Proceedings of the International Gas Turbine Congress 2003 Tokyo
November 2-7, 2003

IGTC2003 Tokyo TS-015

Experimental Investigation into The Behavior of Misaligned Shafts on Balanced Rotors

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1.0 ABSTRACT

Rotor unbalance and shaft misalignment are the two main sources of vibration in rotating machinery such as gas turbine. The vibration caused by unbalance and misalignment may destroy critical parts of the machine, such as bearings, seals and couplings.

Experimentally, the effect of parallel, angular and parallel-angular misalignment shafts on the balanced rotors investigated by using the system of High pressure, Low pressure and generator rotors. The second objective is to study the effect of unbalanced rotors on the well-aligned rotors.

Key words: Rotor balancing, laser alignment, vibration amplitude, shaft-to-shaft

2.0 INTRODUCTION

Over the past twenty years, the level of awareness concerning the importance of accurate and precise shaft alignment has increased dramatically. Therefore, shaft alignment seems to have taken a more important task when installing and maintaining machinery

In today's competitive economic climate rotating machines are driven at higher speeds and placed under more demanding load conditions, whilst modern machine design tends towards lighter weight construction. Such factors render machines more vulnerable to the consequences of misalignment and underwrite the need for effective alignment methods to be applied to your system.

It is generally agreed that proper alignment is critical to the life of the machine and coupling wear, bearing failures, bent rotors, plus bearing housing damage are all common results of poor alignment, We also know that loads on mechanical parts, such as bearings, seals, and couplings, decrease with improved alignment.

This research experimentally determines the effect of shaft alignment to balanced rotors. Previous studies [4,6,7] have indicated that there seems to be a correlation between machine misalignment, and machine vibration. It has long been known that machines that were not in good alignment vibrated at characteristic frequencies, but direct research has been only minor.

3.0 DEFINITIONS OF SHAFT MISALIGNMENT

Shaft misalignment can be divided into two components: offset misalignment, and angular misalignment. As can be seen in Figure 1 (a,b), and as these names suggest, offset (or parallel) misalignment occurs when the centerlines of two shafts are parallel but do not meet at the power transfer point, and angular misalignment occurs when centerline of two shafts intersect at the power transfer point but are not parallel. Often misalignment in actual machinery exhibits a combination of both types of misalignment Figure1 (c) [5].

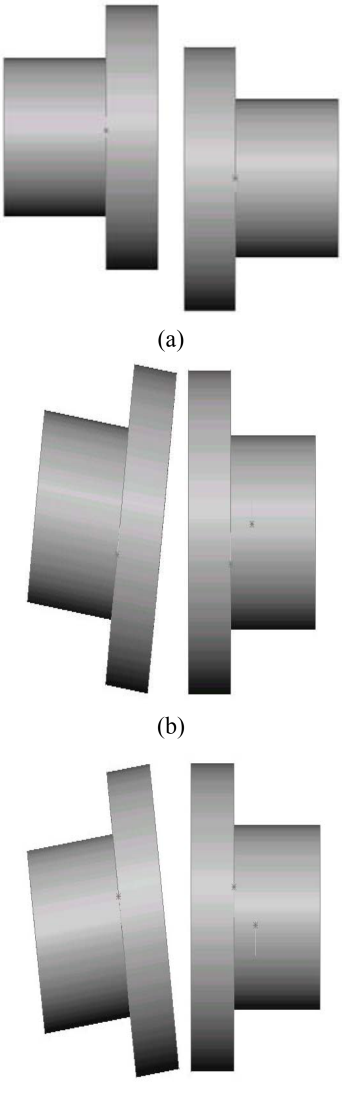

Figure 1 (a) Parallel Misalignment (b) Angular Misalignment (c) Parallel&Angular Misalignment

Manuscript Received on July 3, 2003

4.0 THE OBJECTIVE OF ACCURATE ALIGNMENT

In simple terms, the objective of shaft alignment is to increase the operating life of rotating machinery. To achieve this goal, machinery components that are most likely to fail must operate within their design limits. Since the components that are most likely to fail are the bearings, seals, coupling, and shafts, accurately aligned machinery must achieve the following results:

- Reduce excessive axial and radial forces on the bearings to insure longer bearing life and rotor stability under dynamic operating conditions.
- Minimize the amount of shaft bending from the point of power transmission in the coupling to the coupling end bearing.
- Minimize the amount of wear in the coupling components.
- Maintain proper internal rotor clearances.
- Eliminate the possibility of shaft failure from cyclic fatigue.
- Lower vibration levels in machine casings, bearing housings, and rotors.

5.0 LASER ALIGNMENT

Recent advances in laser alignment technology have made it possible to align the machines, which they drive to within very tight tolerances. A good laser alignment system should have an accuracy of shaft alignment conditions at least 0.00254 mm.

Detection of misalignment has been made simple, but achieving the alignment condition is still a time consuming effort. Often, several iterations are required to reach the desired alignment.

This practice identifies the use of a laser alignment system to obtain optimum alignment, resulting in less wear and increased reliability. The laser system is a low power, pulsed semiconductor laser figure 2. The detector is a biaxial, analog photoelectric semiconductor position detector with a resolution of 1 micron. The linearization characteristics of each laser detector are unique and are stored in the systems computer, thus only the detector and computer specifically matched to each other may be used together. The laser transmitter is attached to the shaft of the stationary rotor and the reflector is attached to the shaft of the machine to be moved.

The prism reflects the beam in a plane parallel to that in which it receives the beam. As the prism shifts along the radial axis during rotation, the spacing between the beams is altered, and from this difference the offset of the shafts is determined. As the prism is rotated about its vertical axis, the angle between the entering and reflected beams changes, permitting angular misalignment to be computed.

The computer receives its input data directly from the detector through a connecting cable and calculates the alignment correction values for the feet of the machine to be moved. The computer can also detect the presence of “soft foot” on the shaft alignment. Soft foot results from the mounting base not providing a level and even surface for securing the equipment, resulting in an unstable installation and misalignment leading to premature failure. In properly installed equipment, there are no outside forces or strains on the bearings or shafts.

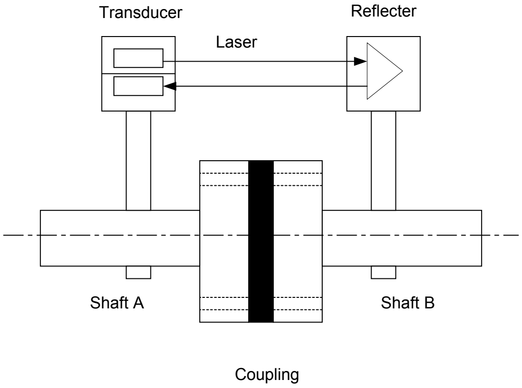

Figure 2 layout of Laser alignment set up

6.0 ALIGNMENT VERSUS VIBRATION

Vibration analysis of rotating machinery is able to identify a large number of systems faults. Shaft bow, shafts unbalance and shafts misalignment make up the major portion of the observed vibration frequency spectra of rotating machinery. These spectra can be used to determine the type of rotating system abnormality, the degree of misalignment and the rate of alignment degradation.

Misalignment is an important cause of vibration problems in rotating machinery. In this paper a survey is made of the various types of misalignments often encountered in the rotating machinery and the vibration characteristics, which arise due to these misalignments [3].

Detecting shaft misalignment using vibration analysis techniques can be difficult and somewhat misleading unless you understand the true mechanism of misalignment and how it affects our rotating machinery. There are several points that we should be aware of concerning the use of vibration analysis for misalignment detection. Vibration should be used as a criterion to judge alignment, because of that the purpose of alignment is to reduce vibration. Also the alignment shall be judged with static measurement instruments fixture to the shafts and judged in accordance with the Alignment Limits [2]. Other factors can cause excessive vibration, such as structural resonances or unbalance.

In a similar manner, noise and excessive bearing temperature could indicate shaft misalignment but these symptoms could also indicate other problems. Noise and excessive bearing temperatures shall not be used alone to judge alignment. In addition the excessive bearing clearance allowed the shaft to move in axial or radial direction. Because of this alignment reading are effected. It is important to know the axial and radial movement of shaft before alignment [1].

7.0 IMPLEMENTING ALIGNMENT STANDARDS

Based on the manufacture data of the equipment used in this study [2], Pruftechnik have developed standards based upon many years of experience in supplying laser systems to industry world wide, these standards are a good guide to upper and lower limits that will improve plant operating condition.
Based on the research and actual industrial machines evaluation, shaft alignment tolerances are now more commonly based on shaft RPM rather than shaft diameter or coupling manufacture's specifications.

Misalignment can be classified into four grades depend on the details from different manufacture including bearing manufacturers, coupling manufacturers, alignment system consultants and so on.

1. Unsafe: the degree of misalignment is outside the tolerance limit.
2. Poor: the degree of misalignment is inside the tolerance limit but outside the recommended limit.
3. Acceptable: the degree of misalignment is in the recommended range for operating.
4. Excellent: the degree of misalignment is close to perfect alignment.

8.0 PROCEDURES FOR EXPERIMENTAL INVESTIGATION

The following listed items are the procedures applied for experimental investigation on the effectiveness of shaft-to-shaft misalignment to their balancing, and unbalanced shafts to their alignment;

8.1 Experimental Apparatus

The experimental apparatus is shown in Figure 3. It consists of 3 shafts. Each shaft is supported by two hydrodynamic bearings and is as a scale dynamic model of a gas turbine. The rig has a sump tank with 3.40 m long, 0.44 m wide and 0.25 m high also it has protector cover with dimension of 3.60m long, 0.45m wide and 0.73 m high for the safety reason also to prevent the lubricant liquid to flood out from the sump tank and the attached correction masses and trial masses which might be not well inserted.

The test rig was driven by 3.0 kW motor (3 phase), which had an operation speed (rated speed) of 60 Hz, with a variable speed controller, the motor speed can be continuously increased or decreased in the range from 0 to 6000 r.p.m At the end of the motor a pulley to drove the shaft through a belt to step up the speed with a ratio (i.e. gear ratio) equal to 4, which was adequate for the purpose of testing. Both the rig pulley and the motor were mounted in a metal foundation below the table. Non-contacting displacement transducers or proximity probes was used for the vibration measurements figure 4a.
The probes measure directly the shaft displacements in the vertical direction relative to the bearing pedestal. Also a phase reference (color mark sensor) was mounted in the rotor-motor coupling figure 4b.

The Data Acquisition System (DAQ) system was integrated into a PC, via (68-pin male SCI-II) type. There was a choice of programming languages that could be used to create the application program. In this case, Matlab 5.1 was chosen. The (DAQ) functions were called throughout the Matlab program, and the desired settings assigned within the program code.

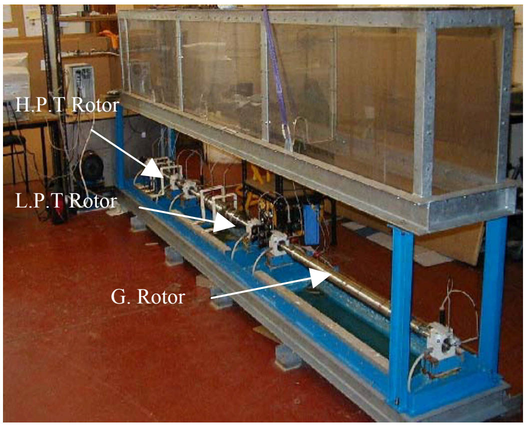

Figure 3 overview of the experimental system

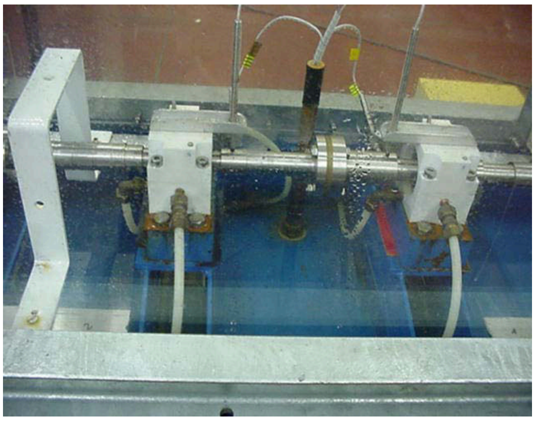

Figure 4a Vibration amplitude measurements instrument

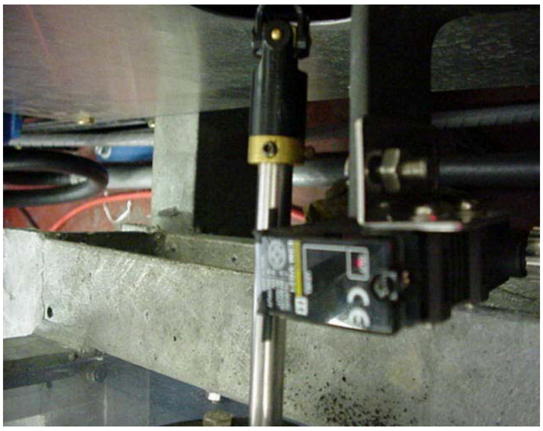

Figure 5b phase angle measurements instrument

8.2 Shaft Alignment Equipment

An OPTALIGN PLUS was used to measure the shaft-to-shaft alignment, with the OPTALIGN PLUS PC DISPLAY software running. The optional OPTALIGNO PLUS Commander program lets you set up alignment jobs in advance, permanently archive measurement files, and create adaptable customized alignment reports for fulfillment of ISO quality standards all with the convenience of Windows on any standard PC. Perfect for transferring alignment jobs from one OPTALIGNO PLUS unit to another, across a local PC. Which allowed participating and seeing every step of the alignment job as it proceeded. The alignment readings obtained can be seen and stored on the OPTALIGNO PLUS laser system for reporting and results. The connection of the alignment equipment to the system High Pressure Turbine (HPT) and Low Pressure turbine (LPT) (HPT ⇔LPT) rotors are shown in figures 5. The most important requirement for any shaft alignment system is repeatability of the readings. This is evaluated with a 360 deg repeatability test. (the symbol ⇔ means the shaft connection)

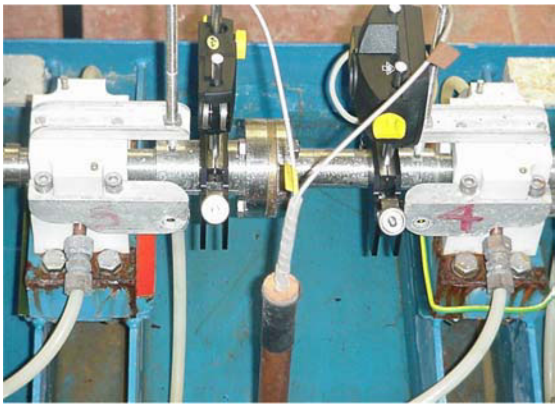

Figure 6a laser alignment equipment (OPTALIGNO PLUS) connected to the system

Figure 7b laser alignment equipment (OPTALIGNO PLUS)

9.0EXPERIMENTAL PROCEDURES

A number of test cases have been run to demonstrate the relation between misaligned systems and balanced rotors. The tests were divided into 2 sections

(1) The HPT rotor was connected to LPT rotor
(2) All the HPT, LPT and Generator rotor are connected to each other.

9.1 Procedure for HPT⇔ LPT Rotors Tests

9.1.1 Initial Data

- Align the HPT⇔ LPT Rotors
- Balance the HPT⇔ LPT Rotors

9.1.2 Effect of Misalignment Shafts on Balanced Rotors

- **Introduce offset misalignment to the system.**
- Align the HPT⇔ LPT Rotors
- Balance the HPT⇔ LPT Rotors
- **Introduce angular misalignment to the system.**
- Align the HPT⇔ LPT Rotors
- Balance the HPT⇔ LPT Rotors
- **Introduce offset & angular misalignment to the system.**
- Align the HPT⇔ LPT Rotors
- Balance the HPT⇔ LPT Rotors

9.1.3 Effect of Unbalanced Rotors on Aligned Shafts

- Align the HPT⇔ LPT Rotors
- Introduce known mass to the system (just to keep the system in unbalance state), check the alignment
- Align the HPT⇔ LPT Rotors
- Balance the HPT⇔ LPT Rotors

9.2 Procedure for HPT+ LPT Rotors⇔G Rotor Tests

9.2.1 Initial Data

- Align the ***HPT***+ ***LPT Rotors***⇔G Rotor
- Balance the ***HPT***+ ***LPT Rotors***⇔G Rotor

9.2.2 Effect of Misalignment Shafts on Balanced Rotors

- **Introduce offset misalignment to the system.**
- Align the ***HPT***+ ***LPT Rotors***⇔G Rotor
- Balance the ***HPT***+ ***LPT Rotors***⇔G Rotor
- **Introduce Angular misalignment to the system.**
- Align the ***HPT***+ ***LPT Rotors***⇔G Rotor
- Balance the ***HPT***+ ***LPT Rotors***⇔G Rotor
- **Introduce Offset & Angular misalignment to the system.**
- Align the ***HPT***+ ***LPT Rotors***⇔G Rotor
- Balance the ***HPT***+ ***LPT Rotors***⇔G Rotor

9.2.3 Effect of Unbalanced Rotors on Aligned Shafts

- Align the ***HPT***+ ***LPT Rotors***⇔G Rotor
- **Introduce known mass to the system (just to keep the system in unbalance state)**
- Align the ***HPT***+ ***LPT Rotors***⇔G Rotor
- Balance the ***HPT***+ ***LPT Rotors***⇔G Rotor

10.0 ALIGNMENT & BALANCING RESULTS

All changes in alignment were made to the system (multi-shaft multi-bearings). Misalignment conditions were varied in the following order for **HPT⇔ LPT rotors** and **HPT+ *LPT Rotors*⇔G Rotor:**

- Offset misalignment
- Angular misalignment
- Combination of offset and angular misalignment

Using OPTALIGNO PLUS for the misalignment experiments collected data. For all cases, the data was transferred to the OPTALIGNO PLUS software then analyzed to determine the change in the expected coupling life with respect to the misalignment condition. The balancing data was taken by using a matlab written by the author in matlab to handle and analysis the balancing data

The list of results tables can be seen in section 9.1.1-9.1.7.

10.1 HP⇔LP Rotors Alignment Tests Results

10.1.1 Initial Alignment

The basic dimensions of the system HPT⇔ LPT Rotors are shown in figure 6. Figure 7 shows a schematic diagram of the balancing planes locations.

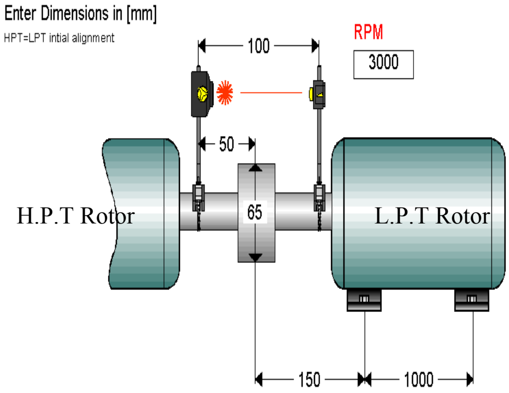

Figure 8 HPT& LPT connection dimensions

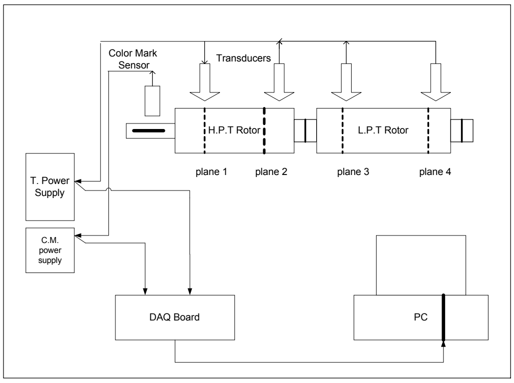

Figure 9 schematic diagram of HPT & LPT rotors test set up

The results of the tests are shown in the section 10 in tables form. The analysis of these results are discussed in section 11

Table 1 HPT&LPT rotors results of initial alignment

Coupling values, Actual		
Measurements Mode	**Continuous Sweep**	
Gap	Vertical	-0.01 mm
Offset	Vertical	0.01 mm
Gap	Horizontal	-0.00 mm
Offset	Horizontal	-0.01 mm
Foot correction values		
Right Rotor		
Left foot	Vertical	-0.02 mm
Right foot	Vertical	-0.10 mm
Left foot	Horizontal	-0.00 mm
Right foot	Horizontal	-0.06 mm

Table 2 Results of the balancing HPT & LPT rotors after been alignment

Correction masses (gram)/phase (deg)				
	Plane (1) 29.3mm	**Plane (2) 37.05mm**	**Plane (3) 48.6mm**	**Plane (4) 48.6mm**
	23.7290@ 18.5524	27.1793@ 104.6661	25.8600@ 79.0162	47.4090@ 48.5887
Balancing Q.G	G 2.5	G 2.5	G 2.5	G 2.5
Vibration before Balancing	0.2882@ 238.6667	0.2198@ 200.5904	0.5006@ 221.5385	0.7424@ 205.9615
Vibration after Balancing	0.1032@ 205.1286	0.1152@ 244.5154	0.2743@ 311.3657	0.4352@ 186.5243

10.1.2 Parallel Misalignment

Table 3 HPT&LPT rotors results of parallel misalignment

Coupling values, Actual		
Measurements Mode	**Continuous Sweep**	
Gap	Vertical	0.02 mm
Offset	Vertical	0.09 mm
Gap	Horizontal	-0.05 mm
Offset	Horizontal	-0.11 mm
Foot correction values		
Right Rotor		
Left foot	Vertical	-0.05 mm
Right foot	Vertical	0.26 mm
Left foot	Horizontal	-0.01 mm
Right foot	Horizontal	-0.79 mm

Table 4 Vibration data for HPT & LPT rotors after introducing parallel misalignment

Vibration amplitude (mm)/ Phase angle (deg)			
Plane (1) 29.3mm	**Plane (2) 37.05mm**	**Plane (3) 48.6mm**	**Plane (4) 48.6mm**
1.2796@ 345.2459	3.5995@ 352.6230	3.7971@ 217.2131	1.3623@ 117.23469

10.1.3 Angular Misalignment

Table 5 HPT&LPT rotors results of angular misalignment

Coupling values, Actual		
Measurements Mode	**Continuous Sweep**	
Gap	Vertical	0.02 mm
Offset	Vertical	0.04 mm
Gap	Horizontal	-0.04 mm
Offset	Horizontal	-0.03 mm
Foot correction values		
Right Rotor		
Left foot	Vertical	0.01 mm
Right foot	Vertical	0.35 mm
Left foot	Horizontal	-0.05 mm
Right foot	Horizontal	-0.61 mm

Table 6 Vibration data for HPT & LPT rotors after introducing angular misalignment

Vibration amplitude (mm)/ Phase angle (deg)			
Plane (1) 29.3mm	**Plane (2) 37.05mm**	**Plane (3) 48.6mm**	**Plane (4) 48.6mm**
1.0720@ 90.0548	3.4428@ 96.9796	3.8013@ 156.3934	1.9634@ 317.2551

10.1.4 Parallel & Angular Misalignment

Table 7 HPT&LPT rotors results of parallel &angular misalignment

Coupling values, Actual		
Measurements Mode	Continuous Sweep	
Gap	Vertical	0.02 mm
Offset	Vertical	0.09 mm
Gap	Horizontal	-0.03 mm
Offset	Horizontal	-0.04 mm
Foot correction values		
Right Rotor		
Left foot	Vertical	-0.04 mm
Right foot	Vertical	0.31 mm
Left foot	Horizontal	-0.03 mm
Right foot	Horizontal	-0.47 mm

Table 8 Data of Vibration amplitude and phase angle for HPT & LPT rotors after introducing parallel and angular misalignment

Vibration amplitude (mm)/ Phase angle (deg)			
Plane (1) 29.3mm	**Plane (2) 37.05mm**	**Plane (3) 48.6mm**	**Plane (4) 48.6mm**
1.5092@ 98.4490	3.5238@ 133.6935	3.6093@ 346.7213	1.9585@ 120.9836

10.1.5 After Finishing The Tests

Table 9 HPT&LPT rotors after finishing the tests

Coupling values, Actual		
Measurements Mode	Continuous Sweep	
Gap	Vertical	-0.00 mm
Offset	Vertical	0.00 mm
Gap	Horizontal	-0.01 mm
Offset	Horizontal	-0.00 mm
Foot correction values		
Right Rotor		
Left foot	Vertical	-0.00 mm
Right foot	Vertical	0.00 mm
Left foot	Horizontal	-0.03 mm
Right foot	Horizontal	-0.23 mm

10.1.6 Balancing Results After Finishing The Tests

Table 10 HPT & LPT rotors balancing data after been alignment

Correction masses (gram)/phase (deg)				
	Plane (1) 29.3mm	**Plane (2) 37.05mm**	**Plane (3) 48.6mm**	**Plane (4) 48.6mm**
	14.8176@ 43.1780	30.1105@ -128.6921	54.7733@ -128.4081	29.1208@ -83.9798
Balancing Q.G	G 2.5	G 2.5	G 2.5	G 2.5
Vibration before Balancing	0.4490@ 50.7383	0.3876@ 31.5207	0.6960@ 46.3366	0.8718@ 221.5385
Vibration After Balancing	0.2435@ 63.1351	0.1851@ 288.6923	0.3658@ 299.2354	0.3320@ 285.2514

10.1.7 Alignment Results After Adding Known Mass to The System

Table 11 HPT&LPT rotors results after adding unbalance mass to the system

Coupling values, Actual		
Measurements Mode	Continuous Sweep	
Gap	Vertical	0.02 mm
Offset	Vertical	0.09 mm
Gap	Horizontal	-0.03 mm
Offset	Horizontal	-0.03 mm
Foot correction values		
Right Rotor		
Left foot	Vertical	0.04 mm
Right foot	Vertical	-0.32 mm
Left foot	Horizontal	0.03 mm
Right foot	Horizontal	0.47 mm

Table 12 Vibration data for HPT & LPT rotors after introducing parallel and angular misalignment

Vibration amplitude (mm)/ Phase angle (deg)			
Plane (1) 29.3mm	**Plane (2) 37.05mm**	**Plane (3) 48.6mm**	**Plane (4) 48.6mm**
1.8359@ 237.2185	3.8021@ 232.1633	3.66983@ 194.7395	2.4866@ 231.6832

11.0 RESULTS ANALYSIS

The alignment and balancing results obtained from both before and after any unbalance and misalignment were made can be seen in data and results tables (1-12). These alignment readings were stored on the OptAlign Plus laser hardware for future reporting and results. Also the balancing data saved in the experimental computer system

The aims of the second set of the tests were to investigate the effectiveness of the misaligned shafts on their balancing condition. To do this test we have to make sure that the system is well aligned and balanced, which was the purpose of the first set of the tests. The desired test require the introduction of misalignment to the system HPT⇔ LPT Rotors, the sequence of the test was as mentioned on the previous part by adding a 2X0.3 mm shim to the bearing baseplate, in order to achieve parallel, angular and angular & parallel misalign shafts. The HPT rotor was the fixed part, which the laser transducer was attach on and the LPT Rotor was the moving part, which the reflector attached on.

The dynamic effect of the hydraulic bearing was neglected, because the rotor unbalance was assumed to be the major force affect the system [8].

From the tables above (2 and 4) for the second tests, it is very clear that the corrections and modifications made to this system had a direct effect on the system vibration amplitude. For instance if we have a look at the results of the vibration amplitude at the alignment speed after introducing the parallel (offset) misalignment, which was increased sharply from 0.1032mm to 1.2796mm, 0.1152mm to 3.5995mm, 0.2743mm to 3.797mm, 0.4352mm to 1.3623mm at measurements location respectively.

The third part of the tests held on the HPT⇔ LPT rotors were to study the effect of unbalanced rotors on the aligned shafts, the procedure was by aligning and balancing the HPT⇔ LPT rotors then introduce a known mass to the rotor in order to establish a unbalanced system. After that the rotor was rotated and vibration amplitude was measured to make sure that the system is in unbalance condition. The next is we test the alignment and see whether the unbalance mass has changed the system alignment condition or not, the results in this particular test showed that as we can see from the results tables (11 and 12), the alignment condition of the system is getting worse after the shafts became unbalanced. It is believed that this change in the vibration amplitude was due to either a rotating unbalance of the system or some sort of structural movement of the base or foundation. Likewise, when applied the same test on the LPT⇔ Generator rotor which connecting the HPT& LPT to became as the fixed part and the G rotor as moving part. The vibration of the system changed following the change in the alignment condition.

Also notice that the results in form of vibration shown in table (4,8,12) that the largest vibration occurs at the bearing closest to the coupling. Therefore there is high probability that an alignment error exists.

Initially the system was aligned and balanced, the vibration amplitude data obtained after every misalignment types introduced to the shafts showed dramatic increase in the vibration response. After these series of tests the system was balanced again, then a known mass added to the system as unbalance mass, in order to made the system at imbalance state. The shafts were aligned again and the vibration data achieved after that shows the effect of unbalanced rotors has affected their aligned condition.

The conclusions of the testes in this study are shown in Table 13, as we can see that the vibration response indicate that shaft misalignment does have a significant affect on the vibration amplitudes of the system. For instance, the results showed that planes 2 and 3 have higher vibration amplitudes (3.5995mm, 3.7971mm) respectively at all type of misalignment, because these plane are closer to the coupling, generally speaking, as the experimental results prove that the vibration amplitude is increased after we introduced the misalignment to the system (Parallel, angular and Parallel, & angular misalignments) gave similar results.

Table 13 Sumerized results

Vibration amplitude (mm)/ Phase angle (deg)				
Vibration amplitudes data after the conduced Cases	**Plane (1)**	**Plane (2)**	**Plane (3)**	**Plane (4)**
	29.3mm	**37.05mm**	**48.6mm**	**48.6mm**
Initial balancing	0.103@ 205.128	0.115@ 244.515	0.274@ 311.365	0.435@ 186.524
Introducing parallel misalignment	1.279@ 345.245	3.797@ 352.623	3.599@ 217.213	1.362@ 117.234
Introducing angular misalignment	1.072@ 90.054	3.442@ 96.979	3.801@ 156.393	1.963@ 317.255
Introducing Parallel & angular Misalignment	1.509@ 98.449	3.523@ 133.693	3.609@ 346.721	1.958@ 120.983
Balancing the system	0.243@ 63.135	0.185@ 288.692	0.365@ 299.235	0.332@ 285.251
Known mass to the system	1.835@ 237.218	3.802@ 232.163	3.669@ 194.739	2.486@ 231.683

12.0 CONCLUSIONS

The ideal rotor excites no vibration whatsoever as a result of pure alignment errors, because no rotating force exist. In practice, however there is no ideal rotor and no sure alignment error. There is always a mixture of various alignment and coupling error, errors in unbalance, bearing failure, therefore you will always find vibration in rotating machines. Alignment is a subject too vast, ranging to allow a comprehensive coverage of all of the areas associated with this field. Structural errors and machine errors often compound alignments. These defects can turn a simple job into an all day affair and also unsatisfactory results despite a conscientious effort and a considerable investment in manpower and downtime

Detecting shaft misalignment can be difficult if not impossible on operating rotating machineries. Even for severe misalignment conditions, sometimes only slight changes in vibration or temperature occur making it difficult to solve the severity of the problem. Not until mechanical degradation actually occurs, can the root cause of misalignment be suspected but by then, the damage has already taken its charge on the equipment. Correcting a known misalignment condition can be one of the most frustrating tasks you could undertake.

The changes in the shaft alignment data condition were due to the force changes in dynamics of machines during operation. For a 3000-RPM speed, the offset values would be considered outside the acceptable tolerance and the angularity values are also higher than would normally be considered acceptable. This also goes directly to the subject of shaft alignment tolerances based on shaft RPM rather than on maximum coupling alignment values as discussed above. Many coupling manufacturers would consider the alignment data acceptable, however, from the vibration data we can see that considerable force can be applied to the machine bearings due to small amounts of shaft misalignment. So that the vibration data in table 4, which collected after adding the parallel misalignment to the system, became higher than the original vibration data.

To sum up the conclusion from the above tests, there is a relationship between the misaligned rotors and the unbalanced rotors, which is; increasing of the misalignment produces higher vibration amplitude. Moreover these results also show that the misaligned shaft has an effect on the balanced rotors, similarly to the unbalanced rotors on aligned shafts.

The results in this paper, which estimate the adverse impact that misalignment has on system vibration, should be considered a minimum estimate. Therefore, according to the series of tests has been carried in this study we suggest that after any balancing procedure we must make sure that the system is well aligned as well, because the results of this paper showed that the higher misalignment shafts will cause higher vibration and subsequently will cause unbalance rotors. Also it desired and recommended to check the vibration condition of the machine after finishing the balancing test, and as the alignment test will not take longer time due to the introduction the modern laser alignment techniques. It is recommended to check the system alignment after the balancing test.

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