resort to a more modular solution regarding the reactor. In this context, modular construction means that the reactor shell and elements are delivered separately. The elements are installed in place with the reactor shell already installed. Consequently, the weight in kilograms of the one-time installation is reduced, and it is possible to carry out maintenance due to element failure, for example, without extensive and long dismantling processes. However, the modular structure also brings its own challenges.

2.2 Wärtsilä NOR

The NOR (NOx reducer) reactor line, developed by Wärtsilä, has a mostly modular structure throughout the product group. The modular structure brings its own advantages and almost without exception the structure of the installation site would not accommodate other solutions. The modular structure presents a challenge in two main forms that bind together strongly. The catalytic elements of the inner structure of the reactor must be tight enough that all the flow inside the reactor passes through the catalytic elements. If exhaust gasses bypass catalytic elements, that weakens the reactor’s efficiency in reducing nitrogen oxides and causes a new environmental and health hazard toa a large extent in the form of ammonia (NH3). Another challenge is the overall tightening of the catalytic elements. Tightening of the catalytic elements and reducing exhaust gas leakage are performed using the same tightening system. Therefore, the tightening system plays a key role in NOR units. /4/.

Figure 1. New Johnson Matthey catalytic element on board Aurora Botnia (Rauma Marine Construction NB6002)

Wärtsilä NOR units are box shaped with tapering in the top and bottom ends for flanges. The height of the unit it determined by the number of catalytic element layers. The catalytic elements are also rectangular in shape to accommodate the reactor shape and the layer layout. The shape of the reactor is one of the most determining factors for the shape of component combined in the assembly including the tightening system. The current tightening system works with a threaded rod and a steel beam. By rotating the threaded rod, the beam moves either closer to the catalytic elements tightening them or further away from the catalytic elements, releasing the tightening pressure. Rotary motion is converted to linear motion by a sled which rides in an angled groove on the steel beam. The sled has a threaded nut in it and by rotating the threaded rod, the sled moves and converts rotary motion into linear motion, thus tightening or loosening the steel beam from the catalytic elements. /4/.

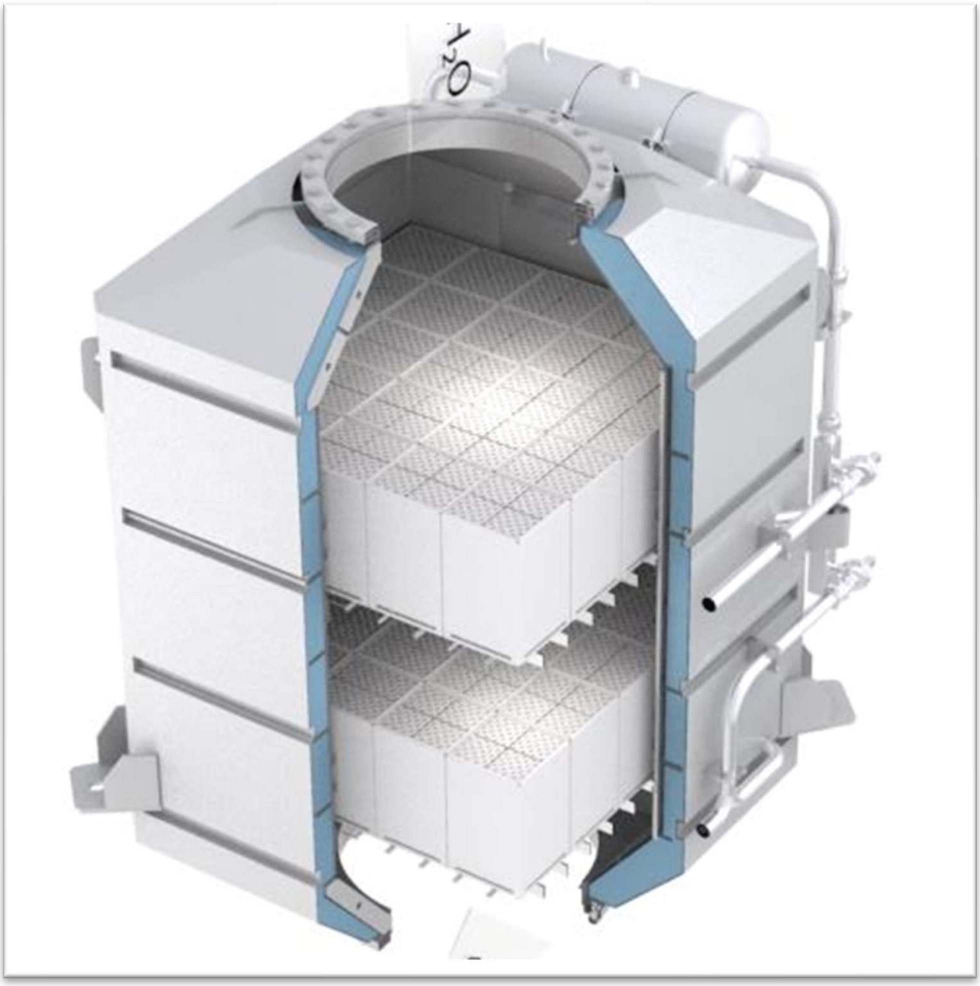

Figure 2. Section view of Wärtsilä NOR reactor

3 BASIS OF CONCEPT DESIGN

To improve design of the catalyst element tightening system, its critical to know constraints. The design concept can be great for tightening, but poor for sealing and that is not acceptable. It is important to know what are the advantaged and disadvantaged of the current design are. A part of these concept design is to evoke new possibilities and out-of-the-box thinking. Nevertheless, it is important to keep concept designs in a reasonable form. A good basis for concept designs is feedback from those who have worked with the product in the field and try to include solutions to problems experts have encountered. Well-rounded knowledge is created by combining own observations and feedback from experts. That will be a basis for concept designs.

3.1 Expert Interviews

Expert interviews contain feedback from two different product experts, Jani Hakala and Mats Knipström. The interviews were implemented by email. Experts were given free speech to talk about experiences, encountered problems and other discoveries. The interviews were a useful tool to learn about the product and get a good scope of the prevailing situation.

There were many similar discoveries between two experts. Similar discoveries were about operational feedback, great forces need to operate and consequences of the aforementioned. Deformations in elements and tightening structures and in other cases loose elements were most encountered defects. A heavy object, tight working spaces, great forces, and lack of feedback from the system in conjunction can cause problems to emerge. There were also mentions of human errors during the installation process. One of these was a surprisingly common issue when transportation bolts were not removed the before element tightening, preventing the tightening mechanism to work as intended. Overall, a common theme is that there is a lot of friction in the system, it is challenging to monitor the operation of the system, and it is challenging to ensure the correct tightness. /5/.

3.2 Interview Conclusions

The interviews gave a good overall perspective of possible problems encountered during the installation and tightening of catalytic elements. Two most prominent are the lack of feedback from the system (hard to tell when desired tightness is achieved) and high friction which emphasizes the first mentioned lack of feedback. There were also mentions of material deformation due to the high forces experienced by the mechanical component and overall structure.

The main conclusion is that there is a need to reduce friction. By reducing friction, feedback potentially gets better, the number of structural damages decrease in both the catalytic elements and reactor structures and the correct way to install and tighten the catalytic elements is much more easily achievable.

4 DESIGNS

For the design process, the most efficient way to bring up different variables is to slice the product into smaller sub-concepts. Using that approach it is more efficient to visualize the effect of different features and combine the best possible combinations. There might be some combinations that work great together and others that are fully, or at all, compatible together, but still have some potential for further evaluation. The designs are split into four different sections:

- Base
    - The interface layer on which catalytic elements rest and slide on
- Element contact component.
    - The interface component between catalytic elements and tightening mechanism.
- Internal tightening system
    - Mechanism/system inside the reactor providing movement for element contact component.
- Outside/operating tightening system
    - Mechanism/system outside the reactor providing movement for element contact component and user operating interface.

Every concept was valuated in the weighted criteria chart (Appendix 1). The chart has every potential concept design valuated with score (higher the better) and with a weighted factor providing a weighted score (higher the better) which tells the importance and effect of different judging criteria with individual aspect and total score.

4.1 The Base

The base is area which provides vertical support for catalytic elements and works as an interface surface for catalytic elements to slide on. Concept designs are included in Appendix 3.

4.1.1 Steel Grid (Current Design)

The current design is a steel grid made by welding flat iron into a grid providing a very rigid base to support the catalytic elements (Appendix 2). This approach has a minimal effect on exhaust gas flows and does not really increase total backpressure of the reactor. Rigidity is one of the best features of this current base solution. One of the weaker points is catalytic elements sliding on the grid. Small touching surface areas with the way the grid is manufactured causes high spot pressures between the grid and the catalytic elements. Spot pressure peaks are prone to cause partial interference while tightening the catalytic elements. Overall, the grid still has many good properties specially what comes to rigidness. For that reason, in concept designs the grid will stay as an underlying support structure.

4.1.2 Cut Plate

Cut plate tries to mitigate spot pressure peaks and provide much smoother sliding in all necessary direction. The main idea is to create as even as possible a surface for the catalytic elements to slide on by replacing the grid as an interface layer with a solid steel sheet with holes for exhaust gasses to flow through. In theory this solution would provide a smoother surface with less manufacturing artifacts which can interfere with the catalytic elements sliding to place. This solution would be easy to manufacture, and it does not add major dimensional differences to the current reactor design. The disadvantage of this solution is inevitably risen backpressure. The amount of extra backpressure can be optimized with different hole patterns, but in the end the backpressure value will rise with this solution.

4.1.3 Guide Rails

Guide rails have the same end goal with the cut plate solution, to mitigate pressure peaks and smoother sliding by providing an even surface. The guide rails can be made from a simple L shaped angle bar or with T shaped extrusion. The main idea of the guide rails is to provide a sideways support for the catalytic elements and therefore, remove the need for tightening from two directions. This solution simplifies the tightening process and in theory provides much a more repeatable tightening process. The rails can be welded over the current steel grid or be integrated as a part of grid. The guide rails have the same disadvantage with previously mentioned the cut plate, backpressures will rise somewhat. The rails need to have a reasonable amount of lip for catalytic elements to slide on. All in all, the guide rail solution will the restrict exhaust gas flow but in theory not as much as the cut plate.

4.1.4 Cell/Pocket Array

This method is the only one using vertical tightening. The base will be formed from cells/pocket for individual catalytic elements. The elements are loaded in by lowering them in a dedicated pocket. The pocket ensures horizontal stability for the catalytic element. This method is also very efficient directing exhaust gases through the catalytic elements and thus minimizing bypass. One main downside of this solution is loss of working space due to needed higher walls for the pockets. In smaller reactors this solution can make the overall reactor dimensions somewhat smaller, but in bigger applications, it is possible that the pocket system can increase the overall size. This solution provides horizontal stability but requires vertical tightening. This solution can be tightened with threaded rods welded on the base pocket structure. There should be more than one rod per element contact component to ensure alignment. The U beam approach can be a viable contact method for this solution consisting of a U beam with holes for threaded rods and simple washer and nut to lock all together.

4.2 Element Contact Component

An element contact component is the component which directly contacts catalytic elements and transfers movement from the tightening system to the catalytic elements. The concept designs are included in Appendix 4.

4.2.1 U Beam (Current Design)

The U beam is the current design where the flat underside of the U beam is in contact with the catalytic elements (Appendix 2). The U beam is moved with a grooved system inside the beam valley. The U beam provides a large and even surface area for contact with the catalytic elements. It is also rigid and simple component to work with. Disadvantages are in two directional tightening and the overall movability of hefty steel beam. Friction from the contact between the catalytic elements and the base interface layer and the friction from the U beam between it and beam guide rails adds up. High friction makes it hard to determinate the correct tightness for the catalytic elements. The U beam approach still has many redeeming qualities which makes it a valid design choice in upcoming concept designs.

4.2.2 Steel Wire

By replacing the U beam with steel wire friction from the contact component can be reduced significantly. The right type of wire can provide enough force for the tightening and mitigate friction challenges. One major disadvantage of the steel wire system is need for a more complex system to keep the wire aligned with the elements. A pulley system needs to be implemented for the wire system to work correctly. The wire system also needs a flat contact surface with the elements to prevent the wires from eating their way through the catalytic elements. This system will drastically increase the number of needed parts and has an effect on the element installation process. The wire system is not reasonable solution for the element contact component, but it has some good features which can be used elsewhere in the tightening system, flexibility being one of them.

4.3 Internal Tightening System.

The internal tightening system in this context means the mechanism and system used inside the reactor to provide movement for tightening. The concept designs are included in Appendix 5.

4.3.1 Threaded Rod (Current)

The movement in the current system is handled by a threaded rod and a caddy which rides on the said rod (Appendix 2). The rod itself does not move outside of rotating, but the caddy moves along the rod. The caddy has poles which interact with the grooves on the interface component inside the U beam valley. The groove is angled to provide the U beam a linear motion. This system is all around working but introduces many high friction points. Those high friction points are in a high temperature and high corrosive environment which is prone to increase friction even more after long periods.

4.3.2 Pulley System

The pulley system is mainly focused to work with the steel wire system (4.2.2). The idea behind the pulley system is to reduce friction drastically. By removing static surfaces as a sliding surface has great benefits and can greatly reduce the force needed to use the system. The main drawback of the pulley system, excluding those of the steel wires, is a highly corrosive environment and high temperatures. ideally the pulleys would have a bearing in them but the bearing would not last in demanding conditions. So, the pulleys without bearings needs to be used and then the friction value will increase. Another drawback is the number of new components and extra space needed for the pulley system to work as intended. The pulley system is still good experiment and has a potential in other applications.

4.3.3 Gravity System (Sloped Rails)

The gravity system uses gravity, as the name suggests. This system uses a variation of the U beam on sloped rails. The idea behind this system is that the weight of the beam is guided slightly downwards and in the direction of the catalytic elements. The weight of the beam will overtime ensure that the catalytic elements stay in place, and if there is a movement on the catalytic elements, gravity and vibrations will push the beam closer, ensuring sufficient tightness in all times. This application needs certain other design elements to work right. The gravity system works best in a one-directional tightening system. In a two directional tightening system it is possible for beams to interact with each other and prevent sufficient element tightening. This system does not need a dedicated mechanism to push the elements, but it needs a way to loosen the contact with the elements. For this application the earlier mentioned pulley system with a steel wire would be suitable. The steel wire provides way to keep the beam as freely affected by gravitation and vibrations as possible and the pulley system provides an effective way to change the movement directions for the best possible operating interface. This system is still highly affected by corrosive conditions and high temperatures, but critical components can be placed further away from the direct exhaust gas flow. One concern is the needed weight for the beam to work as intended. Also, the effect of the needed weight can increase the friction in the system to point where it does not work as intended. The weight should be also considered in the loosening system and how much the weight affects the loosening system size.

4.3.4 Scissor Lift for Pushing.

The scissor lift for pushing tries to solve a problem, where the tightening beam can be distorted during the movement and cause extra resistance or even stoppage. As the name implies, the scissor lift system lends heavily from other applications such as car jacks and access platforms. The main idea is to provide two spread out contact points with the beam to ensure a linear straight motion and even pressure across the beam. This system needs solid mounting ears on the beam and on the reactor wall. The main components are four thick enough beams in pairs of two. Two beams are jointed together from the middle. Each free end connects to either beam or to the reactor wall. In each mounting end the ends of the beam pairs should be overlapped which the other pair to ensure maximised stability. The ends are also jointed on the mentioned contact point on the reactor wall and the beam with a pin joint that ensures free as possible movement for the system. This system can be driven with a threaded rod system, but to ensure the smoothest operation, it would be advisable to place most of the moving parts of the thread outside the reactor out of direct heat and corrosive conditions. This application needs a support structure in the rod axis to minimize bending forces. This support structure can be the U beam that is welded in each end of rod axis. The articulated joints of the scissor mechanism are the weakest link of this concept because of high temperatures and corrosive conditions inside the reactor.

4.4 Outside/Operating Tightening System

The outside tightening system refers to the tightening mechanism located outside the reactor. This section also includes a user interface for the tightening system due to close relation based on the location. The concept designs are included in Appendix 6.

4.4.1 Threade Rod (Current)

The current system a threaded rod. Its internal workings are explained earlier in section (4.3.1). The operating interface of the threaded rod consist of a nut that is welded on the threaded rod to create long “bolt”. By rotating this newly formed bolt head, rotational movement is transferred to the caddy part of the system, which makes rotary movement into linear movement. This system is overall simple, but an effective solution for the application.

4.4.2 Load Tensioner (Pneumatic)

The pneumatic load tensioner lends heavily from on-road timber transportation. In timber transportation, the carried load changes shape into tighter formation because of vibrations and that can leave the load unsecure and risk possible accidents. To combat this many carry structure manufacturers have developed automatic load tensioners. Basically, the system uses already existing pressurized air of the truck to operate system that keeps load securing chains or straps in constant tension. This system can be implemented for automatic element tightening. In the concept picture the system works by using compressed air to provide tension through a simple linkage system and a standard air brake chamber system. This application might be overly complicated but one of the key benefits is its adjustability. Basically, it could be possible to implement the same exact system for every reactor size and set the needed tension by adjusting the amount of air in the chamber. This universal style approach means that in some applications the system might be physically oversized for smaller installations. A good aspect of this system is adjustability and repeatable tightening preventing over or under tightening. The system is complicated and more expensive, but it is possible to have collaboration with the existing manufacturer to keep developing the cost down and have already a reliable proven system.

4.4.3 Load Tensioner (Spring-loaded)

The spring-loaded tensioning system is a simplified version on pneumatic tensioning. This system replaces complex pneumatics and linkage system with a simple spring for providing the needed tension. This also means that all maximum tension adjusting needs to be done accommodating the used reactor size with correctly rated springs. The most challenging part of the spring-loaded system is to create spring carriage which allows disabling the spring for element installation and service. On other hand, the spring needs to have a sufficient freedom of movement in use. Simplicity, repeatable operating, and cost are the strongest points pf this system.

4.5 Discussion and Discarded Ideas

Harsh conditions inside the reactor makes designing a reliable system hard. The main problem is still the amount of friction experienced in the system and that amount will rise over the usage hours. Those problems can be solved by using exotic materials that can withstand high temperatures and corrosive conditions, but that will bring costs up. Some form of lubrication on sliding surfaces could be an option, but most lubrication forms would burn and evaporate in high temperatures so that lubrication would not be helping when loosening the system. It also needs to be reapplied during services and that might cause an excess amount of disassembly. There is also an argument that which lubricants are environmentally sustainable to be burnt and how these lubricants affect the performance of catalytic elements. Bearings can be an option but bearing performance will be compromised by conditions inside the reactor.

What comes to preventing overtightening of the catalytic elements, physical stopper would be a working solution. The problem is that it does not accommodate loose tolerances of the catalytic elements. In some scenarios a physical stopper would work well, but in others overtightening or under tightening can still occur. In most cases, the physical stopper would probably lead to insufficient tensioning of the catalytic elements.

Most concept designs heavily lay on the idea that tightening should be done from one side only. Reasoning for that decision is improved working conditions due to fewer moving components inside the reactor, more repeatable tightening, and less interference between two tightening directions.

5 CONCLUSIONS

5.1 Designs with the Most Potential

All the concept designs have their own strengths and weaknesses. Some are easy to work with, others are simple by design, and some are just more practical than others. After evaluating different plausible combinations by using a weighted value chart, given feedback from Wärtsilä and thing learned during the research and modeling, two of the most sensible solutions were found.

5.1.1 Combination 1

The first combination uses guide rails with a U-beam and spring-loaded tensioner. This combination provides a smooth linear sliding surface and horizontal support for catalytic elements. With this approach, the need for two-sided tightening system is eliminated. As a result, the number of components will decrease, and the operating system should be easier in theory. The spring-loaded tensioner limits the input variables made by the person responsible for tightening. As said, the spring-loaded tensioner relies on vibration to move catalytic elements to the right place while providing pushing to keep them in place. This combination has few a theoretical downsides. It still must overcome the friction due moving to parts in the tightening assembly and the tension spring needs to be sized correctly to provide sufficient force. More advantageous features are simple design, lower internal part count and ability to reduce human errors. The concept designs are included in Appendix 7.

5.1.2 Combination 2

The second combination is mechanically the most simplistic solution to solve issue. This is the only vertical tightening solution on the concept list. The base consists of a pocket for individual catalytic elements, vertical threaded rods welded on pocket junctions and simple beam and nut solution to tighten elements down. This solution can have a minor impact on the overall reactor dimensions and working space during element installation. A simple and reliable tightening process still makes this solution worth considering. With sensible rod placement and right beam solutions this approach can be highly effective. Concept designs are included in Appendix 7.

5.2 Conclusions

Creating concept designs to improve or replace an existing product has its own challenges. Knowledge from the existing design can be a limiting factor for innovative design approaches. Too ambitious a design approach can also be a hindrance to a good design when choices affect things they should not. A balance between a sensible design and overengineering is critical to find. There are multiple ways to approach this situation even without the dedicated system for tightening and sealing the catalytic element assembly. One such solution could be designing the element housing, so they interlock with each other and with the reactor.

The conclusions were made using many different approaches. The one of the most important ways was visiting manufacturing facilities at JTK Power Finland located in Vöyri, Finland. Seeing the reactors in different manufacturing phases and without any insulations or additional component blocking the view of the structure was immensely beneficial for inspecting structures and functions. Another beneficial visit was on NLC Ferry’s (Wasaline) M/S Aurora Botnia in Vaasa. The vessel was built by Rauma Marine Constructions (RMC) and the vessel contains several Wärtsilä technologies including SCR-systems. The Visit took place during the reactor maintenance. Monitoring the process gave good knowledge of how the processes are handled at the site. The theoretical knowledge was gathered inspecting the existing CAD-models and available literature. The most important guide to concept design was vast knowledge of current product, what it does well and where is room for improvement. By combining the theoretical information and aspects learned during the visits gave a well-rounded basis and direction for the concept designs.

After many ideas from slightly modifying the existing design to ambitious new approaches, the most potential concepts were found. The connecting factors between potential concepts are effectivity, simplicity, and innovation. Those factors can be contradicting in whole, but there is a place for all in smaller subsections. The product needs to be effective, economical and as user-friendly as feasibly possible. By compiling the compatible concept subsections with the learned knowledge from the visit and the existing, the most efficient and feasible concept design were created. A good concept design balancing act.

Regarding the catalytic element tightening system of Wärtsilä NOR SCR-reactor, there is a section where a different approach or even slight modifications can result in more reliable and simple installation and operation. The included concept design can provide valuable approaches and outside-the-box thinking. In the end, it is almost impossible to create something that is perfect in all scenarios, but the best possible solution is always reachable. Innovation and improvement are the keys.

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