The Case of Acoustic Cleaning of Industrial Boilers at Sasol Synfuels Power Station in Secunda

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Abstract

This paper is a review of boiler maintenance technologies currently used in the main power generation plants in South Africa, Sasol (coal fired plants). The poor maintenance of the boilers at these plants has been the main cause of shortage of power due the boiler breakdowns, while the demand of energy usage remains a necessity for households and businesses. At Sasol Synfuels power station in Secunda, the use of soot blower cleaning technology has contributed a lot to failure resulting in unplanned outages, with high cost of maintenance. A recently published paper discusses the design of an acoustic horn and its beam as an alternative technology that may be a better solution either to be used along with the current soot blower technology or independently for new design of boilers. In this paper the regulations for maintenance of pressure vessels in South Africa governing the maintenance of pressure equipment are reviewed for the case of the boilers at these power plants. South African National Standards (SANS), American Standards of Mechanical Engineering (ASME) and American Petroleum Institute (API) are the used international standards in supporting pressure equipment regulations (PER) and Occupational Health and Safety Act (OHSACT).

Keywords: Breakdowns, Energy, Regulation, Pressure Vessels.

1. Introduction

Coal fuel and natural gas is part of every power plant in generating electricity. These fuel types are used by power plants to power boilers, which are known to produce ash. The ash forms slag deposits over the tubes running though the boilers. The slag affects the efficiency of the boilers due to the poor heat exchange or high pressure drop. The cost to the company is very high in buying the coal for firing up the boiler that does not reciprocate efficiency that is relative to the coal used because of the slag and failure of current cleaning techniques. Sasol Synfuels Power Station in Secunda consists of 17 boilers in total (9 boilers at eastern side and 8 boilers at western side). Each produce 560 t/h at 42.50 bar high-pressure superheated steam [1, 2]. Each boiler contains a box of steel tubes [2]. The tubes convey the water by means of natural circulation passing the furnace from the bottom upwards turning converting water into steam. Energy is transferred from fire in the furnace to the water (radiation, conduction & convection). The fire is from burning coal. The soot blow system provided on each boiler is used to blow ash off the boiler wall tubes (short soot blowers) and the super heater and convection tubes (long soot blowers). High-pressure (HP) steam is taken from the HP steam outlet, reduced to ± 1000 kPa and is blown inside the boiler to remove the ash. Air from the Primary Air system is used as a cooling medium to keep the soot blowers cool when not in use [3, 4]. The objective of the project is to design an acoustic horn cleaner to be used in cleaning a boiler whilst it is operating with a small vibrating beam as an alternative solution to minimise soot blower use.

2. Literature Review

Any component designed and manufactured to contain fluid under pressure equal to or greater than 50 kPa is a pressure vessel and is regulated using Pressure Equipment Regulation (PER). The boilers at Sasol falls under pressure vessels as they operate at HP steam of more than 1500 kPa and their soot blowing system operates at more than 1000 kPa. There are different regulations applied in the maintenance of these boilers depending on the type of equipment/piping and their category according to hazard category as specified by SANS. Their classification of pressure equipment is according to the level of risk taken from the design pressure and the volume of the medium it carries. The regulations for pressure equipment (PER) is intended to help users, manufactures, approved inspection authorities and importers of pressure equipment to understand the content as well as to assist with the interpretation and implementation of the pressure equipment regulations [5]. The risk of injury arising from defects in the construction of pressure equipment and non-pressure equipment is related to the consequences should failure occur during use. These consequences are primarily dependent on the hazard level. An increased hazard level requires an increased degree of independent conformity assessment or verification. Should a certified management system be controlled by the manufacturer, the involvement of the Approved Inspection Authority (AIA) will be decreased [5] (NPT, 2020).

2.1 SANS

2.1.1 Pressure Accessories

According to SANS pressure accessories on piping are applicable depending on whether the Volume (V) or the Nominal Size (DN) is appropriate for classification of the pressure accessory. Where both the volume and the nominal size are appropriate, the pressure accessory is classified in the higher category. The cleaning technology (acoustic horn) is an assembly which is both pressure accessory and safety accessory for the equipment which is the boiler in the case of this research (Department of Labour, 2017).

2.1.2 Safety accessories

These are generally classified as category IV in SANS 347. Safety accessories manufactured for specific equipment are classified at the same category as the equipment that they protect. This means the acoustic device or horn is categorized as the boiler itself [5].

2.1.3 Assemblies

Assemblies are subjected to a global conformity assessment procedure comprising:

- Assessment of each item of pressure equipment making up the assembly which has not been previously subjected to a conformity assessment procedure and to a separate marking the assessment procedure are determined by the category of each item of equipment.
- The assessment of the integration of the various components of the assembly which are determined by the highest category applicable to the equipment concerned other than that applicable to any safety accessories; and
- The assessment of the protection of an assembly against exceeding the permissible operating limits are conducted in the light of the highest category applicable to the items of equipment to be protected.

2.2 ASME

Piping components need not be defined as pressure accessories when purchased and certified in accordance with a referenced standard listed in the applicable health and safety standard(s). The manufacturer of the equipment that uses the piping components remains liable for their integrity. Examples would include standard valves that comply with ASME B16.34 or API 600 when used in piping in accordance with ASME B31.3 [8].

2.3 Other Standards

There are other standards that are taken into consideration with regards to pressure piping accessories, safety accessories, assembles, modifications and repairs that the South African Bureau of Standards (SABS) has specified. Although SANS document is based on the European Directive, changes have been made to accommodate specific requirements in the vessels under pressure regulations, renamed as the Pressure Equipment Regulations (PER) in the Occupational Health and Safety Act, 1993 (Act No. 85 of 1993). Every effort has been made to ensure that the manufacture of pressure equipment is carried out in a safe manner to prevent injury to the user as well as to the public. List of standards as per SABS:

- API 600, Steel gate valves – Flanged and butt-welding ends, bolted bonnets.
- ASME Section VIII – Division 1, Rules for construction of pressure vessels.
- ASME B16.34, Valves flanged, threaded and welding end.
- ASME B31, Code for pressure piping.
- SANS 3834/ISO 3834, Quality requirements for fusion welding of metallic materials (all parts).
- SANS 9001/ISO 9001, Quality management systems – Requirements
- SANS 10019, Transportable containers for compressed, dissolved, and liquefied gases – Basic design, manufacture, use and maintenance.
- SANS 10227, Criteria for the operation of inspection authorities performing inspection in terms of the Pressure Equipment Regulations.
- SANS 10228, The identification, (2) and classification of dangerous goods for transport.

Over and above Sasol modifies the combination of these standards to give rise to their specifications and incorporate them into the organizations work standards and procedures which are numbered according to their criteria. The purpose of this procedure is to provide guidelines for the person appointed in terms of the Occupational Health and Safety Act, GMR 2(1), the inspection personnel, maintenance and production personnel for the identification, registration, frequency of inspection, re-rating, inspection, modifications and repair of pressure equipment and storage tanks. This is done to ensure that all pressure equipment and storage tanks are kept in a condition that is safe for operation and that all in-service requirements are adhered to.

2.4 Boiler Operation and Cleaning

When combustion happens in the boiler the by-product ash is produced. This ash contains several non-combustible products like silicates, clays, and others, depending on the type of coal used as well as the combustion process itself. If ash is left unchecked, one of its effects on the boilers surfaces is in loss of efficiency of heat transfer which can create a loss of reliability by causing the unit outages to effect the removal of massive ashes. The degree of the damage is dependent on the load profile of the unit, the ash characteristics, and the boiler design. This challenge is addressed or minimized by effective cleaning system while the boiler is in operation [9]. The process of combustion in a power plant with boilers that use coal produces ash that accumulates on the surfaces of the boiler tubes resulting in insulation of the heat transfer surfaces. After some time, it is found that huge amounts of deposits detach from the suspended tube positions and are dumped automatically to the bottom of the furnace, which has a huge impact on the tube damages and ash-handling plant [9]. In most cases, the mechanism for controlling the negative effect of ash build-up on the boiler tubes is the injection of steam to remove the ash and this is commonly known as Soot Blowing (SB). Other cleaning mechanisms other than soot blowing exist such as self-shedding, water cannons for furnace cleaning, and ultrasonic for back-end and air heaters cleaning [9]. These cleaning mechanisms have been found to have advantages as well as disadvantages which opens a gap for more research to be done in the field of boiler cleaning in power plants [10]. The other technique is the use of water lances and water cannons as an effective method of removing slag deposits. This method is also found to cause damages boilers tubes [11].

In the past decade there have been many advances in impulse cleaning systems, and they have become more accepted by utility and other industrial boiler operators. A significant benefit of impulse cleaning systems over soot blowers is that they can be operated very aggressively in terms of their cleaning frequency per day without causing the tube erosion caused by soot blowers [12]. The great advantage of a proactive cleaning cycle is that it provides a more consistent heat transfer profile and removes the ash deposits before they have an opportunity to harden or sinter into place. Impulse cleaners typically operate multiple times per hour throughout the day and therefore maintain higher heat transfer efficiencies. An additional advantage of impulse cleaning systems over soot blowers, see figure 1, is the ability of the pressure wave to encompass the tube surface throughout the depth of the tube bank, providing non-line-of-sight cleaning and deeper penetration throughout the tube bundle [12].

2.5 Water Lances

Water lances is another method for cleaning slag in boilers by using high pressured water jets. The jets use hydro blasting equipment which pumps up to 1200 gallons per minute through hoses [10]. The jets can also be remote controlled [10]. Water lances can be used offline and online but online cleaning can only happen on specific boilers. Water lances can clean further distances and can be more effective [10]. Depending on whether imported or manufactured in South Africa the same rules will apply for the use of water lances according to SANS and ASME regulations.

2.6 Soot Blowers

Soot blowers use high pressured air, steam, or water to clean the build-up of slag on the boilers. Soot blowing can be performed while the plant is still online. A company having one of the advanced soot blowing systems can increase the efficiency by 1% [8]. This method can avoid the risk of boiler erosion. Depending on whether imported or manufactured in South Africa the same regulations will apply according to SANS and ASME.

2.7 Explosives

Use of explosives is one of the old methods in cleaning slag inside boilers and some plant operators still prefer its use. This was first being used by Norm Harty of N.B. Harty general contractor Inc. Explosives are used by a primer cord wound around tubes that avoid any damage. The cord has connectors which delay the charge which helps to limit damage to the boiler insulations [8].

2.8 Chemical Cleaning

Chemical cleaning has been used for years and is used on the waterside of the fire tube boilers where mineral based chemicals are formed. Industries use scale removal chemicals to remove calcium carbonate and other scales that stick to the heating surfaces [9].

2.9 Boiler Tube Maintenance at Sasol Synfuels Power Station in Secunda

A boiler contains a lot of the components that have strong enough materials to withstand the stresses caused by high temperatures. The components in a boiler are drums, tubes, ducts, and auxiliary equipment. Some boiler tubes extend the entire length of the boiler, some are bent. The tubular length is determined by the boiler some of them do not extend through the boiler. The tubes are passed through a metal sheet shown in Figure 2. As shown the tubes vary in size, thickness, and length. Figure 3 shows a man inside a boiler firebox where the boiler tubes are being cut out from the firebox tube sheet and pushed out while someone on the other end pulls it out. This process involves the taking out of the tubes and changing them if they are damaged. Thus, Figures 2 and 3 shows how the tubes will be removed from a boiler. The Sasol power plant in Secunda predominately uses soot blowers for cleaning the boiler tubes.

2.9.1 Soot Blowers

The soot blower system is the most used system to clean boiler and is used extensively at Sasol Synfuels power station in Secunda. This cleaning system uses compressed air, steam, or water to prevent slag build up while the plant is in operation. The technology is becoming more sophisticated: there are basic soot blower technologies as well as advanced technologies [10]. The basic technology does the minimum by keeping the boiler clean while online, there is no need to be offline for cleaning to occur. The advanced technology targets the areas that requires intensive cleaning hence maintaining the boiler performance for the plant to work more efficiently. Currently the Sasol plant in Secunda uses the advanced technology.

2.9.2 Intelligent Soot Blowers

This is an adaptive process which uses Artificial Intelligence (AI) techniques to maintain optimal boiler surface cleanliness. It determines which boiler section to clean and when to clean them subject to the optimization goal and operating constraints. This is also referred to as optimized soot blowing. The factors that need to be taken to consideration for this soot blowing are steam usage, maintenance to repair erosion of tubes, as well as stress experienced by the boiler tubes. This is to be balanced against the efficiency gains made by SB within a load profile [12]. This technology is yet to be widely used at the plant in Secunda due to damage to the soot blowers and erosion of the boiler tubes. This is discussed in another paper.

2.9.3 Automatic Soot Blowing Operations: Direct Slag Monitoring Techniques

At Sasol Synfuels Power Station in Secunda, the furnaces are sub-divided into multiple heat transfer zones, which consists of automatic control systems to control the soot blowers and each zone has a heat flux sensor. The signal on the automatic controls display and indicate clean or dirty conditions and thus initiates queue to the soot blowers for requirements of cleaning. A fundamental part of the automatic control is the method of handling the dirty heat transfer surface after the respective soot blowers are operated. Depending on the soot blowing system, controllable parameters, such as blowing pressure, number of back-to-back operations, jet progression velocity, etc., are used to adjust soot blower operating conditions for successive operations to realize cleaner heat transfer surfaces [12].

2.10 Acoustic Cleaning Technologies

Acoustic cleaning a technology began in the early 1970s with experiments using ship horns or air raid sirens. The first acoustic cleaners were made from cast iron [13, 14]. From 1990 onwards the technology became commercially viable and began to be used in dry processing, storage, transport, power generation and manufacturing industries. The latest technology uses 316 spun stainless steel to ensure optimum performance [13, 14]. An acoustic cleaner consists of a sound source like an air horn found on trucks and trains, attached to the material-handling equipment, which directs a loud sound into the interior. It is powered by compressed air rather than electricity so there is no danger of sparking which could set off an explosion. It consists of two parts:

- The acoustic driver.
- The Bell.

2.10.1 The Acoustic Driver

In the driver, compressed air escaping past a diaphragm causes it to vibrate, generating sound. It is usually made from solid machined stainless steel. The diaphragm, the only moving part, is usually manufactured from special aerospace grade titanium to ensure performance and longevity [1, 2].

2.10.2 The Bell

This is a flaring horn usually made from spun 316 grade stainless steel. The bell serves as a sound resonator and its flaring shape couples the sound efficiently to the air, increasing the volume of sound radiated. An acoustic cleaner will typically sound for 10 seconds and then wait for a further 500 seconds before sounding again. This ratio for on/off is approximately proportional to the working life of the diaphragm. Provided the operating environment is between −40 C and 100 °C, a diaphragm should last between 3 and 5 year [13]. The wave generator and the bell have a much longer life span and will often outlast the environment in which they operate. The older bells which were made from cast iron were susceptible to rusting in certain environments [13]. The new bells made from 316 spun steel have no problem with rust and are ideal for sterile environments such as found in the food industry or in pharmaceutical plants.

2.10.3 The Acoustic Technique

Acoustic cleaners are very rapid and powerful sound induced systems that use compressed air to clean solid particles of ash, dust, granules, or powders. The materials resonate causing them to detach from adjoining surfaces and from the surface they are adhering to. Once detached, the materials will fall off because of gravity, in some cases they may be carried by the process gas or air streams. [13, 14]. The mostly used medium or equipment for the vibrations are sonic horns which work as a means of fluidizing unwanted dust and agglomerated particulate in industrial environments.

There are generally 4 ways to control the operation of an acoustic cleaner:

- The most common is by a simple timer.
- SCADA (Supervisory Control and Data Acquisition).
- PLC (programmable logic controller).
- Manually by Ball valve.

2.11 Acoustic Cleaning VS Steam Soot Blowers

The Sasol power plant at Secunda currently does not use acoustic cleaning solutions. The migration of the cleaning system at the plant from soot blowing to a combined soot blowing - acoustic cleaning system and eventually to a full acoustic cleaning system is the subject of ongoing research by these authors. In this section we show why the acoustic cleaning solution will be of advantage to the plant. Table 1 gives comparison between acoustic cleaning and steam soot blowers. It shows some of the limitations that soot blowers have and their need of water and steam which brings about erosion and corrosion of the boiler tubes.

3 Methods

Boiler cleaning is an important aspect for a power plant to work efficiently. Boilers will build up ash which forms slag deposits on the boiler heat transfer surfaces. The slag acts as an insulator thus the boiler requires more fuel to reach the same temperature. Cleaning the boiler increases the efficiency from 1 to 4 % and reduces the emission produced due to less fuel being used [8]. The methods of boiler cleaning vary from offline cleaning which is when the plant is not on and online cleaning which is when the plant is still on. All accessories of boilers are categorized in terms of the SANS for compliance.

Table 1: Acoustic cleaning vs steam soot blowers

Advantage	Acoustic cleaning	Steam Soot blowers
1. Fast and easy installation even when boiler is running	✓	✓
2. Can be used in all temperature areas of a boiler	✓	✓
3. Can be used also with molten or partly molten ash	✓	✓
4. Can be used with no steam available or a shortage of steam	✓	×
5. Continuous cleaning of the process	✓	×
6. Also cleans shadow areas and around the corners	✓	×
7. Can be used together with other cleaning methods	✓	✓
8. No water needed	✓	×
9. Doesn't cause erosion	✓	×
10. No corrosion	✓	×
11. No mechanical wear	✓	✓

3.1 Criteria for Determining Hazard Categories According to SANS

3.1.1 Hazard Categories

Categories are used to determine how the statutory regulations will apply to specific items of pressure equipment. There are five categories used by manufacturers:

- Sound Engineering Practice (SEP),
- Category I.
- Category II.
- Category III; or
- Category IV.

SEP is not subjected to conformity assessment for equipment, but it is designed and manufactured in accordance with sound engineering practice (best practice) to ensure safe use. The equipment that falls under this category usually ensures that manufacturing and design contemplate all the applicable aspects that impact safety during its projected lifetime. The equipment should consist of the identification of the manufacturer as well as instructions for use.

3.1.2 Category I Equipment

In this category manufacturer ensure that equipment complies with the requirements of the applicable health and safety standard(s). A certificate of conformity confirming that the equipment is manufactured in accordance with the applicable code of construction is issued by the manufacturer as well as the design requirements of such equipment.

3.1.3 Category II and Above

Category II and above requires to be approved by a suitably registered professional (i.e. registered Pr. Eng. Pr. Technologist or Pr. Cert. Eng.) (competent in this field) to a health and safety standard and verified by the AIA or certification body as applicable. In the case of countries which do not fall within the recognition agreements (e.g. Washington accord, etc.), the design engineers with equivalent qualifications and relevant experience may be accepted through an agreement by verification engineer of an AIA for designs done outside of South Africa. Imported pressure equipment does not have to meet the requirements provided they are:

- CE and Pi marked equipment.
- ASME stamped equipment.
- DoT stamped equipment/

Acoustic cleaning systems are used to clean ash in coal fired boilers by sending sound wave energy through the boiler which reduce damage or fatigue of the material of the boilers. Acoustic horns are fitted on to the boilers with advanced acoustic technologies which is specified by the requirement of the plant [8, 9]. Since the Acoustic device is a boiler accessory operating at 1500kPa (Design pressure indicated by a horizontal green line of Figure 1) high pressure (HP) steam with pipe inside diameter of 100mm according to SANS 347 this will be categorized as the boiler itself. Figure 1 is a which shows the various categories for dangerous liquids (HP steam) contained in piping inside a boiler. This graph shows that the device falls under SEP hence it will follow the SEP requirements of SANS 347.

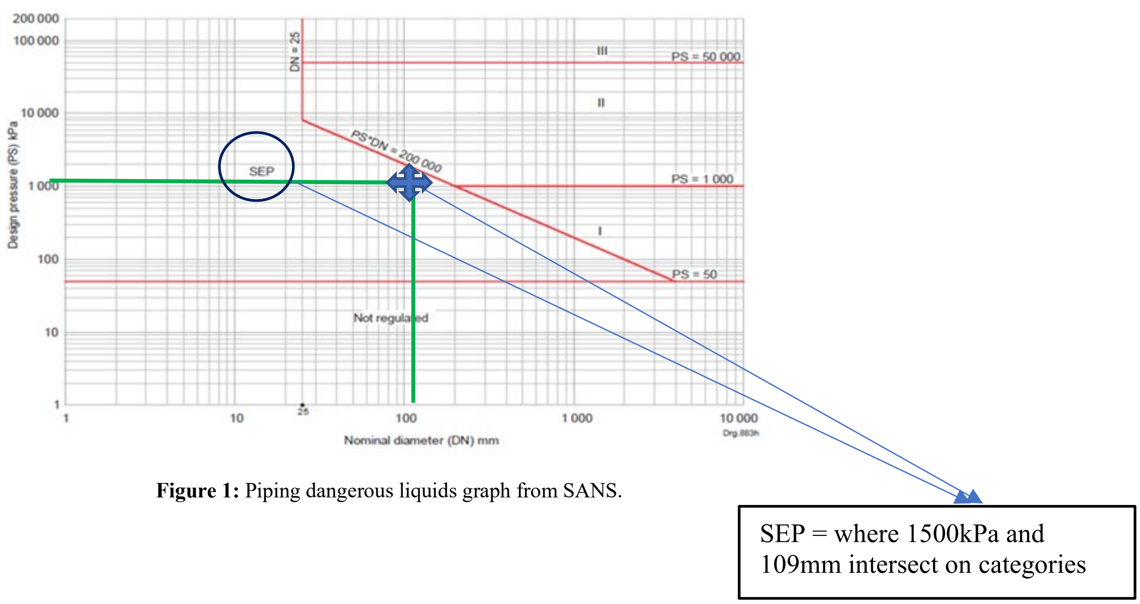

Figure 1: Piping dangerous liquids graph from SANS.

4 Data Collection

A model on a tube designed was done using AutoCAD Inventor 2016, where parameters used were for the Acoustic horn and beam modelled. The design and operating pressure that were used are on Table 2 resembling the real condition inside the boiler as well as its heat radiation. The materiel used is carbon-molybdenum steel which is an alloy working environment of the tube. The range of 58-85 Hz frequency was used to be able to withstand operating frequencies of 75 Hz without failure as per the same frequency used for the design of the Acoustic horn and the beam. Assuming the same arrangement of piping as of the soot blower system the acoustic horn can go parallel with them.

Table 2: Design and operating conditions used for simulation.

Design Pressure [kPa]	5650
Design Temperature [°C]	440
Operating Pressure [kPa]	4250
Operating Temperature [°C	435
Medium	Superheated Steam
Material of construction	DIN 17175 15Mo3 (carbon-molybdenum steel)
Thickness of the material	4.5 mm

5. Results and Discussion

At time of the simulation the operating steam pressure measured was 4250kPa on a single superheater tube, which was still an acceptable pressure since the design pressure is still above which is 5650kPa. The operating temperature was 435°C which is also an acceptable operating temperature if compared to design temperature of 440°C of the tube. In the real plant practice a carbon steel seamless tubes (DIN 17175 15Mo3) are used with 4,5mm thickness of the pipe.

5.1 Cleanness Maintained Constantly.

Acoustic cleaning technology does not require stoppage or interruption of the power plant. This may significantly reduce or even eliminate downtime and increase equipment availability which is a major problem at the plant at present. At the same time, acoustic cleaning systems can be used during plant shutdowns to minimize requirement of manual cleaning [1, 13]. From tests conducted suing a horn and simple beam for a tube, it is found that the cleaning is at a high level of efficiency [22, 23].

5.2 The Most Energy Efficient Cleaning Solution

Acoustic cleaning systems offer several distinct advantages as a superior and cost-effective alternative to soot blower cleaning method used at Sasol. They can maintain plant efficiency at a high level. Acoustic cleaning systems can continuously removes soot, ash, and particulate matter deposits from surfaces, thus preventing formation of build-ups and maintaining heat transfer efficiency in boilers, reducing pressure drops in bag filters, limiting vibration levels in fans etc. at desired levels. It has been demonstrated that the plant at Secunda could easily install an acoustic cleaner for its boilers [2].

5.3. Substantial Cost Savings

Acoustic cleaning systems are very cost-effective solution. This is mainly because acoustic cleaning systems use compressed air for their operation lowering operating costs as compared to the soot blowers used at the plant. The cost of maintaining the system is almost negligible due to non-moving parts. Most acoustic cleaning systems are compact and occupy much less space compared to conventional cleaning devices such as long retractable soot blowers. The current cost of maintaining this soot blower system is documented in another paper by these authors.

5.4Discussions

Superheated steam from the boiler outlet HP header is used as blowing medium to clean the tubes. The steam is taken off at a pressure of 4150kPa and a temperature of 435ºC and is reduced via an adjusting screw at the poppet valve to a pressure of between 800-1100kpa [1, 2]. The HP steam lines are kept free of condensate by steam traps on the drain lines situated on the first level east and west side of the boiler. Any condensate entering the soot blower will mix with the ash and cause clinkers. The superheated steam is also used as a cooling medium while passing through the soot blower lance. The steam temperature is ± 310ºC compared to ± 1081ºC and 646ºC in the boiler so even though it is hot it helps to keep the lance cool. If a soot blower lance gets stuck inside the boiler, for any reason this ensure that the steam to the soot blower always remains open [22, 23]. While the soot blower is stuck in the boiler with the steam isolated will result in the lance overheating and bend and maybe even burn off and fall into the drag-chain where it can cause damage, see Figure 2.

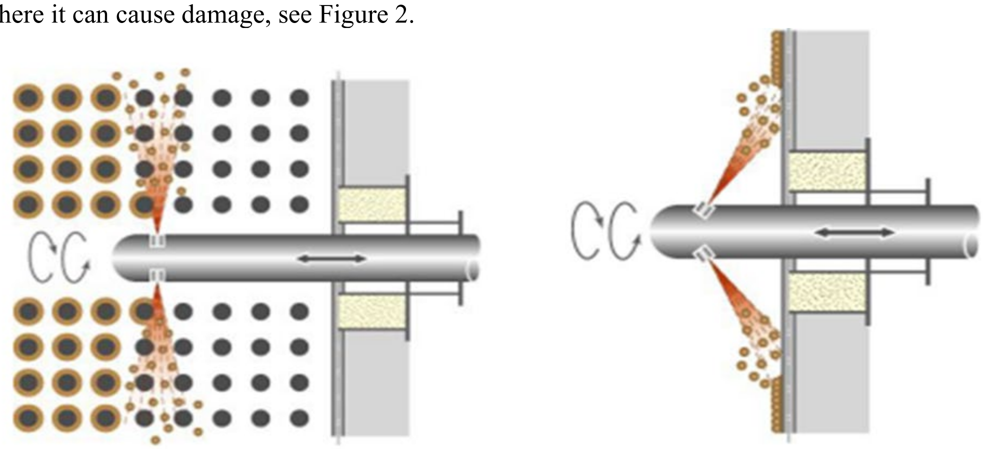

Figure 2: Soot blower system currently used at Sasol.

6. Numerical Results

6.1 Simulations on parts of the design (Acoustic horn and beam) vs Calculations

Critical components of the acoustic horn are identified and simulated against the working stresses and pressures that apply to them. An acoustic device was design as shown in Figures 3 and 4.

6.1.1 Simulation of Model on components

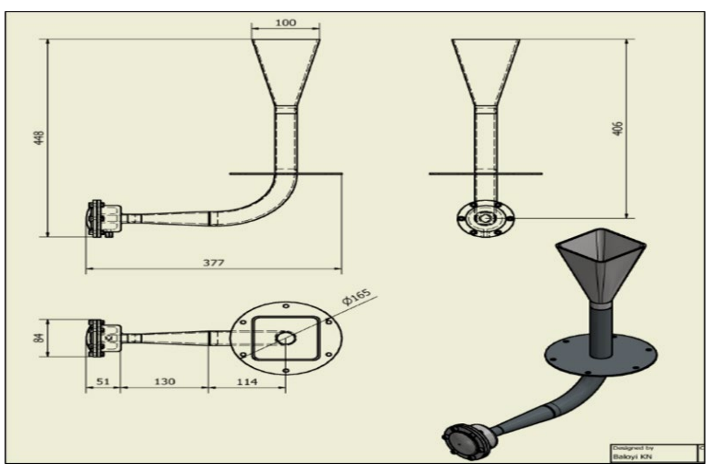

Figure 3: Design of an acoustic device.

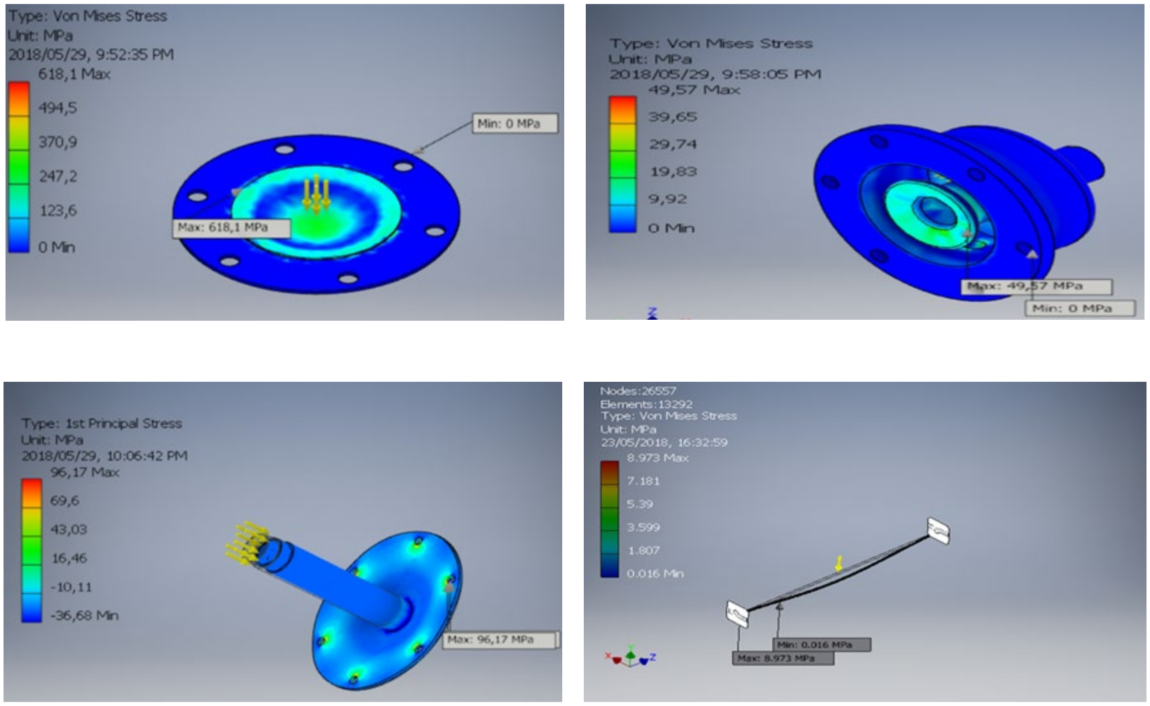

Figure 4: Design of an acoustic device.

6.1.2 Calculations

The following tests and calculations were performed to determine the critical points, stresses, and physical restraints such as size, diameters, and length. The calculations restraints are the frequency which resonates at 75 Hz, the operating pressure which is 5,52 bar and the Output power level which is 147 dbs. From these restraints the necessary diameter and thickness of the diaphragm and other components are determined. The simulations were carried out at the critical points which were assumed as the points of failure and designed to be the easiest to maintain and replace. The stress analysis was conducted on each component of the acoustic air horn, with its preferred material. The operating pressure is used as the force acting on each component. The component that was mostly likely to fail from the results obtained was then analysed and discussed.

Table 3: Critical Stress Results for the components form Calculations.

Components	σ_Θ (MPa)	σ_r (MPa)	σ_z (MPa)
Front Flange	0.787	0.279	0
Pipe on front Flange	0.184 & 0.2734	0.279 & 0.279	0
Pipe curve	0.2734	0.279	0
Mounting bracket	1.6404	0.279	0
Cone	0.301	0.279	0
Most critical value	1.6404	0.279	0

The results obtained from the calculations on Table 3 as a guideline on what the minimum and maximum requirements are for each component of the specified material. Analysing the results of the titanium diaphragm it is observed that for a frequency of 75Hz a certain diameter for the 1mm thick disk is required. An exact diameter of 367 mm is required to resonate the specified frequency throughout the acoustic device. The diameter can be reduced by reducing the thickness of the disk, but due to the difficulty of manufacturing such a thin disk a thickness of 1mm is to be considered the minimum as per calculations. With the analysis of the other components minimum lengths are required to resonate the specified frequency. The minimum length of the cone is of concern as it is directly proportional to the increase in diameter, which aids in amplifying the sound coming out of the acoustic air horn. Analysing the results obtained from the critical stress calculations, it is seen that the two most critical regions are the front flange, connected to the vibrating diaphragm and the mounting plate-pipe intersection. These two circumferential stresses are the critical stresses that need to be taken into consideration when designing the respective components, this will therefore affect the factor of safety for each component. From the critical stress calculations, the mounting plate-pipe intersection, has the highest stress concentration, this being 1.6404 MPa. This is the most critical component because it is the most likely to fail.

5.2 Graphical Results

The graph in Figure 5 shows direct proportionality of the calculated values and simulated values, they are both linear positively. Graph in Figures 5 to 7 show that the stress and deflection calculated showed a maximum deflection of 26.2866mm for the simulated and 43.088mm for calculated values at the force of 820 applied. The simulations represented by the deflection and the stress show how if a vibrational force is applied to the beam the waveform generated will also affect a beam and remove slag. Figures 5, 6 and 7 show that when the beam is vibrating it may reach the same deflection in the upward direction. In the stress v force graph figure, there is a clear statistical agreement in the trends between 220 N and 440 N where the two graphs show the same trend.

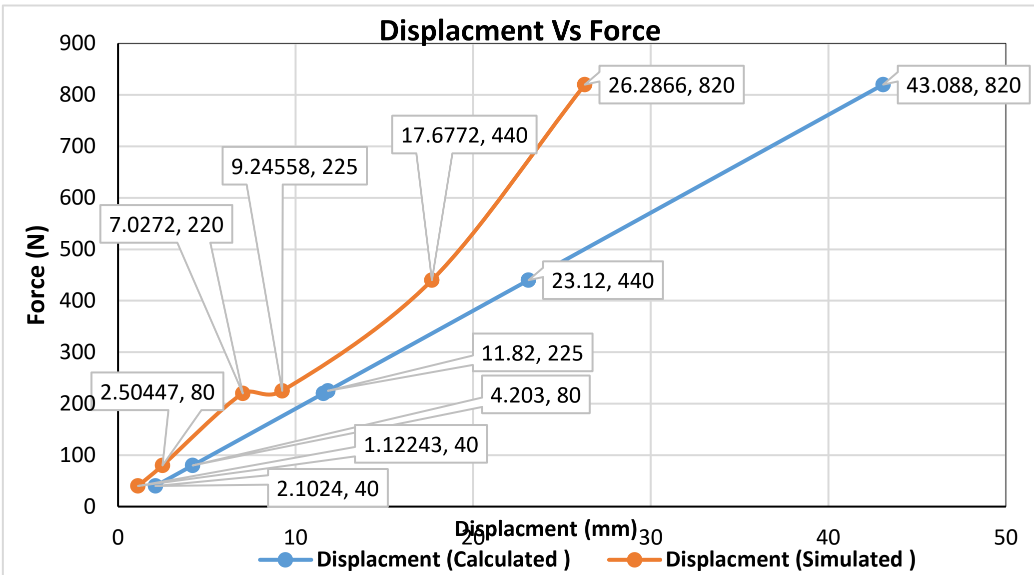

Figure 5: Displacement vs force graph.

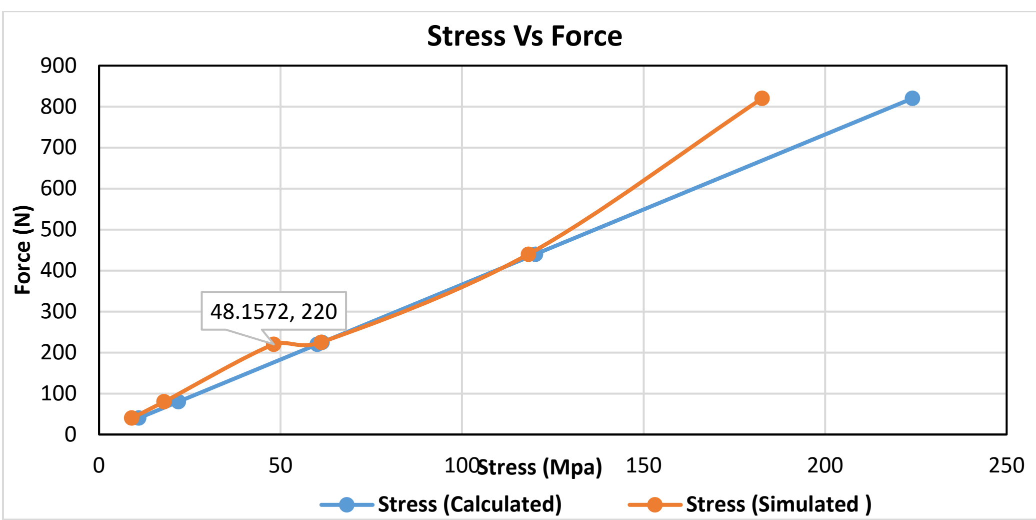

Figure 6: Stress vs force.

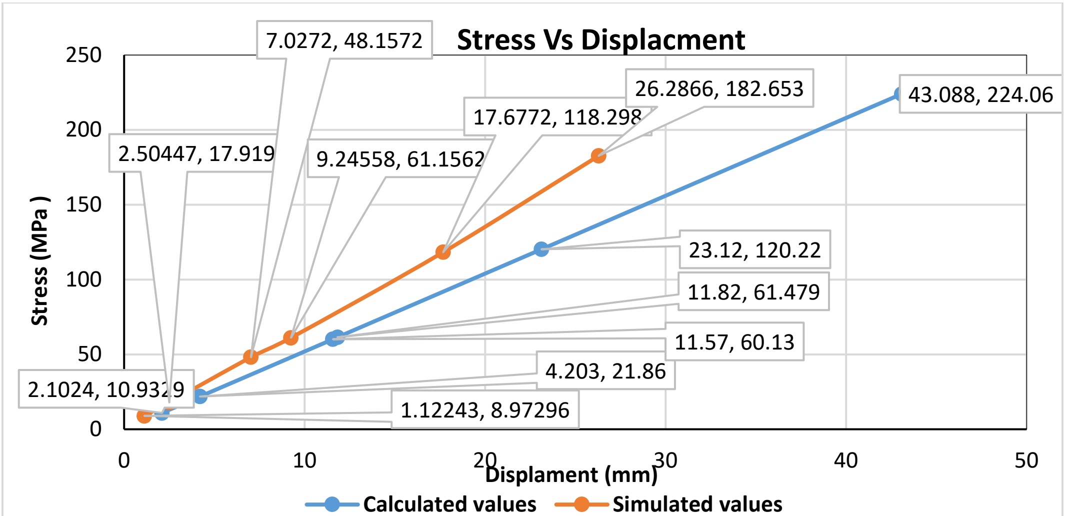

Figure 7: Stress vs displacement.

5.3 Proposed Improvements

- It is recommended that optimizations be performed on the acoustic horn to reduce material wastage and hence not over design the horn.
- It is recommended that the maximum force and stress is will not be used as this can affect longevity of the beam as to strong stress and force, therefore, to much vibration will Couse the beam to fracture quicker and easier.
- If the beam does not remove the any slag and soot because vibrations are to low the multistage horn device can be used as well as to increase the frequency delivered form the horn.
- It is recommended to place the horn such that the vibration get distributed evenly throughout the beam.
- Instead of brittle material such as cast iron any ductile material can be used as it can also be cost saving and due to its ductility and malleability as well it can be very effective.

5.4 Validation

It is recommended to construct this design and a field test to be done to see if it works. Although this is a conceptual design, it would be helpful to do a model of the acoustic horn.

6. Conclusion

Using good practice of engineering regulations and national standards, a design of an acoustic device can be used a solution/alternative to minimize breakdown costs for coal fired power plant.

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Dr Daramy Vandi Von Kallon is a Sierra Leonean holder of a PhD degree obtained from the University of Cape Town (UCT) in 2013. He holds a year-long experience as a Postdoctoral researcher at UCT. At the start of 2014 Dr Kallon was formally employed by the Centre for Minerals Research (CMR) at UCT as a Scientific Officer. In May 2014 Dr Kallon transferred to the University of Johannesburg as a full-time Lecturer and later a Senior Lecturer in the Department of Mechanical and Industrial Engineering Technology (DMIET). Dr Kallon has more than twelve (12) years of experience in research and six (6) years of teaching at University level, with industry-based collaborations. He is widely published, has supervised from master's to Postdoctoral and has graduated seven (7) Masters Candidates. Dr. Kallon's primary research areas are Acoustics Technologies, Mathematical Analysis and Optimization, Vibration Analysis, Water Research and Engineering Education.