Scrap Metal Reduction as the Effect of Combustor Upgrade in GTG 1.3 PLTGU Muara Karang

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Abstract. Metal as one of the most common used materials in industry, needs a proper management for it will not contaminate the land. Metal waste, or also called scrap metals, is disposed in a scrap yard. To prevent the accumulation of scrap metals in the scrap yard area, reducing the generation of it is important. Especially when the auction procedure for scrap metals takes a long time. PLTGU Muara Karang had upgraded GTG 1.3 to Advanced Extendor Combustion System in October 2016 to improve its operational excellence. The impacts of upgrading gas turbine to Advanced Extendor Combustion System, are not only for better efficiency in performance, but also extending the maintenance interval up to 32000 hours. By extending the maintenance interval, combustion inspection, which is usually performed every 8000 hours, can be dismissed. The total maintenance duration needed also reduced from 120 days to 66 days on 8 years period. This leads to reducing metal waste generated during maintenance. By calculating the spare parts that required to be replaced in one combustion inspection, the metal waste reduction potential is 2.26 ton. For 8 years period, the combustor upgrade help to reduce metal waste generation about 75.02%.

1. Introduction

Waste is a problem that follows upon the rise of industry. Therefore, an environment friendly process is needed. Metal is one of the most common used materials in industries. Waste that comes from metals, usually called scrap metals, inevitably requires a proper management so that it will not contaminate the land. Scrap metals usually dispose in a special area called scrap metal yard or junk yard. The increase of an industry’s activity might lead to an accumulation of scrap metals.

Even though scrap metal is not determined as hazardous waste and is highly sought to recycling industry, reducing the generation of scrap metals is also important to avoid high accumulation in scrap metal yard. This condition can be seen in PLTGU Muara Karang, as the designated scrap yard is getting full. The company policy stipulates scrap metals to be auctioned since they are specified as fixed assets. The problem is the auction procedure takes a quite time to proceed. Thus, it is important to reduce the disposal to scrap yard while its management is being improved.

Other industries have done scrap reduction as well. By reducing its scrap generation, not only increase its productivity and efficiency, but also helped to reduce the pollutant that released to environment. In steel and aluminium production, the liquid steel and liquid aluminium that don’t make it to final products, is diverted as process scrap and recycled. This process could reduce total energy use by 17% and 6%, and total CO₂ emissions by 16% and 7% for the steel and aluminium industry respectively [1]. Increased process capability in pot production process of one of the aluminium
smelting furnace proved to decrease scrap about 6% while the material productivity increased to 0.05% [2]. In automotive industry, 15% reduction of scrap was achieved by identifying that machine is the main generator of scrap [3]. In the die casting process, it needs to improve the process optimization, so that it will reduce the defects that leads to scrap. By determining the filling time and total shrinkage porosity distribution in casting process, it enables to reduce the scrap percentage from 14% to 9% [4].

In October 2016, PLTGU Muara Karang, as a gas fuel power plant, upgraded one of its gas turbines. The combustor in GTG 1.3 was upgraded to advanced extender combustor system which claimed to be more efficient in performance and increase availability. This upgrade is needed due to the increase of electricity demand in Indonesia, therefore PLTGU Muara Karang must increase its operational excellence with long-term benefits in its development. The following impact of it is the extended maintenance interval required. Extending the maintenance interval makes less overhaul or inspection needed. This caused the waste produced of said activity reduced. The aim of this study is to identify the reduction on scrap metals following the combustor upgrade compared to its condition before the upgrade was done.

2. Method
This study will compare the metal waste before and after the extendor upgrade by calculating the total weight of spare parts need for one Combustion Inspection done. Figure 1 shows the workflow to collect the data. For a comprehensive study, we need to classify the data requirements into primary data and secondary data.

![Workflow to collect data](image)

**Figure 1.** Workflow to collect data

2.1 Primary Data
In this study, scrap data was obtained by identifying list of component when a combustor inspection performed through Outage Management Division. After the identification, stock code of each material was checked in system to help locate them in warehouse easier. Once the stock code obtained and the location was found, the materials were weighed using weight scales. List of each component will be inputted in data excel to become summary. Table 1 shows the total spare parts of each component.

| DESCRIPTION                                | QTY | UNIT |
|--------------------------------------------|-----|------|
| Fuel Nozzle Assy (Spesific)                | 85  | ea   |
| Fuel Nozzle Assy (Consumable)              | 84  | ea   |
| Transition Piece & Combustor Liner         | 126 | ea   |
| Combustion Chamber Arrangement (Spesific)  | 56  | ea   |
| Combustion Chamber Arrangement (Consumable)| 196 | ea   |
| Ultraviolet Flame Detector Assy            | 3   | ea   |
| Damper                                     | 44  | Ea   |
| DESCRIPTION       | QTY | UNIT |
|-------------------|-----|------|
| Radiator          | 12  | Ea   |
| Consumable Machine| 347 | Ea   |
| Bearing Motor     | 26  | Ea   |

![Figure 2. Weighing Process of Flow Sleeve Combustor](image)

![Figure 3. Combustor Liner and Transition Piece](image)

![Figure 4. Weighing Process Fuel Nozzle Assy](image)

### 2.2 Secondary Data

Secondary data in this study consist of overhaul type that is utilized in PLTGU Muara Karang, the cycle of inspection applied and the maintenance duration. In PLTGU Muara Karang, based on the manufacturer’s recommendation, there are 3 types of overhaul:

- **Combustion Inspection** which is performed every 8000 EOH. The combustion inspection is a relatively short disassembly, mainly concentrates on the combustion liners, transition pieces, fuel nozzles, and end caps, which are recognized as being the first to require replacement and repair in a good maintenance program. A proper inspection, maintenance, and repair may contribute to the longer life of the downstream parts [5].

- **Hot Gas Path Inspection** which is performed every 24000 EOH. The purpose of hot gas path inspection is to examine those parts exposed in high temperatures from the hot gasses discharged in combustion process. The key parts to check are nozzles, buckets, strator shrouds [5].

- **Major Inspection** which is performed every 48000 EOH. The purpose of major inspection is to examine all of the internal rotating and stationary components from inlet of the machine through the exhaust [5].

The cycle of inspection that is usually applied is MI – CI – CI – HGPI – CI – CI – MI.
Table 2. Duration of maintenance for each type of overhaul

| No | Scope of Maintenance                  | Duration (day) |
|----|---------------------------------------|----------------|
| 1  | Combustion Inspection (CI)            | 9              |
| 2  | Hot Gas Path Inspection (HGPI)        | 21             |
| 3  | Major Inspection                      | 45             |

3. Result and Discussion

3.1 Scrap Metal
Scrap metal originates from end-of-life products, structures, construction and demolition debris, or out-of-specification metal products. It can be generated from vehicles, machinery, discarded appliances, and other metal-contained waste [6]. In Indonesia, scrap is defined as a product that contain similar components, which its shape and its function is not the same as the original one [7]. By its definition, scrap metal is also not listed as hazardous waste as stated in Indonesian Government Regulation Number 101 Year 2014 about Hazardous Waste Management [8].

3.2 Maintenance Interval
The life of gas turbines is affected by starting up cycle, the power level, type of fuel, the amount of steam or water injected [9]. Maintenance interval function (MIF) is a commonly used methodology to determine the recommended maximum maintenance interval where it also defines maximum number of starts and firing hours. The maximum number of starts and firing hours defined in the baseline MIF depends on the type of turbine and manufacturer. Major overhaul inspections can be carried out within a range from 8000 to 24000 h and from 400 to 1200 starts [10]. Factors that can reduce maintenance intervals are fuel, load setting, steam/water injection, peak load firing operation, trips, start cycle, hardware design, and off-frequency operation.

3.3 Advanced Extendor Combustor System
Combustor components suffered severe damage after 8000 EOH. Gaps formed at the mating surface leads to wear, while the high temperature of combustor leads to creep that creates noise and vibration problem [11]. Wear damage is the life limiting factor that must be mitigated to extend maintenance interval. Modification of surface properties may improve its resistance to reduce wear [12]. The Extendor System is a combination of wear-resistant coatings, wear-resistant materials, enhanced clearances, and several mechanical design improvements that reduce combustion component wear [13]. Advanced Extendor Combustor System is claimed to be more efficient as it extends the maintenance interval, thus increasing the availability. The maintenance interval is extended up to 32000 EOH, which increasing the availability until 4 years. By less combustion maintenance interval, it also reduces the lower parts refurbishment. The parts that improved in this Advanced Extendor are enhanced thermal barrier coating, material changes, wear coating, hardening of surface in contact, clearance reduction.
Supporting features of advanced extendor combustor system:

a. Combustion system using canned arrangement

b. Standard combustor fuel nozzle
   - One piece machined tip to increase the life of wear rings
   - Bolted design to provide tighter fuel control

c. Standard combustor liner
   - Double leaf hula seal provides tighter air control and reduces seal temperatures
   - Spring loaded stops for uniform loading, reduced wear and wear variation, improved installation
   - Thicker liner body reduces risks of bulging and crack initiation

d. Standard combustor transition piece
   - Using Nimonic 263 for better creep and strength
   - Full length class-C thermal barrier coating (TBC) to reduce metal temperature
   - Integral mount reduces aft frame deformation and improves its durability
   - Cloth type side seals
   - New TP bullhorn design

e. Standard combustor cross fire tube
   - Using alloy material for inner male and female cross fire tube material to provide better heat resistance
   - Wear coating applied on collars

The benefits by upgrading the combustor to Advanced Extendor Combustion System are shown at table 3.

Table 3. The benefits post-upgrade extendor

| No | Parameter         | Benefit                                      |
|----|-------------------|----------------------------------------------|
| 1  | Availability      | Less inspection needed                       |
|    |                   | Increase availability                         |
| 2  | Repair cost saving| Reduced combustion maintenance cost          |
3 Reliability improvement

Increase durability

Less test (i.e. overspeed)

3.4 Advanced Extendor Combustor System Upgrade and Its Impact on Metal Waste

After the upgrade was done in 2016, the maintenance interval for GTG 1.3 increased. Below are shown the maintenance interval pre and post upgrade.

Table 4. Maintenance duration before-after combustor upgrade

| No | Operation Hour | Scope Pre-Upgrade | Overhaul Duration (days) | Scope Post-Upgrade | Overhaul Duration (days) |
|----|----------------|-------------------|--------------------------|--------------------|--------------------------|
| 1  | 8000           | CI                | 9                        | -                  | -                        |
| 2  | 16000          | CI                | 9                        | -                  | -                        |
| 3  | 24000          | HGPI              | 21                       | -                  | -                        |
| 4  | 32000          | CI                | 9                        | HGPI              | 21                       |
| 5  | 40000          | CI                | 9                        | -                  | -                        |
| 6  | 48000          | MI                | 45                       | -                  | -                        |
| 7  | 56000          | CI                | 9                        | -                  | -                        |
| 8  | 64000          | CI                | 9                        | MI                | 45                       |
|    | Total          |                   |                          |                    | Total                    |

As shown in Table 4, the condition of combustor post-upgrade increased the longer maintenance interval, from previously every 8000 hours to every 32000 hours. Combustion Inspection which is usually performed twice in 2 years respectively can be dismissed, and Hot Gas Path Inspection can be performed on 32000 hours interval instead, then Major Inspection to be performed on 64000 hours interval. This also caused the maintenance duration in 8 years period reduced, from 120 days to 66 days.

For one combustor inspection done, there is a potential reducing metal waste generation to a certain quantity. To calculate the reduction potential, we need to list down spare parts that will be changed and their weight to determine the total potential that can be reduced in a year.

Table 5. Metal waste generation for one combustor inspection

| DESC.                                      | QTY | UNIT | TOTAL WEIGHT (KG) |
|--------------------------------------------|-----|------|-------------------|
| Fuel Nozzle Assy (Spesific)                | 85  | ea   | 102.96            |
| Fuel Nozzle Assy (Consumable)              | 84  | ea   | 11.34             |
| Transition Piece & Combustor Liner         | 126 | ea   | 1918.7            |
| Combustion Chamber Arrangement (Spesific)   | 56  | ea   | 56.28             |
| Combustion Chamber Arrangement (Consumable) | 196 | ea   | 4.09              |
| Ultraviolet Flame Detector Assy            | 3   | ea   | 0.71              |
| Damper                                     | 44  | ea   | 35.55             |
| Radiator                                   | 12  | ea   | 42                |
| Consumable mesin                           | 347 | ea   | 44.73             |
| Bearing Motor                              | 26  | ea   | 40.779            |

**TOTAL METAL WASTE GENERATION** 2257.139
Table 5 shows the reduction potential for each component that required replacement for CI in 2017. Spare part that includes in this criteria are from replaceable spare parts, such as nozzle heat, outer tip, gaskets, bearing motor, etc. Based on the table above, by dismissing one CI, it can reduce 2.26 tons metals. In 8 years period before the upgrade, the metal waste generation from combustor is 18.06 ton. After the upgrade, the metal waste generation from combustor is 4.51 ton in 8 years period. This shows that the combustor upgrade help to reduce metal waste generation about 75.02%.

3.5 Scrap Metal Reduction and Its Impact on Environment
One of the problem faced by developed nations is land contamination and caused the shortage of ‘greenfield’ available for development. Scrap metal yards are identified as potential contributor to groundwater pollution [14]. Even though scrap metal is mostly valuable and will be auctioned, reducing its disposal to scrap yard is also important. The technology upgrade is not only benefitting the production efficiency, but also environmentally. Longer availability dan durability of technology will help reducing its maintenance interval. It will lead to less metal waste to dispose to scrap yard and reduce the potential to land contamination caused by metal contaminants that released to surrounding area.

4. Conclusion
The combustor upgrade to advanced extendor combustor system has several impacts, not only in its efficiency and availability, but also increased its maintenance interval. The increased maintenance interval resulted to dismiss the combustion inspection, which usually performed every 8000 EOH, to directly perform hot gas path inspection in 32000 EOH and major inspection on 64000 EOH. The total maintenance duration required during 8 years period reduced from 120 days to 66 days. The less maintenance required leads to less metal waste generated, which mostly consist of replaceable spare parts, up to 2.26 ton for a year. In 8 years period, the combustor upgrade help to reduce metal waste generation about 75.02%.

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