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New Alignment Method Using Hydraulic Jack for Accelerating SWD 16 TM 410 R Engine and Generator Coupling[1]

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Abstract
In 2019, the #6 PLTD Trisakti SWD (Stork Werkspoor Diesel) 16 TM 410 R underwent critical engine rehabilitation due to severe issues that had persisted since 2018. The rehabilitation necessitated the replacement of the crankshaft and bedplate. Given the engine and generator positioning adjustments, an alignment process was crucial to ensure correct realignment. Subsequently, the comprehensive rehabilitation efforts, containing alignment and engine-generator coupling, were concluded in March 2021. A misalignment issue was identified during the running test program as the generator shaft exhibited an imbalance. A realignment process and reattachment of fitted bolts were considered necessary to rectify this imbalance. The previous approach for this task demanded an extensive 54-day timeframe without a guaranteed resolution. This paper will discuss a breakthrough method for shaft alignment. By applying this new method, the alignment focus is directly at the point of the farthest deviation, compared to the previous method, which had to look for the midpoint of the x and y arcs. So that the alignment process can be carried out quickly and precisely. Apart from that, this innovation also proposes a new reaming method using line boring. This tool works more effectively than hand reaming, which requires more time and manpower. This innovation achieved an exceptional 81% reduction in processing time, concurrently leading to a significant decrease in the requisite workforce.

Keywords: rehabilitation, alignment, reaming, fitted bolt, coupling

Abstrak
Pada tahun 2019, PLTD Trisakti SWD (Stork Werkspoor Diesel) 16 TM 410 R #6 menjalani rehabilitasi mesin yang kritis karena masalah serius yang telah berlangsung sejak tahun 2018. Rehabilitasi ini membutuhkan penggantian *crankshaft* dan *bedplate*. Mengingat penyesuaian posisi mesin dan generator, proses penjajaran menjadi krusial untuk memastikan penyesuaian yang tepat. Selanjutnya, upaya rehabilitasi menyeluruh, termasuk penjajaran dan kopling mesin-generator, selesai pada Maret 2021. Masalah ketidaksempurnaan penyesuaian teridentifikasi selama program uji coba berjalan karena poros generator menunjukkan ketidakseimbangan. Proses penyesuaian ulang dan pemasangan ulang baut yang pas dianggap perlu untuk memperbaiki ketidakseimbangan ini. Pendekatan sebelumnya untuk tugas ini membutuhkan waktu yang lama, yaitu 54 hari, tanpa jaminan penyelesaian. Makalah ini akan membahas metode terobosan untuk penyesuaian poros. Dengan menerapkan metode baru ini, fokus penyesuaian langsung pada titik deviasi terjauh, dibandingkan dengan metode sebelumnya yang harus mencari titik tengah dari lengkungan x dan y. Sehingga proses penyesuaian dapat dilakukan dengan cepat dan akurat. Selain itu, inovasi ini juga mengusulkan metode baru penggunaan line boring untuk pekerjaan merata. Alat ini lebih efektif daripada pekerjaan merata manual yang memerlukan waktu dan tenaga kerja lebih banyak. Inovasi ini berhasil mencapai penurunan waktu proses sebesar 81%, yang pada saat yang sama mengurangi signifikan kebutuhan akan tenaga kerja.

Kata kunci: rehabilitasi, penyesuaian, merata, baut pas, kopling

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1. INTRODUCTION

ULPLTD/G Trisakti operates as a power plant unit under UPDK Barito, a division of PLN Indonesia Power. The unit comprises PLTD Trisakti, PLTG Trisakti, and PLTD Kapuas. Six of the engines at PLTD Trisakti are in place, but only five are in operational condition. Engine number 6, manufactured by SWD (Stork Werkspoor Diesel), was undergoing rehabilitation due to severe issues. This particular engine is known as SWD 16 TM 410 R, named after its cylinder count and piston diameter of 410 mm ((Diesel, 1987).

In 2019, the #6 PLTD Trisakti SWD 16 TM 410 R underwent significant engine rehabilitation to address severe issues persisting since 2018. This overhaul included the replacement of both the crankshaft and bedplate. Precise realignment was vital, given the engine and generator positioning adjustments.

The rehabilitation initiative commenced in July 2019, with a planned completion date in 2020. However, unexpected challenges arose, delaying the arrival of all engine components until August 2020. Consequently, the scheduled completion was extended to December 2020. Subsequently, the extensive rehabilitation efforts, encompassing alignment and engine-generator coupling, were successfully concluded in March 2021. During the running test program, an imbalance was detected in the generator shaft, necessitating a realignment process and the reattachment of fitted bolts to rectify the issue.

The US Navy first made people aware of shaft alignment's importance in the late 1950s. They investigated design improvements in crucial areas such as alignment, fatigue, vibration, and corrosion in ship shafting systems (Michel, 1959). The importance of shaft alignment in avoiding misalignment- related damage to reduction gears was brought to light by this investigation (Anderson and Zrodowski, 1965). Further evidence for the significance of bearing spacing in supporting shafts came from a 1961 study by Lehr and Parker (Lehr and Parker, 1967), which also showed the bearing's significant influence on shaft integrity. For the shafting system as a whole to remain stable, the correct distance between support bearings must be maintained (Lee, 2018).

The extensive rehabilitation entailed replacing the crankshaft and bedplate, consequently altering the engine's position relative to the generator. This change necessitated an alignment job. Following alignment approval by the manufacturer, the engine and generator were coupled using a specialized custom bolt known as the fitted bolt. Due to the usual misalignment in hole positions between engine and generator flanges, an additional task called reaming was essential.

However, the alignment process utilizing the OEM technical services method spanned over 14 days, and the subsequent reaming process carried out manually, consumed a significant 40 days. These prolonged durations strained resources and time, prompting the search for more efficient methods.

This paper will discuss a breakthrough method for shaft alignment using hydraulic jack to overcome this problem. By applying this new method, the alignment focus is directly at the point of the farthest deviation so that the alignment process can be carried out quickly and precisely. Apart from that, this innovation also proposes a new reaming method using line boring. This tool works more effectively than hand reaming, which requires more time and manpower. A more detailed discussion of the method and its impact will be discussed in this paper.

2. METHODS

A. Dial Indicator Data Method

Dial Indicator, also known as dial gauge or dial test indicator, is a precision measuring tool used to measure small differences in distance or thickness. This tool consists of a needle connected to a measuring wheel which shows the measurement results on a scale on the dial.

This tool can be used to measure the tilt of the crankshaft. When the crankshaft is installed incorrectly or tilted, the output from the dial indicator becomes greater, where the oscillations of the rotating crankshaft become greater.

In this experiment, we employ the rim and face method. The rim and face method involves selecting one machine axis as a reference, and then directly measuring the relative displacement and relative alignment angle of another axis by physically making contact between the machine components (such as shafts and couplings) and the measuring device (such as a dial indicator). It is important to assume that the relative alignment of the axes remains stable throughout the measurement process. As a result, this method can be categorized as relative, contact-based, manual, and static (Czompo et al., 1993).

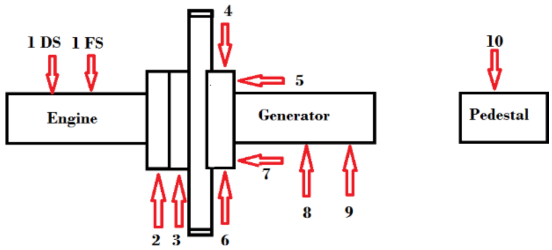


Figure 1. Dial Indicator Position for Shaft Alignment

In Figure 1, the depicted positions showcase the data collection for shaft oscillations utilizing a dial indicator. In the earlier approach, dial indicator testing was confined to the connection point between the diesel and generator, explicitly focusing on the radial (4) and axial flange generator (5). Relying solely on these 2 data points led to the assumption that the shaft was correctly installed due to the oscillations within acceptable limits at those locations. However, recognizing the extensive length of the crankshaft, we expanded our testing to encompass 9 points along the shaft, as illustrated in Figure 1. These 9 points are listed below:

1. Damper side / Flywheel side shortshaft journal
2. Shortshaft flange
3. Flywheel flange
4. Radial flange generator
5. Axial flange generator
6. Radial from earth
7. Axial from earth
8. Generator shaft radial 1
9. Generator shaft radial 2
10. Pedestal shaft radial

These additional testing points provided a more comprehensive understanding of shaft oscillations, enhancing our ability to ensure precise shaft installation and alignment.

Upon conducting a thorough analysis, it became evident that the oscillation value of the short shaft, initially meeting the prescribed standards when connected to the crankshaft, had experienced a notable increase. These deviations stem from potential imperfections that could arise during the assembly or operational phases. The center or ideal center point on the generator and engine should align precisely, facilitating smooth and efficient movement. However, in this particular scenario, a misalignment in position or orientation exists, giving rise to undesirable friction and conflicting forces. Consequently, this imbalance in the overall system has led to a more significant and less stable oscillation value, a departure from its previous controlled state.

B. Alignment

Shaft alignment is the process of aligning two or more shafts with each other to within a tolerated margin. The resulting fault if alignment is not achieved within the demanded specifications is shaft misalignment, which may be offset or angular. Faults can lead to premature wear and damage to systems. The primary objective of accurate alignment is to increase the operating life span of rotating machinery. To achieve this goal, machinery components that are most likely to fail must operate well within their design limits. As the parts that are most likely to fail are the bearings, seals, coupling, and shafts, the accurately aligned machinery will reduce excessive axial and radial forces on the bearings to insure longer bearing life and rotor stability under dynamic operating conditions (J. Piotrowski, 2007).

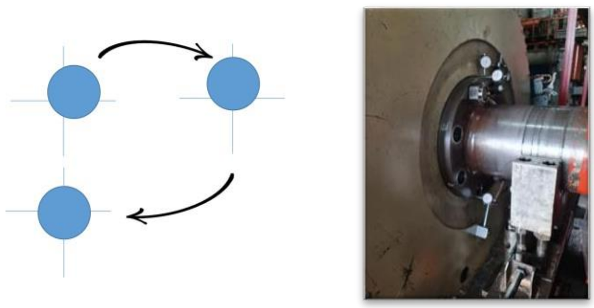
In this particular engine, the manufacturer has a standard for connecting two pieces of flanges as shown in Table 1. We can use this as guidance to couple the engine and generator flanges. The data obtained from the dial indicator measurements is then compared with Table 1 to determine whether the machine needs repairs.

Table 1. Criteria For The Geometry Of Crankpins, Journals, and Flanges (Diesel, 1987)

Diameter main journal or crankpins	New (mm)	No-go Criteria/Repair limit (mm)
Coupling flanges, nominal diameter	640.025 & 639.975	As new
Straigtness, concave or convex	0.02	0.06
Radial run out on gage	0.02	0.06
Axial run out on gage	0.03	0.06
For repairs by grinding several undersize bearing are available		

Swift corrective actions are imperative to promptly address this deviation by realigning the position and orientation of the generator and engine, ensuring they return to the appropriate center point. These necessary repairs and adjustments are paramount in reducing friction, achieving a balanced load distribution, and mitigating damaging forces. Consequently, this intervention guarantees the optimal operation of the system, enhancing efficiency and minimizing the potential for critical component damage. Moreover, these proactive measures contribute to the system's long-term sustainability, providing enduring benefits to operational continuity and equipment reliability (Todd, 1994).

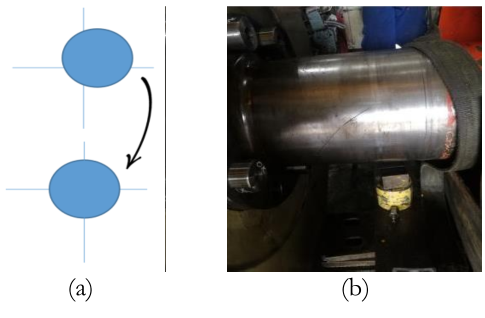
Upon identifying discrepancies in the dial indicator measurement results, it is evident that an alignment process is essential. In the prior method, alignment involved utilizing a modified cap main bearing, allowing for shaft movement in both the x and y directions—namely, right and left and up and down. There are two different kinds of tools that are used when the diameter and the straightness of the main bearing caps and the camshaft bearings are being measured, the laser measurement tools and the optical measurement tools . The alignment process commenced by locating the center point of the x-axis of the shaft through x-axis shifts. In the measurement records for the alignment of the main bearing caps and for the camshaft bearing caps gathered from the measurement the x-line and y-line can be seen (Mattans, 2011). From this it is very easy to see if the straightness of the bearings is within the tolerances. Subsequently, alignment was fine-tuned along the y-axis until the crankshaft precisely aligned with the center axis. Figure 2 illustrates the alignment process, displaying the shaft movement using conventional methods on the generator flange. During the engine's idle speed operation (250 rpm), it became apparent that the generator shaft movement exhibited an unbalanced nature.



(a) (b)

Figure 2. Old alignment method using cap main bearing (a) Illustration of the shaft alignment movement process (b) Cap main bearing for shaft Alignment Process

In a groundbreaking approach, the novel method significantly emphasizes pinpointing the most prominent diagonal deviation, departing from the conventional focus on specific x and y-axis coordinates. The integration of a hydraulic jack, illustrated in Figure 3, introduces remarkable flexibility in adjusting shaft alignment, thus substantially accelerating the overall processing time, vividly showcased in the accompanying visualization. A vigilant monitoring of dial indicator readings on the flange accompanies our meticulous control over the shaft's movement. Once these readings align with the predefined standards listed in Tabel 1, we secure the shaft and measure oscillation values along the shaft to validate the alignment process's effectiveness. The pivotal role of hydraulic jacks in relocating the generator shaft, guided by dial indicators at positions 8 and 9, is pivotal in achieving optimal alignment. The primary objective revolves around minimizing values at critical junctures, notably points 1, 2, 8, and 9, recognizing their importance in the fundamental connection between the engine (short shaft) and the generator (generator shaft).



(a) (b)

Figure 3. Breakthrough Method Using Hydraulick Jack (a) Illustration of the shaft alignment movement process (b) Hydraulick Jack for shaft Alignment Process

C. Reaming

Reaming is a cutting process in which a cutting tool produces a hole of a very accurate size. Reaming is done to a hole which has been already drilled, to produce a truly circular hole of exactly the right diameter.

After completing the shaft alignment, we ream the eccentric hole to accommodate the bolts. Figure 4 shows the condition of the hole after alignment. Due to the movement of the shaft, some parts of the hole do not fit properly, so a reaming process needs to be carried out.

Figure 4. Holes After Alignment Process

The SWD 16 TM 410 R unit comprises eight holes that necessitated reaming. Each hole required five days to complete the reaming and bolt fitting process. The time- consuming nature of this task is due to the use of an adjustable hand-reaming tool as shown in Figure 5, requiring substantial physical effort, involving a team of 6 individuals in each session.

Figure 5. Adjustable Hand Reaming Tool

In the current stage of our project, we are faced with reaming the remaining eight holes. Using traditional methods, this task would consume a significant amount of time, approximately 40 days. Recognizing the need for a more efficient approach, we opted to innovate and design a specialized tool. This tool, presented in Figure 6, adapts a line boring tool customized to suit our reaming requirements. The implementation of this tool remarkably streamlined our operations, reducing the duration of the reaming process to a mere six days. Additionally, the manpower required was notably diminished, with only a team of 2 individuals operating this specialized tool.

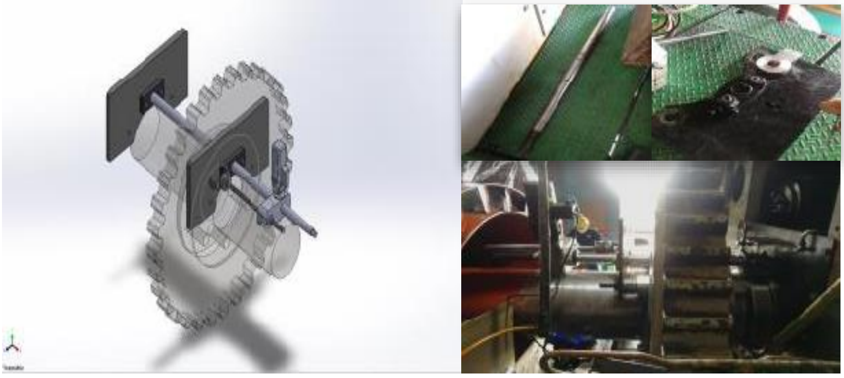


Figure 6. Line Boring Tool for Reaming

Upon completing all the reaming tasks and successfully fitting bolts, we achieved precise coupling between the engine and generator, a significant milestone in our project.

3. RESULT & DISCUSSION

A. Alignment and Reaming at First Attempt

Following the initial alignment process, the engine was set in motion at idle speed (250 rpm), revealing visible oscillations and instability in the shaft. These observations unequivocally indicated an imperfect shaft installation. After we saw the unbalanced shaft we investigate what was happening. So, we decided to use more of dials indicator and placed in many points as shown in Figure 1. The measured shaft oscillation results at each point along the shaft are presented in Table 2, obtained through dial indicator readings.

Table 2. Alignment Result at First Attempt

	1 DS	1 FS	Short shaft	Fly-wheel	4 Radial	5 Axial	Radial Bumi	Axial Bumi	Gen Shaft	Gen Shaft	10
A	0	0	0	0	0	0	0	0	0	0	0
B	-0,07	-0,08	0	-0,01	+0,03	-0,01	+0,25	-0,02	+0,98	+0,66	+0,01
C	-0,09	-0,10	-0,013	-0,019	+0,02	-0,03	+0,47	+0,03	+1,80	+1,50	+0,02
D	-0,10	-0,11	-0,016	-0,018	+0,02	-0,04	+0,55	+0,08	+2,23	+1,82	+0,02
E	-0,10	-0,12	-0,012	-0,021	0.000	-0,05	+0,45	+0,11	+2,00	+1,57	+0,02
F	-0,07	-0,08	-0,02	-0,019	-0,02	-0,02	+0,35	+0,06	+1,20	+1,76	+0,01
G	-0,04	-0,03	+0,09	-0,014	-0,03	-0,01	+0,20	-0,02	+0,30	+0,86	0
H	-0,03	-0,02	+0,11	-0,06	-0,03	0	-0,08	-0,04	-0,15	+0,50	0

Within Table 2, comprehensive measurement data is presented and systematically organized for analysis. The position of each column corresponds to the points along the shaft, as indicated in Figure 1. Furthermore, each row, denoted from A to F, corresponds to precise shaft peripheral points, meticulously calculated clockwise, as shown in Figure 7. This structured arrangement allows for a clear correlation between the measured values and their respective positions along the shaft, providing valuable insights for further assessment and necessary adjustments.

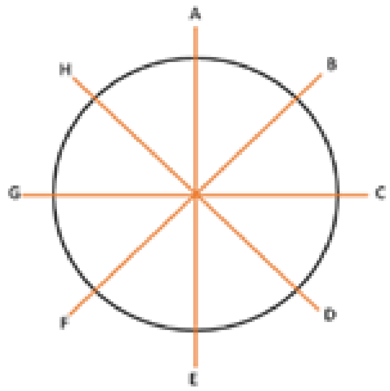


Figure 7. Dial Indicator Peripheral Position

Initially, measurements were conducted solely at points 4 (Radial flange generator) and 5 (Axial flange generator). As illustrated in the Table 2, the values at points 4 and 5 satisfied the standards outlined in Table 1, with the minimum threshold for improvements set at 0.06.

However, due to the considerable length of the shaft, oscillation measurements increased proportionally with the distance from the flange. Even the engine parts shown in points 1 and 2 also experience oscillation due to the shaft installation. Notably, at points 9 and 10 within the generator shaft section, the measurement values surged to 2.00, surpassing the standard limit by over 32 times, necessitating urgent corrective actions.

B. Alignment and Reaming with Breakthrough Method

We decide to re-align the engine. This time we use more dial indicators. And we use hydraulic jack to move the generator shaft with guidance from dial indicators at point 8 and 9. Basically, we try to minimize the value at point 1,2, 8 and 9. Because we are connecting the engine (shortshaft) and the generator (generator shaft).

Table 3 shows the dial indicator measurement results after implementing our recent breakthrough alignment method. As explained earlier, our measurements were strategically conducted at multiple designated points, illustrated in both Figure 1 and Figure 7, for a comprehensive understanding of the alignment adjustments.

Table 3. Alignment Result with Breakthrough Method

	1 DS	1 FS	Shorts haft	Fly-wheel	4 Radial	5 Axial	Radial Bumi	Axial Bumi	Gen Shaft	Gen Shaft	10
A	0	0	0	0	0	0	0	0	0	0	0
B	0	0	-0,01	0	+0,03	-0,01	0	-0,01	+0,01	+0,01	0
C	0	0	-0,01	-0,05	+0,02	-0,03	0	-0,03	+0,01	+0,01	0
D	0	0	-0,005	-0,10	+0,02	-0,04	-0,01	-0,02	-0,01	+0,01	+0,02
E	0	0	+0,01	-0,11	0.000	-0,05	-0,02	-0,03	-0,02	+0,01	+0,02
F	0	0	+0,01	-0,10	-0,02	-0,02	-0,03	-0,02	-0,03	-0,02	-0,01
G	0	0	0	-0,07	-0,03	-0,01	-0,03	-0,01	-0,02	-0,02	-0,01
H	0	0	0	-0,03	-0,03	0.000	-0,02	+0,005	-0,01	-0,01	-0,01
I	0	0	+0,01	0	0	0	0	0	0	0	0

Based on the dial indicator measurements results presented in Table 3, a noticeable and substantial improvement in the oscillation values is evident. Particularly in the generator shaft section, where the oscillation had previously peaked at a concerning value of 2.00, we have successfully mitigated it to an exemplary standard of 0.03, well below the permissible limit of 0.06. This improvement is consistent across various points along the shaft, all falling within the acceptable tolerance range. The achieved precision in installation is evidenced by the stabilized engine parts, illustrated by the dial indicator displaying minimal values of 0, indicating no oscillation. The generator and engine are now impeccably aligned, affirming this through consistent dial indicator readings at all ten designated points.

Implementing a hydraulic jack in the alignment process significantly expedited the process, showcasing successful alignment within a reduced timeframe. Moreover, employing line boring for the shaft reaming process proved notably efficient, requiring a mere six days to ream eight holes. Consequently, the work process duration has been significantly reduced, notably minimizing the timeline from an initial 54 days to a remarkable 10 days. This equates to an impressive 81% reduction in the overall time required for the task.

This marked improvement led to a remarkable reduction in the required workforce, now streamlined to just two individuals for 4 days, in contrast to the previous necessity of 6 workers per shift. The previous approach relied on hand- reaming tools powered directly by human effort. In contrast, introducing a line boring tool streamlined the reaming process, facilitating a quicker and more manageable workload for the workers. A comparative analysis between the traditional and the new methods for both the alignment and reaming processes is detailed in the Table 4.

Table 4. Comparison Between Old and New Method of Alignment and Reaming Process

	Old Method	New Method
Alignment Duration	14 Days	4 Days
Reaming Duration	40 Days	6 Days
Manpower	6 People in Shft	2 People

4. CONCLUSION

An accurate and efficient alignment process is significant when installing diesel engine shafts. A pioneering approach utilizing a hydraulic jack for alignment has revolutionized this process. By strategically focusing on the most significant deviation values, we achieved a highly successful alignment with an impressive time savings of 71.4%. Optimizing the reaming process through a line boring tool also resulted in heightened efficiency, making the task faster and more manageable for workers. This innovative reaming approach saved up to 85% of the processing time compared to traditional hand-reaming methods while significantly reducing the required workforce. In summary, this groundbreaking method for the shaft alignment process has unequivocally proven its success, resulting in an outstanding total time savings of 81% with less workforce needed.

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