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ADVANCED SELECTIVE CATALYTIC REDUCTION TECHNOLOGY (ASCRT) FOR NOx EMISSION CONTROL IN AUTOMOTIVE ENGINES

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ABSTRACT

Selective Catalytic Reduction (SCR) technology is a widely adopted method for reducing nitrogen oxides (nox) emissions from diesel engines, essential for meeting stringent environmental regulations. This paper reviews recent advancements in SCR systems, focusing on improvements in catalyst materials, urea-based reductions, and integration. System It discusses the evolution of SCR technology from its early implementations to current state of-the-art systems, highlighting key innovations such as high efficiency catalysts and optimized dosing strategies. The paper also addresses challenges related to catalyst deactivation, temperature management, and integration with engine control systems. Through experimental data and real-world applications, the study demonstrates the effectiveness of modern SCR systems in achieving substantial nox reduction and explores future directions for enhancing performance and reliability.

Key words*: ASCRT,* Selective Catalytic AdBlue, IMO, DEF.

1.INTRODUCTION

Selective Catalytic Reduction (SCR) is a system used in marine engines to reduce nitrogen oxide (NO_X) emissions. Here's a brief overview of how it works and its benefits SCR systems inject a reducing agent, usually urea (AdBlue), into the exhaust gases of the engine. This agent reacts with nox in the presence of a catalyst to convert it into harmless nitrogen and water. SCR catalysts is a coated ceramic or metallic substrate that facilitates the chemical reaction. Urea Injection System: This system includes a tank for storing urea and a dosing unit for injecting it into the exhaust stream.

Manages the operation of the urea injection and monitors the SCR system's performance. Reduced nox Emissions: SCR can lower nox emissions by up to 90%, helping ships meet stringent environmental regulations Compliance Helps vessels comply with IMO Tier III emission standards and other regional regulations.

2. HOW TO PRODUCE NOX EMMISSION FROM MARINE DIESEL ENGINE

High Combustion Temperatures: nox forms when temperatures exceed 1,500°C (2,732°F) in the combustion chamber. This is because at such high temperatures, nitrogen (N2) and oxygen (O_2) in the air react to form nox compounds. Lean Air Fuel Mixture: Engines running with a lean air-fuel mixture (more air than fuel) tend to produce more nox this is because lean mixtures burn hotter and at higher temperatures compared to richer mixtures. High Engine Load and RPM: Operating an engine at high loads and high revolutions per minute (RPM) generally results in higher combustion temperatures, which can increase nox emissions. Advanced ignition timing (igniting the fuel-air mixture earlier) can also lead to higher combustion temperatures, contributing to increased NOx production.

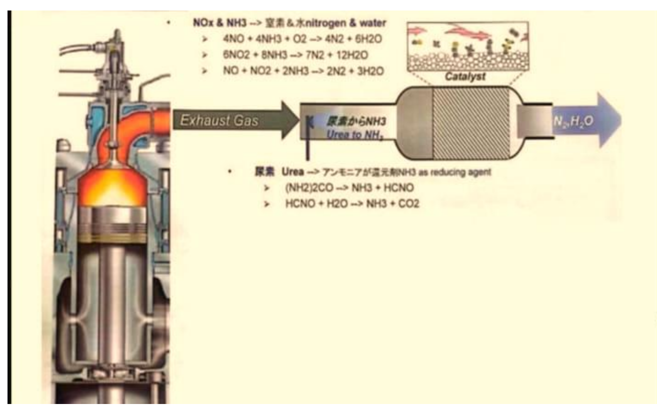


Fig. 1 SCR PROCESS

3.SELECTIVE CATALYTIC REDUCTION

The catalytic converter contains a catalyst that reacts with NOx in the engine exhaust to convert it into nitrogen and water vapor. Nitrogen-based solutions (typically called diesel-based fluids or DEF) are used in injection system engineering prior to entry into prototyping. DEF reacts with NOx in the exhaust to form nitrogen and water vapor.

The control system monitors the engine and exhausts conditions and adjusts the amount of DEF injected to optimize the performance of the SCR unit. The control system also monitors the catalytic converter to ensure that it is functioning properly and alerts the crew when maintenance is required. SCR units are effective in reducing NOx emissions from marine diesel engines, making them an important technology for meeting emissions regulations. However, they require regular maintenance, including refilling the DEF tank, replacing the catalytic converter, and cleaning the injection system.

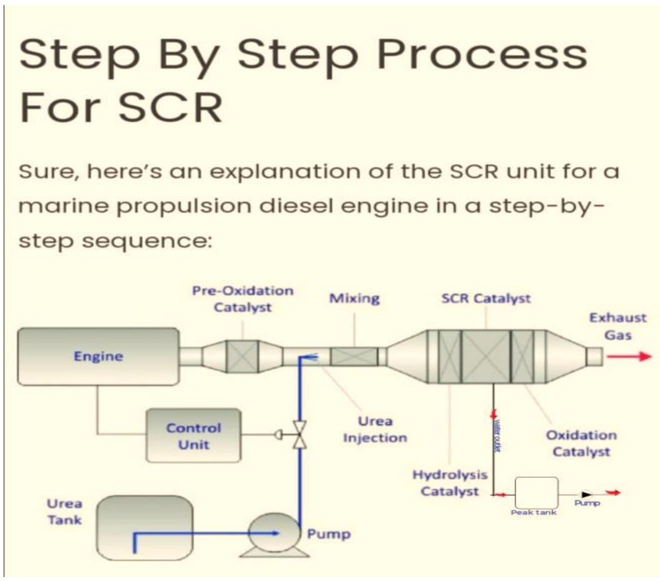


Fig. 2 GENERAL CONCEPT OF FLUE GAS CLEAN UP

The exhaust gases produced by marine diesel engines are first directed to the SCR unit. ⍰ Before entering the SCR unit, a urea-based solution (DEF) is injected into the exhaust gases. DEF reacts with nitrogen oxides (NOX) in exhaust gases to form nitrogen and water vapor. This reaction takes place in the catalytic converter present in the SCR unit.

The catalytic converter is composed of a catalyst, usually made of platinum, rhodium or palladium, which facilitates the chemical reaction between DEF and NOx.

The clean exhaust gases, which are now free of most of the nox, are then released through the exhaust stack.

The control system monitors the engine and exhaust conditions and adjusts the amount of DEF injected to optimize the performance of the SCR unit.

4. NEED SELECTIVE CATALYTIC REDUCTION (SCR)

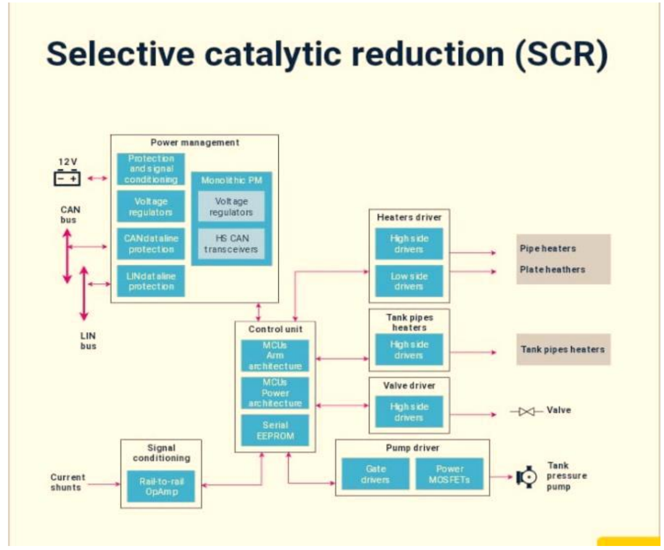


Fig.3 POWER TRANSMISSION &MANAGEMENT PROCESS

Environmental regulations: Marine diesel engines are a major source of air pollution, especially nitrogen oxide (NOx) emissions. To reduce the environmental impact of shipping and protect air quality, various international and regional regulations have been introduced that limit the number of toxic substances emitted by ships. The use of SCR systems helps ships meet these regulatory requirements

Public Health

NOX waste can have significant adverse effects on human health, including respiratory failure, respiratory failure, and other respiratory diseases. Technological use of SCR helps reduce these products, improving public health.

Reputation and Competitiveness

Shipping companies that can demonstrate that they are operating in an environmentally responsible manner are more likely to be viewed favorably by customers, regulators, and other stakeholders. By using SCR systems, shipping companies can improve their environmental and increase their reputation and competitiveness.

Fuel efficiency: SCR systems can also help to improve a fuel efficiency by optimizing the combustion process in the engine. This This can result in lower fuel consumption, lower operating costs and reduced greenhouse gas emissions

GRAPH

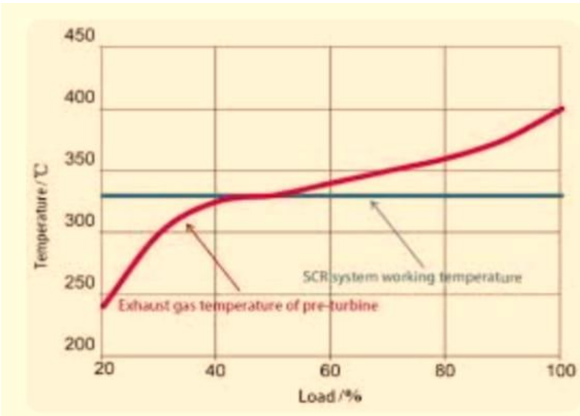


Fig. 4 TEMPERATURE BASED IN SYSTEM

4.1 SCR SYSTEMS IN SHIPS INCLUDE

Selective Catalytic Reduction (SCR) systems in ships are used to reduce nitrogen oxide (NOx) emissions from marine engines and meet international emission regulations, such as those set by the International Maritime Organization (IMO). The SCR process works by injecting a reductant, typically ammonia or urea, into the exhaust stream, which reacts with NOx over a catalyst to form harmless nitrogen (N2) and water vapor (H2O).

4.1.1 CATALYST REACTOR

The core component of the SCR system is the catalyst reactor, where the chemical reactions occur. The catalyst is usually made of materials like vanadium, titanium, or zeolites. These materials facilitate the reaction between NOx and the reductant without being consumed in the process.

4.1. 2. REDUCTANT INJECTION SYSTEM

The reductant (often an aqueous urea solution or ammonia) is injected into the exhaust gas stream before it reaches the catalyst. The urea decomposes to form ammonia, which then reacts with the NOx. The injection system is precisely controlled to ensure optimal reduction.

4.1.3 CONTROL SYSTEM

SCR systems are equipped with sophisticated control systems that monitor the engine load, exhaust gas temperature, and NOx levels. The system adjusts the amount of reductant injected based on these variables to ensure efficient NOx reduction without excess ammonia slip (unreacted ammonia exiting the system).

4.1.4 AMMONIA SLIP CATALYST (OPTIONAL)

To reduce the risk of ammonia slip, where unreacted ammonia escapes into the atmosphere, some systems are equipped with an additional catalyst stage to convert any residual ammonia back into nitrogen and water.

4.1.5 TEMPERATURE MANAGEMENT

SCR systems require the exhaust gas temperature to be within a specific range (typically 300–400°C) for effective NOx reduction. Systems often include heaters or other mechanisms to maintain the necessary temperature in low-load conditions, such as during idling or slow steaming.

4.1. EXHAUST GAS MIXING

For the SCR system to work efficiently, the reductant must mix thoroughly with the exhaust gases. Mixing devices or specific exhaust designs are often used to ensure uniform distribution of ammonia or urea in the gas stream before it reaches the catalyst.

4.1.7 NOX SENSORS AND MONITORING

The system often includes NOx sensors to continuously monitor the concentration of nitrogen oxides in the exhaust both before and after the SCR system. This allows for real-time adjustments and compliance with NOx emission limits.

4.1.8 MODULAR DESIGN

Many SCR systems are designed to be modular, which allows for flexibility in installation. This is important for fitting SCR systems into different types of ships, where space may be limited.

4.1.9 DURABILITY AND LOW MAINTENANCE

The catalyst materials are designed to be long-lasting, typically requiring replacement only after several thousand operating hours. Additionally, the system is designed for low maintenance, with periodic cleaning of the catalyst and injectors being the primary upkeep tasks.

4.1.10 Compliance with IMO Tier III Regulations

SCR systems are primarily used to comply with the IMO Tier III regulations, which mandate strict NOx reductions in certain Emission Control Areas (ECAs). By reducing NOx emissions by up to 90%, the SCR system ensures compliance with these stringent environmental standards.

4.1.11 SPACE AND WEIGHT CONSIDERATIONS

Given the large size and weight of SCR systems, especially for large engines, the design must be optimized for minimal impact on the ship's layout and weight distribution. Some ships may need customized installations to fit the SCR system properly.

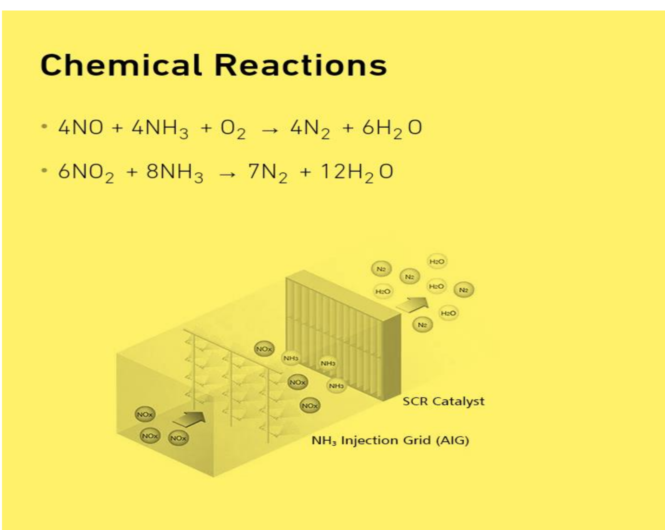
4.1.12 Redundancy Features

Many systems include redundancy features to ensure continuous operation, even if parts of the system fail. This might include multiple injection nozzles or catalyst segments that allow for part of the system to be serviced while the rest remains operational.

4.1.13 COMPATIBILITY WITH DIFFERENT FUEL TYPES

SCR systems are designed to work with engines running on various marine fuels, including Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO), and Liquefied Natural Gas (LNG), provided the exhaust gas meets the required temperature and NOx levels.

By integrating these features, SCR systems ensure the ship meets environmental standards while maintaining operational efficiency.



4.2 ENIVERNMENTAL ASPECTS

Possible NH3 emissions due to the process not being completed effectively (NH3 slip). Used catalyst Laughing gas (N2O) can be produced as a by-product. In "high-dust" switching, the flue gases are laden with NH3

4.3 ENERGY USE

Energy use for heating flue gases in "low dust configuration. Efficiency NOX:90-94% Residual emissions: Possible aerosol- forming from ammonium chloride and ammonium sulphate

5. APPLICATIONS

Selective catalytic reduction is used within combustion installations in the following sectors: Waste incineration; Energy plants; Metal industry; Greenhouse horticulture.

6 . ADVANCED SCR IMPLEMENTATION TECHNIQUE

6.1 Dual SCR Systems:

To enhance NOx reduction, particularly in wide operating conditions (low and high temperatures), some systems use a dual SCR configuration.A low-temperature SCR catalyst can operate efficiently at lower exhaust temperatures (e.g., in csold-start conditions or city driving).A high-temperature SCR catalyst operates effectively at higher temperatures, typically during highway driving.

6.2 SCR on Filter (SCRF)

Some advanced systems combine the SCR function with a diesel particulate filter (DPF), integrating them into a single unit called SCR on Filter (SCRF).This combination reduces system complexity and saves space while providing both NOx reduction and particulate matter (PM) filtration in a single unit.

6.3 Urea Dosing Optimization

Advanced algorithms and machine learning techniques are being used to precisely control the amount of urea injected, ensuring optimal NOx reduction and minimizing urea consumption.These algorithms take into account real-time factors like load, exhaust temperature, and NOx sensor feedback

6.4 .Ammonia Storage and Release

In some advanced systems, catalysts are designed to temporarily store ammonia at lower temperatures and release it when the temperature rises, ensuring that NOx reduction can occur over a broader range of operating conditions.This approach minimizes NOx emissions during transient driving conditions (e.g., accelerations and decelerations)

6.5 Integrated Thermal Management

Optimizing exhaust temperature is critical for SCR efficiency. Advanced thermal management systems adjust engine parameters (e.g., injection timing, exhaust gas recirculation) or even use auxiliary heaters to maintain the ideal SCR operating temperature.

6.6 NOx Storage Catalysts

Another strategy used is NOx storage reduction (NSR), where NOx is temporarily stored in a catalyst during lean conditions and then reduced during rich conditions.NSR can be combined with SCR to ensure NOx reduction across varying conditions.

7. CONCLUSION

Overall, SCR is a critical component in reducing the environmental impact of diesel engines and industrial processes, contributing to cleaner air and compliance with regulatory standards.

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