REVIEW CHEMICAL ONLINE CLEANING CENTRIFUGAL COMPRESSOR OF GAS TURBINE IN ONE OF CENTRAL PROCESSING PLATFORM (CPP)

Meninjau Pembersihan dengan Kimia Dalam Kondisi Beroperasi Pada Kompressor Centrifugal dengan Penggerak Turbin Gas disalah Satu Platform Pengolahan Pusat (CPP)

PAUL DAVID REY
Departement Mechanical Engineering Islamic University of As-syafi'iyah
Email: pauldavidrey@uia.ac.id

ABSTRAK

Makalah ini menyajikan beberapa hasil penelitian yang dilakukan untuk meninjau pembersihan kimia dalam kondisi beroperasi/online yang dilakukan dengan sukses pada Kompressor Sentrifugal dengan penggerak Turbin Gas dan memberikan saran atau rekomendasi sesuai dengan literatur teknis. Berdasarkan penyelidikan, kinerja Kompresor Sentrifugal menurun dari 65% menjadi 58% dan karenanya pembersihan Kompresor Sentrifugal dalam kondisi beroperasi/online dengan menggunakan zat kimia telah dilakukan dengan menggunakan bahan kimia (Roachem Fyrewash-1) yang diinjeksikan melalui nosel jet ke dalam pipa hisap Kompresor yang terletak di dekat nosel isap Kompresor Sentrifugal dengan volume injeksi adalah 25 ~ 30 liter / hari dan waktu injeksi adalah 12 jam hingga 1 (satu) minggu untuk mencapai kembali normal kinerja kompresor 65%. Untuk mengurangi konsumsi bahan kimia ke pembersihan Kompresor Sentrifugal secara online menggunakan bahan kimia tersebut, beberapa item dapat dilakukan seperti Pindahkan titik injeksi jarak sejauh mungkin dari nosel masuk Kompresor, konfigurasi Injeksi adalah contraflow agar tetap seragam, memasang mixer statis pada pipa saluran masuk kompressor, Mencoba dengan meningkatkan volume injeksi kimia (maks. 3%) dan mengevaluasi dengan mengurangi waktu injeksi.

Kata kunci: Kompresor Sentrifugal, Pembersihan Kimia, Performa Kompresor dan Volume Injeksi Kimia.

ABSTRACT

This paper presents some of the results of a study conducted to review the chemical online cleaning was done successfully and give suggestion on Centrifugal Compressor or recommendation in accordance to technical literature. Based on investigation, the Compressor performance degrades from 65% to 58% and hence the compressor chemical online cleaning has been conducted using the Chemical (Roachem Fyrewash-1) injected through the jet nozzle into the suction pipe of compressor which located near the suction nozzle of compressor with the volume injection is 25~30liter/day and the time injection is 12hours up to 1 (one) week in order to achieve back the normal of compressor performance 65%. In order to reduce the chemical consumption to the Centrifugal Compressor online chemical cleaning, some items may do such as Relocate the distance injection point as far as possible from inlet nozzle of Compressor, Injection configuration is contraflow to keep uniformly, Install the static mixer on the line pipe of suction Compressor, Trial with increase the volume chemical injection (max. 3%) and evaluate with reduce time injection.

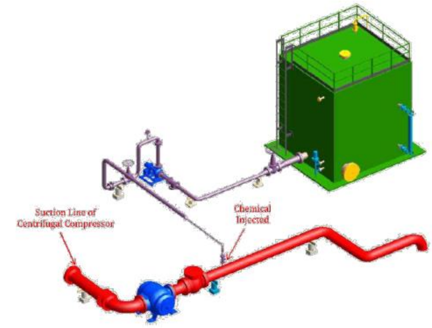
***Keywords**: Centrifugal Compressor, Chemical cleaning, Compressor Performance and Volume of Chemical injection.*

1. INTRODUCTION

Online chemical cleaning was done for Centrifugal Compressor of Gas Turbine Set type Solar Taurus-60 with detail below:

- Compressor type Solar C33 with flow rate 65MMSCFD.
- Temperature in 85°F and out 275°F,
- Pressure in 160psig and out 550psig.
- Compressor sends the production Gasfrom one of central processing platform (CPP) to another CPP.

Based investigation on one of CPP at Java Sea of Indonesia, the Compressor performance was degraded from 65% to 58%. Accordingly the compressor chemical online cleaning had been conducted with using the Chemical (Roachem Fyrewash-1 MSDS) and to be injected through the jet nozzle into the suction pipe of compressor which located near the suction nozzle of compressor as shown on the Picture-1 below with the volume injection is 25~30liter/day and the time injection is 12hours up to 1 (one) week in order to achieve back the normal of compressor performance 65%.



Picture-1: Compressor Chemical Cleaning

The compressor chemical online cleaning had successfully done remove the fouling which occurred inside of Compressor as shown on the picture-2 below.

Before Chemical Injection **After Chemical Injection**

Picture-2: Before and After Chemical Cleaning injection.

2. LITERATURE REVIEW

2.1 Compressor Washing

Sometimes dirt, polymer build up, or other substances can clog the compressor internally and seriously degrade performance. Very small amounts of dirt on axial blades alter the blade profile and degrade performance. Washing a compressor may be all that is required to regain ‘‘like new’’ performance.

A centrifugal compressor can be easily cleaned during normal operation (design speed) by using mild abrasives such as cooked rice or
walnut shells. More common is the use of liquid cleaning agents sprayedinto the process and into the return channel areas of the compressor [22].

2.2 Classification Compressor Washing

There are four typical techniques of compressor washing. The basic technique involves a manual cleaning using brushes and washing detergents. This method is very effective to recover the losses due to fouling. However, this technique requires shutting down the engine, time and human work. The second is by the ingestion of solid particles such as nutshells, rice, or synthetic particles. This is a fast way for washing but also requires shutting down the engine and unfortunately produces erosion in the blades[4]. The compressor washing off line (crank washing) is another possibility. This technique is very effective to wash the compressor and can recover almost 100% of the losses produced by fouling [14]. The off line operates in a low speed shaft and the injection includes high quantities of water with a low risk of erosion [21].The typical procedure for this method is to use the starter motor of the engine and to inject the cleaning detergent into the inlet. In this process the cleaning fluid passes through all the compressor stages and the wash is drained away[23].The disadvantage of washing off line is that only it is possible to operate when the engine is shutting down[14]. In addition, running the shaft at a low speed reduces the starter motor life of the engine and then increases the washing costs. This last problem is important in places where the space is limited or where it is necessary to produce the water as such as ships and offshore rigs[23].

The new technique is compressor washing on line (fired washing) that operates at full load of engine operation. This maintenance extends the intervals between compressor washings off-line and corrects automatically the fouling losses produced in the compressor. The system of compressor washing on line is based on the state of the art and involves the following characteristics: droplet size, speed and angles of injection (nozzle location)[24].

Compressor washing off line and online are different in three principal characteristics: number and location of nozzles (more nozzles are required in on line), quantity of fluid (more liquid is required in off line) and washing effectiveness (better results in off line)[25] However there is a comment that compressor washing on line cleans partial the fouled deposits on the compressor blade[26]. This last result was recognized in previous studies, but it gives a good alternative to abate the compressor fouling[4,25].

2.3 Cleaning Fluid For Compressor Washing

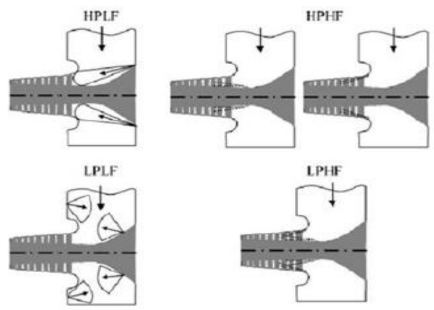
During the eighties the use of demineralised water, water-detergent mixtures and water-petroleum solvent were used as cleaning fluid[15]. The chemical formula for the cleaning fluid patented by Woodson, Cooper, White, and Fischer (1989) [27] increased the boiling point of the water. Later on, the use of anti-freezer as additive in the cleaning fluid allowed the compressor washing under low temperatures. In the nineties, the improvements of the cleaning fluid resulted to be fully combustible and biodegradable[28]. The use of corrosion inhibitors mixed with the cleaning fluid increased the effectiveness of compressor washing[26]. For example, a marine engine study resulted that the use of antifouling inhibitors gave a smooth finished protection on the surface and un-reactive dirt or salt deposition[29]. The environmental law have limited the use of some chemical products and regulated the disposition of the cleaning fluid. For example, soil pollution that contains mineral oils adhered to the airfoils cannot be thrown into the drainage. The same case applies to aromatic-hydrocarbons mixed with the compressor washing cleaner that are considered harmful to people′s health by skin contact or inhalation[26]. However, the improvements on the solvent cleaners have been developed for the use against the organic pollution (hydrocarbon particles)[21]. Today three types of fluids are commercially available: demineralised water, solvents-based and aqueous-based cleaning fluids, but in some places due to environment regulations the use of solvents is limited[23]. Information about the chemical formula of the cleaning fluid is not available due to the policy of the companies[2].

However, the supplier guarantee that the cleaning fluid is a water-based formulation, non-toxic, nonflammable, non-corrosive, readily biodegradable, no harmful effects for the engine and broad spectrum cleaning of fouled compressor blades[5]. The detergent concentration plays an important part in cleaning the compressor[30]. This because the wet time that the fluid is on the blades depends on the surface tension and viscosity of the cleaning fluid[10]. It is important that the cleaning fluid properties remain liquid (no steam) in the early stages of the compressor. Because, the fouling deposition is highly dominant in the first four stages and it is almost zero in the rear stages[23]. However, the gas turbine operators and cleaning fluid suppliers have reported that a hard layer was adhered to the airfoils from the rear stages due to high temperatures that bake′s the deposits[15]. For that reason, it is important that the cleaning fluid remain in a liquid state until the last stages. The chemical composition for the cleaning fluid has resulted to have solid states of the droplets until 400ºC (sixth stage for typical industrial axial compressors) [5]. The chemical treatment to improve the evaporation point. The conventional washing fluid can operate in temperatures around of - 10ºC but with the use of anti-cooling mixed with the fluid the temperature could be lower than -15ºC[21].

2.4 Cleaning Fluid Injection

The cleaning fluid injection is an essential characteristic of compressor washing on line. The objective of compressor washing is to wet the more possible region from the blade surfaces [14]. Also, a wet region reduces the possibility of evaporation of the cleaning fluid and increase the effectiveness of the washing [18]. However, the water droplets tend to follow the air stream and not all the blade surface is wet [17]. For that reason, the number of nozzles and angles of injection are very important in the installation of compressor washing on line [14].

The speed and size of the droplet from the injection of compressor washing on line play an important role to clean the blades surfaces. The numerical study demonstrated that that the velocity between the washing liquid and the air is the parameter that regulates the droplets impact on the blade surface. In this study was demonstrated that the air stream velocity has a low impact in changing the droplet size[4]. The selection of the injection angle is a difficult task and involves the centrifugal and coriolisis effects in the droplet trajectories (see picture 3 below) and demonstrated that the angle of injection between 0 to 90 degrees relative to the air stream direction can reduce the size of the droplet[4, 15].



Picture-3: Typical nozzle locations and for online washing systems [15].

2.5 Cleaning Fluid Droplets

The effectiveness of washing as was mentioned before depends from the droplet size, velocity and temperature on the air stream [20]. These characteristics modify the momentum (mass and velocity) resulting in some droplet trajectory [17]. Hence, the droplet is produced by the nozzle and can follow the trajectory of the flow stream, rebound on the blade surface or stay on the surface and build a wet film. The size of the droplet depends on the pressure injection of the nozzle and it is Divided into three categories:

i. Low pressure systems: 1Mpa (10 bar) and droplet size of 100 to 150 µm [19].
ii. High pressure systems: 5MPa (50bar) and droplet size of 150 µm [17].
iii. Nozzle assisted by air: It produces small droplets size at high pressure systems [15] .

The problem of erosion on the airfoils surfaces by water injection has been linked to impacts from big droplets [4]. The different sized droplets produced from the compressor washing system have been studied to avoid erosion problems. The results have demonstrated that droplets with a small size (less 80 µm) do not cause erosion [4]. It had demonstrated that droplets used for the fogging systems with size between 30 to 40 µm produced no erosion in the blades [14]. However, the small droplet size follows the air stream and they do not touch the blade surface [4]. Large droplet sizes are more suitable to be in contact with the blade surfaces and in a short period they do not represent a problem of erosion [4,5]. The phenomenon of rebounding and nonrebounding from the droplet in the Compressor has been studied in different applications. For example, it had demonstrated that small droplets between 18 to 24 µm are non-rebounding in the inlet of helicopters. However, in the case of industrial application the small droplet size (less than of 40 µm) evaporates due to the ambient temperature [4]. It had suggested an optimal range of droplet size between 80 to 120 µm to clean the first stages and 130 to 170 µm to clean the rear stages [8].

The Axial Compressor Performance Deterioration and Recovery through Online Washing below table [3].

	Practical Limit	Range applied in this work
Water-to-air ration	3% by mass	0.4% to 3% by mass
Fluid temperature	Above freezing, fluid heating not required	15-20 °C
Droplet size	10 µm – 400 µm avoid erosion	25 µm – 400 µm (VMD)
Droplet velocity	Depends on nozzle design and position in air intake	-
Duration	Depends on deposit solubility 2-30 min. industry practice	Up to 10 minutes
Frequency	Depends on deterioration rate	Daily to every 3rd day
Spray pattern	As uniform as possible	Uniform

Table-1: Table limits for online washing parameters [3].

The numerical study suggested droplets from 50 to 300 µm in a multistage axial compressor (16 stages) [4]. The results could be summarized that only large size droplets arrived to the rear stages in the liquid stage For engine applications without the presence of salt formation the range of droplet size suggested is 80 to 160 µm (compressor washing on line).

2.6 Compressor Degradation

Fouling and erosion have been demonstrated to affect the thermal efficiency and output power of the engine [6]. The deposition of the particles in critical areas can change the geometry of the airfoils and then the flow condition is modified [14]. In addition, the accumulation of dust reduces the tip clearance and increases the roughness of the surface roughness [13]. These changes in the blades affect the compressor delivery pressure (CDP) and reduce the mass flow. There was calculated the impact of degradation mechanisms in the compressor performance based on the output power of the engine reported that fouling decreased by 5% the output power due to mass flow reduction as shown on Picture-4 below [9, 12].

Picture-4: Compressor performance based on output power of engine [12]

Typically, in power plants, online washes are performed everyday (on continuously running compressor). This involves utilizing a built-in set of spray nozzles that inject heated distilled water and/or detergent into the compressor while at about 80% load. The washing continues for about 10 to 15 minutes. This recovers much of the deterioration that has accumulated over the previous 24 hours. Online washes are usually supplemented by a periodic off-line was, the frequency of which varies from maintenance strategy employed, anywhere between 2 weeks and 6 months. This further permit recovery of compressor performance.

2.7 Centrifugal Compressor Online Washing

Centrifugal Compressor online wash has been applied for process compressor and effectiveness is evaluated. New concept of

Centrifugal Compressor online wash was developed with the following optimization:

- Injection location near impeller tip is most appropriate.
- Injection flow rate and injection hole is decided by momentum ratio.
- Injection droplet size, Injection angler

3. RESULT AND DISCUSSION

- Based on above literatures that the Axial Compressor online washing used to recover the loss performance due to fouling.
- Centrifugal Compressor online washing has been applied for process Compressor and effectiveness was evaluated with new improved method.
- One of CPP at Java Sea of Indonesia has successfully done the Centrifugal Compressor online chemical cleaning with the following data:

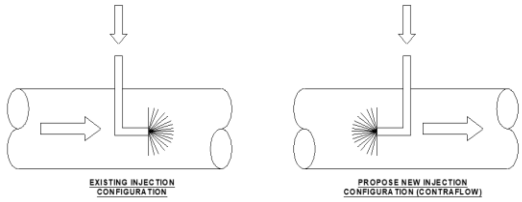
  Compressor Gas Flow Rate = 65 MMSCFD = 1840605 S.m3/day. 82170 kmol/day
  Molecular Weight = 18.9
  Compressor mass flowrate=1553010 kg/day = 64709 kg/h.
  Hence:
  The Volume chemical injection is 30 liters/day = 0.03 S.m3/day.
  Chemical Roachem Fyrewash-1 Density at 20°C: 0.915 gr./S.cm3 = 915000 kg/S.m3
  Chemical Mass Flow Rate = 27450 kg/day = 1144 kg/h
  As on above the washing ratio is 1144 / 64709 = 1.77% → OK due to less than 3% (Refer to section 2.5 says that the practical limit online washing for water to air ratio is 3% by mass)

4. CONCLUSION

The Centrifugal Compressor online chemical cleaning was done NOT the Centrifugal Compressor online washing and after the Centrifugal Compressor online chemical cleaning applied, there is no material damage on static part of Centrifugal Compressor (i.e. impeller) and inside section was clean as shown on picture 2 of section 1 above due to the Injection droplet size maximum is 200 μm and ratio liquid agent (water) to air/gas maximum is 3%.

In order to reduce the chemical consumption to the Centrifugal Compressor online chemical cleaning, the following items may do as consideration on future research:

- Relocate the distance injection point as far as possible from inlet nozzle of Compressor OR
- Injection configuration is contra flow OR
- Install the static mixer on the line pipe of suction compressor OR
- Trial with increase the volume chemical injection (max. 3%) and evaluate with reduce time injection.
- Injection configuration is contra flow as shown on picture 5 below to keep uniformly OR



Picture-5: Injection Configuration

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