Analysis of the Causes of Exhaust Valve Guide Failure in the Doosan GV 180 TI Engine at PT Bima Golden Powerindo

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Abstract.
Damage to the exhaust valve guide in the Doosan GV180 TI gas engine can reduce engine performance and reliability, potentially disrupting the continuity of power generation at PT Bima Golden Powerindo, Melibur Site. This study aims to identify the types of exhaust valve guide failures, analyze their contributing factors, and determine corrective action priorities using the Failure Mode and Effects Analysis (FMEA) method and Pareto Diagram. The research employed a case study approach, with data collected through field observations, visual inspections, dimensional measurements of the valve guide, and preventive maintenance records at 750 running hours. The results indicate that the dominant failure modes include excessive wear, ovality, valve sticking, overheating, and lubrication failure. FMEA analysis revealed that excessive wear has the highest risk level, making it the primary priority for corrective action. The main factors contributing to the failures are high operating temperatures, inadequate lubrication, and prolonged engine operating hours. Therefore, periodic inspections, proper lubrication system control, and replacement of the valve guide according to the manufacturer's specifications are recommended to improve engine reliability and extend its service life.
Keywords: *Exhaust valve guide, Doosan GV180 TI, Failure Mode and Effects Analysis (FMEA), Pareto Diagram and wear.*

I. INTRODUCTION

Electrical energy is one of the fundamental necessities that plays a crucial role in supporting economic growth, industrial development, and improving the quality of life. The availability of a reliable, sustainable, and high-quality electricity supply is essential for supporting various social and economic activities. However, in Indonesia's archipelagic and remote regions, the provision of electrical energy continues to face numerous challenges, including limited infrastructure, geographical constraints, and the high operating costs of diesel-fueled power plants.

One of the regions experiencing these challenges is the Meranti Islands Regency, which consists of numerous small islands with limited access to the main electricity grid. Before the development of modern power generation facilities, the electricity system in this region relied primarily on small-capacity diesel power plants, resulting in an inadequate electricity supply that was not available continuously for 24 hours (Ministry of Energy and Mineral Resources of the Republic of Indonesia, 2020).

To address these issues, the Indonesian government, through PT PLN (Persero), has promoted the development of gas-fired power plants that offer higher efficiency and lower environmental impact, namely Gas Engine Power Plants (PLTMG). One such implementation is the PLTMG located at Melibur Site, which is operated by PT Bima Golden Powerindo as an independent power producer.

Compared with diesel-fueled power plants, gas engine power plants provide several advantages, including higher thermal efficiency, lower exhaust emissions, and more economical operating costs (Heywood, 2018). Furthermore, the utilization of natural gas as a fuel supports the national energy diversification policy and reduces dependence on petroleum-based fuels.

Technically, a PLTMG utilizes gas engines as the prime movers for electrical generators. One of the engines employed is the Doosan GV180TI gas engine, which operates based on the internal combustion engine principle using a spark-ignition system. This engine is designed to deliver high performance and is suitable for continuous operation in power generation applications (Doosan Engine Manual, 2019).

Despite its reliability, the gas engine is still susceptible to failures in several critical components, one of which is the exhaust valve guide. This component functions as a guide for the exhaust valve movement, ensuring proper alignment during the opening and closing processes. Wear of the valve guide may result in compression leakage, reduced engine efficiency, and increased fuel consumption (Stone, 2012).

One of the most critical components in the Doosan GV180TI gas engine is the valve mechanism system, particularly the exhaust valve guide. The exhaust valve guide serves to maintain the alignment of the exhaust valve with the valve seat during valve operation. In addition, it stabilizes the valve under high-temperature operating conditions and facilitates heat transfer from the valve stem to the cylinder head, thereby preventing excessive thermal stress (Pulkrabek, 2014).

To identify the causes of component failure and evaluate their impact on engine performance, a systematic analytical method is required. One widely recognized approach is Failure Mode and Effects Analysis (FMEA**)**. This method is employed to identify potential failure modes, evaluate their associated risks, and establish priorities for corrective and preventive actions (Stamatis, 2003).

Damage to the exhaust valve guide is commonly characterized by an increased clearance between the valve stem and the valve guide, uneven wear (ovality), and dimensional changes exceeding the manufacturer's specified tolerances. These conditions may lead to several serious operational problems, including exhaust gas leakage, reduced cylinder compression, increased fuel consumption, and an overall decrease in engine power output (Ganesan, 2015).

Based on the above discussion, research on the failure analysis of the exhaust valve guide in the Doosan GV180TI gas engine at the Melibur Site Gas Engine Power Plant (PLTMG) is essential to improve the reliability, operational efficiency, and long-term performance of the electrical power generation system.

II. METHODS

Failure Mode and Effects Analysis (FMEA**)** is defined as a systematic and structured methodological approach used by engineers to evaluate the reliability of a system. This method identifies potential failure modes, investigates their root causes, and analyzes their effects or consequences on the overall performance and functionality of the system.

This study employed an experimental research method, in which the researcher directly examined the exhaust valve guide of the Doosan GV180TI gas engine through field inspection, dimensional measurements, and failure analysis. Quantitative data obtained from observations, measurements, and maintenance records were analyzed using the FMEA method to determine the priority of corrective actions.

Research Variables

The variables used in this study are classified into two categories:

A. Independent Variables

The independent variables in this study are as follows:

1. Exhaust valve operating temperature, which affects the thermal expansion and mechanical strength of the valve guide material.
2. Engine operating hours, which influence the wear rate caused by continuous friction.
3. Lubrication condition, which affects the magnitude of friction between the valve stem and the valve guide.
4. Valve guide clearance, which determines the stability and alignment of the valve stem movement.

B. Dependent Variables

The dependent variables in this study include:

1. The wear level of the exhaust valve guide.
2. Changes in the internal diameter of the valve guide.
3. The clearance between the valve stem and the valve guide.

Data Collection Techniques

Data collection is the process of obtaining both primary and secondary data required for research. In general, data collection methods are divided into primary and secondary data collection as follows.

A. Primary Data

Primary data were obtained through field research, using the following techniques:

1. Direct Observation

Direct observations were conducted on the Doosan GV180TI gas engine at PT Bima Golden Powerindo (PLTMG) Melibur Site to identify the initial symptoms of exhaust valve guide failure and evaluate the operating condition of the engine.

2. Dimensional Measurement

Dimensional measurements were carried out after the cylinder head had been dismantled. The measurements included the valve stem diameter and the inner diameter of the exhaust valve guide to determine the wear level and the possibility of ovality.

3. Documentation

Documentation was conducted by photographing the condition of the exhaust valve guide, recording the measurement results, and collecting engine operating-hour data and maintenance history.

B. Secondary Data

Secondary data consist of information that was not directly observed by the researcher. These data include machine documentation, maintenance records, previous research, and technical references. The secondary data were obtained from the Doosan GV180TI Technical Manual and relevant literature (Doosan, 2017; Pulkrabek, 2017).

Research Procedure

The research was carried out systematically through the following stages:

1. Conducting a literature review related to gas engines and exhaust valve guides.
2. Collecting the technical specifications of the Doosan GV180TI gas engine from the manufacturer's manual.
3. Collecting maintenance records and engine operating-hour (running hours) data from the Doosan GV180TI gas engine at PT Bima Golden Powerindo (PLTMG) Melibur Site.
4. Performing an initial observation of the engine condition.
5. Dismantling the cylinder head.
6. Conducting a visual inspection of the exhaust valve guide.
7. Measuring the dimensions of the valve guide and valve stem.
8. Processing and analyzing the measurement data using the FMEA method.
9. Interpreting the results, preparing the discussion, and drawing the research conclusions.

III. RESULT AND DISCUSSION

This study was conducted on the Doosan GV180TI Gas Engine operating at PT Bima Golden Powerindo, Melibur Site. The engine serves as the prime mover of the generator in the Gas Engine Power Plant (PLTMG) and operates continuously for 24 hours a day to supply electricity to the Meranti Islands Regency.

The research focused on the exhaust valve guide because this component is exposed to the highest operating temperature among the valve train components, making it more susceptible to wear and premature failure.

The observation period was carried out by reviewing historical documentation from seven consecutive 750 Running Hours (RH) Preventive Maintenance (PM) cycles. The investigation primarily focused on recording the valve clearance values and evaluating their changes over time. All field inspection data are presented chronologically in the following sections.

Results of PM 750 RH Inspections

The preventive maintenance inspections were conducted during seven consecutive maintenance cycles. The inspection data include intake valve clearance, exhaust valve clearance, and exhaust valve clearance measurements for each cylinder head.

Results of PM 750 RH Inspections(siklus 02-7-2025)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex 31.5
1	0.50	0.50		28.9
2	0.50	0.05		30.6
3	0.50	0.50		30.9

4	0.50	0.30		29.6
5	0.55	0.50		30.4
6	0.50	0.50		31.3
7	0.50	0.30		30.8
8	0.50	0.40		29.7
9	0.50	0.50		31.2
10	0.40	0.30		30.2

Results of PM 750 RH Inspections((siklus 05-08-2025)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex 31.5
1	0.50	0.55		29.9
2	0.50	0.05		31.7
3	0.50	0.30		31.4
4	0.50	0.05		30.7
5	0.55	0.50		30.8
6	0.50	0.50		31.6
7	0.50	0.30		31.2
8	0.50	0.50		30.1
9	0.50	0.50		31.5
10	0.40	0.30		30.5

Results of PM 750 RH Inspections((siklus 06-09-2025)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex 31.5
1	0.50	0.45		28.9
2	0.50	0.20		31.9
3	0.50	0.50		31.7
4	0.50	0.50		31.0
5	0.55	0.50		30.6
6	0.50	0.50		31.8
7	0.50	0.30		31.4
8	0.50	0.15		30.7
9	0.50	0.50		31.5
10	0.40	0.20		31.2

Results of PM 750 RH Inspections((siklus 20-10-2025)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex 31.5
1	0.50	0.45		29.0
2	0.50	0.20		32.5
3	0.50	0.50		32.2
4	0.50	0.50		31.2
5	0.55	0.50		30.9
6	0.50	0.50		31.9
7	0.50	0.50		32.0
8	0.50	0.30		31.1
9	0.50	0.50		31.6
10	0.40	0.50		31.6

Results of PM 750 RH Inspections(RH (siklus 18-11-2025)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex 31.5
1	0.50	0.50		29.0
2	0.50	0.05		30.4
3	0.50	0.30		29.6
4	0.50	0.50		31.6
5	0.55	0.50		30.1
6	0.50	0.50		31.9
7	0.50	0.40		31.8
8	0.50	0.30		31.3
9	0.50	0.50		31.8
10	0.40	0.10		28.4

Results of PM 750 RH Inspections (siklus 23-12-2025)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex 31.5
1	0.50	0.80		29.1
2	0.50	0.05		30.5
3	0.50	0.15		30.0
4	0.50	0.40		31.6
5	0.55	0.40		30.9
6	0.50	0.10		29.4
7	0.50	0.15		29.4
8	0.50	0.20		31.9
9	0.50	0.05		30.0
10	0.40	0.15		29.6

Results of PM 750 RH Inspections (siklus 20-01-2026)

Cylinder Head	Standart In 0.50	Standart Ex 0.60	RH 750	Standart Clearance Ex31.5
1	0.50	0.50		29.1
2	0.50	0.05		31.4
3	0.50	0.05		30.6
4	0.50	0.30		29.6
5	0.55	0.50		31.0
6	0.50	0.05		30.0
7	0.50	0.40		29.9
8	0.50	0.30		29.3
9	0.50	0.30		30.5
10	0.40	0.10		30.1

Visual Inspection Results

The cylinder head disassembly revealed that several exhaust valve guides exhibited the following failure characteristics:

1. Surface wear.
2. Diameter enlargement.
3. Ovality.
4. Carbon deposits.
5. Surface discoloration caused by prolonged exposure to high temperatures.

Furthermore, scratches were observed on the valve stem surface, indicating excessive friction between the valve stem and the valve guide during engine operation.

Valve Guide Measurement Results

No.	Cylinder	Standard (mm)	Measured (mm)	Condition
1	3	12.00	14.01	Worn
2	5	12.00	14.50	Worn
3	10	12.00	15.20	Worn
4	9	12.00	14.01	Worn
5	8	12.00	14.00	Worn

The measurement results indicate that several exhaust valve guides exceeded the manufacturer's allowable tolerance and therefore required replacement. Five out of the ten cylinders experienced exhaust valve guide failure, with valve guide ovality identified as the dominant failure mode.

Risk Priority Number (RPN) Analysis

No.	Failure Mode	S	O	D	RPN
1	Excessive Wear	8	8	6	384
2	Valve Guide Ovality	9	7	5	315
3	Valve Sticking	8	6	5	240
4	Overheating	7	5	4	140
5	Lubrication Failure	7	5	3	105

Discussion

Based on the visual inspection and dimensional measurements of the exhaust valve guides in the Doosan GV180TI gas engine, it was found that five out of ten cylinders experienced wear beyond the manufacturer's allowable tolerance, making component replacement necessary. The observed damage included surface wear, increased diameter, ovality, carbon deposits, and discoloration caused by prolonged exposure to high operating temperatures. These findings indicate that the exhaust valve guides experienced progressive deterioration resulting from the combined effects of mechanical loading and thermal stress during continuous engine operation.

The failure mode identification revealed five dominant failure modes affecting the performance of the exhaust valve guide: Excessive Wear, Valve Guide Ovality, Valve Sticking, Overheating, and Lubrication Failure. These failure modes were further analyzed using the Failure Mode and Effects Analysis (FMEA) method by evaluating the Severity (S), Occurrence (O), and Detection (D) ratings. The calculated Risk Priority Number (RPN) values differed among the identified failure modes, allowing maintenance priorities to be established based on their associated risks.

The RPN analysis showed that Excessive Wear contributed the highest percentage of the total failure risk **(**32.41%**),** followed by Valve Guide Ovality **(**26.58%) and Valve Sticking (20.27%)**.** Collectively, these three failure modes accounted for 79.26% of the total RPN, indicating that they should become the primary focus of the preventive maintenance program. In contrast, Overheating and Lubrication Failure contributed only 20.74% of the total RPN and may therefore be considered secondary maintenance priorities after the dominant failure modes have been effectively controlled.

IV. CONCLUSION

Based on the results of the visual inspection and dimensional measurements of the exhaust valve guides in the ten-cylinder Doosan GV180TI gas engine, several failure modes were identified, namely excessive wear, valve guide ovality, valve sticking, overheating, and lubrication failure. These failures were caused by a combination of mechanical loading due to continuous friction, high combustion temperatures, inadequate lubrication conditions, and prolonged engine operating hours. These conditions resulted in an increase in the clearance between the valve stem and the valve guide, reducing valve movement stability and negatively affecting overall engine performance.

The results of the Failure Mode and Effects Analysis (FMEA) indicated that Excessive Wear was the failure mode with the highest risk level, with a Risk Priority Number (RPN) of 384, making it the highest priority for corrective action. This was followed by Valve Guide Ovality with an RPN of 315, Valve Sticking with an RPN of 240, Overheating with an RPN of 140, and Lubrication Failure with an RPN of 105. These findings indicate that mechanical wear is the dominant factor contributing to exhaust valve guide failure.

The reliability of the Doosan GV180TI gas engine can be improved through a well-planned preventive maintenance program. Recommended maintenance activities include periodic inspection of valve guide clearance, dimensional measurement of the valve guide using a bore gauge, continuous monitoring of exhaust gas temperature, regular monitoring of lubricating oil pressure, and replacement of the valve guide when wear exceeds the manufacturer's specified limits. The implementation of these maintenance practices is expected to extend the service life of the exhaust valve guide, reduce the risk of unplanned shutdowns, and maintain the overall reliability of the power generation system.

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