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Research Article

A Comparative Study on Shaft Alignment Systems (SAS)

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Abstract

Improper alignment between the shafts often leads to severe vibration problems in many rotating machines and causes premature failure of components like bearing, coupling, seals etc. To realize the effect of misalignment, an experiment setup was developed and the system performance was evaluated by measuring the system-vibration using accelerometer at different rotational speed (3.5Hz, 7Hz, and 11Hz). The analysis of FFT signals indicated shortcoming of alignment-system based on the mechanical (spirit level + dial gauge) components. The system is then aligned using dual Laser Aligning System (LAS) and experiments were performed again. The results of acceleration signals and corresponding FFT signals have been presented.

Keywords: *Alignment, laser aligning system, FFT, Acceleration.*

1. Introduction

Misalignment in a rotating machinery causes high cost to the industry as it causes premature failure of bearings (Hirani *et al*, 1998, Hirani *et al*, 1999, Hirani *et al*, 2000, Hirani *et al*, 2000, Hirani *et al*, 2001, Hirani *et al*, 2001, Hirani, 2004, Hirani, 2005, Hirani, Suh, 2005, Hirani, Samanta, 2007, Hirani, 2009, Hirani, Verma, 2009, Lijesh, Hirani, 2014, Lijesh, Hirani, 2015, Lijesh, Hirani, 2015, Lijesh, Hirani, 2015, Muzakkir *et al*, 2011, Muzakkir *et al*, 2013, Muzakkir *et al*, 2014, Muzakkir *et al*, 2015, Rao *et al*, 2000, Hirani, Samanta, 2007, Shankar *et al*, 2006) seals (Hirani and Goilkar, 2011, Goilkar and Hirani, 2009, Goilkar and Hirani, 2009, Goilkar and Hirani, 2009, Goilkar and Hirani, 2010), brakes (Sarkar and Hirani, 2015, Sarkar and Hirani, 2013, Sarkar and Hirani, 2013, Sarkar and Hirani, 2013, Sarkar and Hirani, 2013, Sukhwani, Hirani, 2008, Sukhwani *et al*, 2008, Sukhwani, Hirani, 2008, Sukhwani *et al*, 2009, Sukhwani *et al*, 2007), gears (Shah, Hirani, 2014, Hirani 2009), valves (Hirani and Manjunatha, 2007, Muzakkir and Hirani, 2015, Muzakkir and Hirani, 2015), coupling etc.

As per Piotrowski, 1995, 99% of the rotating machinery are misaligned and attaining the perfect alignment between the driving and driven machines is very difficult (Goodwin, 1989, Vance, 1988). Piotrowski, 1995 emphasized that by running any machinery with misalignment reduces life time to less than 1 month from 200 months if the misalignment in the machinery is increased from 0.2mils/inch to 100mils/inch. In other words, the main objective of shaft alignment is to increase the operating lifespan of rotating machinery. Therefore, it is necessary to minimize the misalignment in the system.

There are two types of misalignment: parallel and angular misalignments. With parallel misalignment, the center lines of both shafts are parallel but are offset. With angular misalignment, the shafts are at an angle to each other. Alignment error can be parallel misalignment, angular misalignment or a combination of the two. It is expected that every system will have combination of both parallel and angular misalignments. The misalignment can be identified from the FFT plots obtained from the acceleration signals. As per Shekar and Prabhu (1995) the misalignment in the coupling can be identified by observing magnitudes of the frequencies equal to twice the multiples of the rotating frequency.

In primary industries, mechanical (visual inspection, dial gauges and spirit levels) aligning techniques are used for aligning the shafts. These aligning methods lack precision and do not provide any assistance to align the shaft-system except intimating the presence of misalignment. There is a need to use more sophisticated aligning system such as Laser Aligning System (LAS). Even though the cost of LAS is comparatively higher, but it may payback in the form of long life of component, energy saving, gain in production. The aim of the present paper is to utilize LAS and compare system performance with the mechanical aligning methods such as combination of spirit level+ dial gauges + visual inspection.

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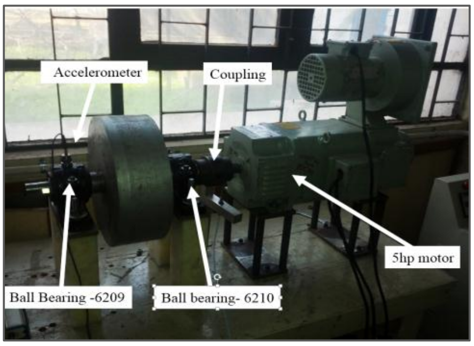
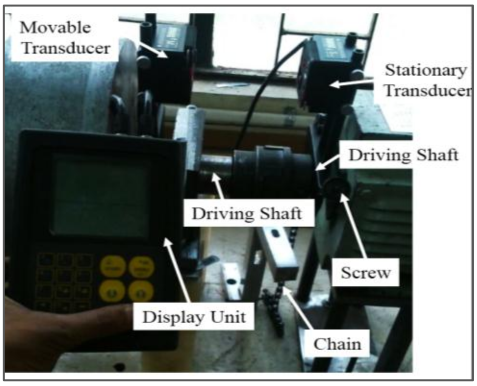
2. Experimental Results and Discussion

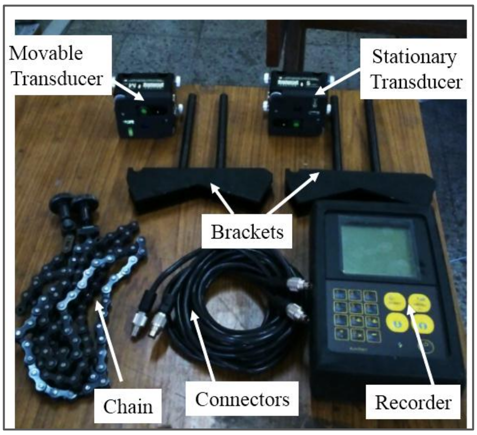
Experimental setup considered for the present work is shown in figure 1(a). This test setup is consist of a 5hp motor with controller, flywheel of 20kg, and two ball bearings: (i) bearing 1: bearing no.6210 and (ii) bearing 2: bearing no.6209. The jaw type coupling is used to connect the driving shaft (motor) and driven shaft (consisting of ball bearings and flywheel). The accelerometer, mounted on bearing 1 is required to measure the acceleration.



(a) Test setup



(b) LAS attached to the setup

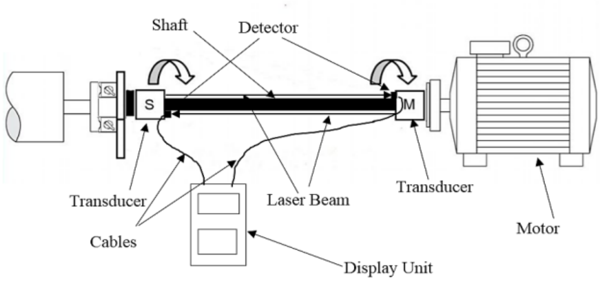


(c) Accessories of LAS

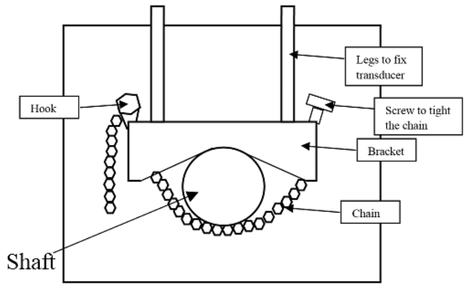
Fig. 1 Experimental setup and LAS

To obtain two rotating shafts co-linear, laser shaft alignment is the fastest and most accurate. The Laser Aligning System (LAS), used in the present work is shown in figure 1(b). The components of LAS are shown in figure 1(c). In LAS, there are two transducer (i) transducer attached to the fixed-system, named as 'stationary transducer' and (ii) transducer attached to the system which has to be adjusted is called movable transducer. In the present case the motor is fixed and system containing driven shaft is to be adjusted.

A sketch of the LAS is shown in figure 2(a). The transducer used in the present work employs two position sensing detectors (PSDs) and laser emitters (as shown in figure 2(a)) to measure the errors in the shaft-alignment. Lasers radiate in a single wavelength, in one direction and in a straight line, and are detected by PSDs. PSDs convert the center of energy of the laser spot into a calibrated digital reading for output to a hand-held display unit.



(a) Schematic figure of LAS



(b) Bracket attached to shaft

Fig. 2 LAS system

Laser planes are used as references to measure the flatness, straightness or squareness of surfaces or machine axes and at least three reference points in the angular direction are needed to make the laser plane. To obtain the position of the reference point (in the present case it is coupling center), four planes are required (shown in figure 3) (i) 'a'- distance between the stationary transducer (S) and Plane 1, (ii) 'b'- distance between the stationary transducer (S) and Plane 2 (M), and (iii) 'c'- distance between the stationary transducer (S) and Plane 3 and (iv) 'd'- distance between the stationary transducer (S) and Plane 4. The values of 'a', 'b', 'c' and 'd' needs to be recorded in processing unit of the LAS. The misalignment of the system with respect to the plane 1 from the Plane 3 and plane 4 by using the similar triangle principle shown in figure 4. The actual misalignment (C) with respect to the Plane 3 is calculated by: $C_{x,y}=h'_{x,y}-(a_{x,y}/c_{x,y})h_{x,y}$, similarly the procedure is repeated for Plane 4. For parallel alignment two points are enough but for angular adjustment three reading are required.

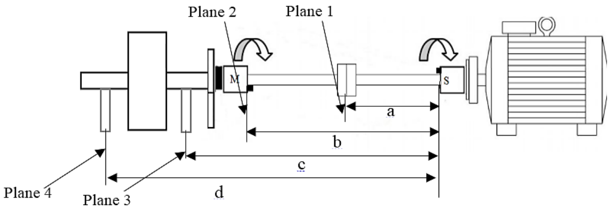


Fig. 3 distance to be measured and fed to LAS

The steps to carry out the aligning of two shafts: (i) driving shaft and (ii) driven shaft are as follows:

1. Mount the bracket rail on the motor shaft and flywheel shaft.
2. Mount the stationary transducer (S-transducer) and movable transducer (M-transducer) on the brackets as shown in figure 1(b).
3. Connect the S-transducer and M-transducer to the display unit and start the Cardan program to switch on the lasers.
4. Adjust the brackets rails so the center (green dots) of the S-transducer is hit by the laser emitted by M- transducer. Similarly, the center (green dots) of the M transducer shall hit by the laser emitted from S-transducer.
5. Open the shutter (shown in figure 5(a)). Press Enter button in the display unit to record the first value. The display will indicate a circle symbol when the value is recorded as shown in figure 5(b)
6. Turn both the transducers to a degree more than 100 (requirement of LAS) to left side of the motor from the vertical position as shown in figure 6(a) and press Enter button again to record the second value. The display will indicate as shown as shown in figure 6(b).

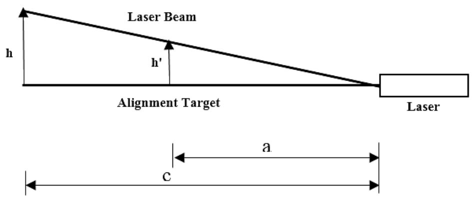
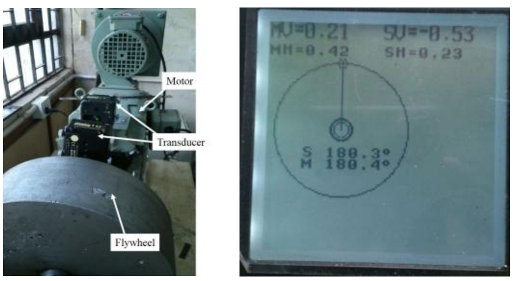
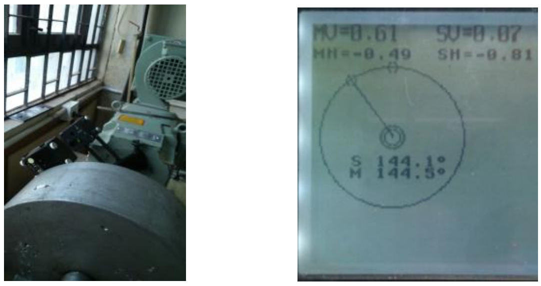


Fig. 4 Similar triangle



(a) Transducer position (b) Display unit

Fig. 5 Position of shafts in the vertical position



(a)Transducer position (b) Display unit

Fig. 6 Position of shafts rotated >100 left

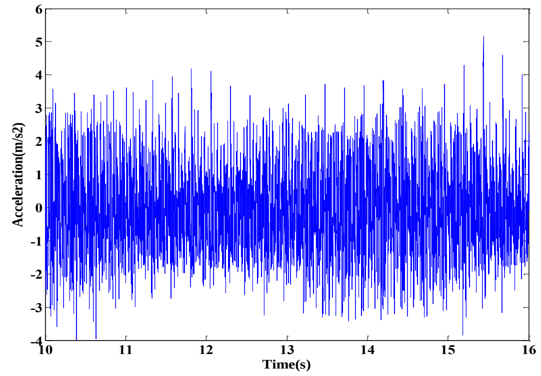
(a)Transducer position (b) Display unit

Fig. 7 Position of shafts rotated >100 left

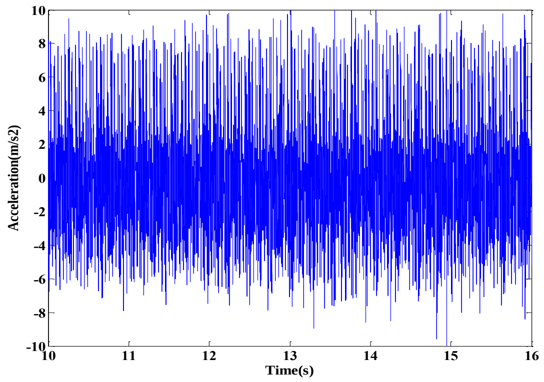
7. Turn both the transducers to a degree more than 100 (requirement of LAS) to right side as shown in figure 7(a) and press enter button again to record the second value. The display will indicate as shown as shown in figure 7(b).
8. After pressing enter, the deviation in horizontal and vertical direction of two legs will be displayed.
9. Based on the obtained values the system is adjusted to obtain '~0' in F1 and F2 in horizontal and vertical directions.

3. Results and Discussion

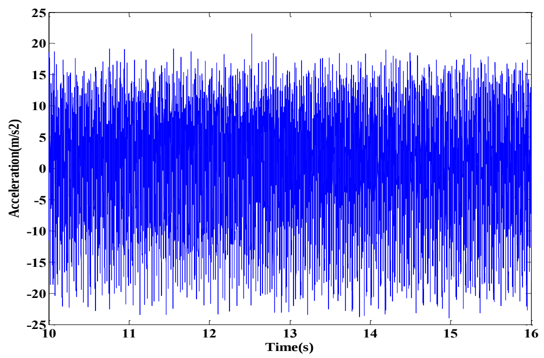
The acceleration signals were acquired using accelerometer at different rotational speed (3.5, 7, and 11Hz). The results for system aligned using mechanical aligning technique and LAS are plotted in figure 8 and 9 respectively. Figures 8(a)-(c) show the acceleration magnitude for 3.5Hz, 7Hz and 11Hz for mechanical aligned system and Figures 9(a)-(c) shows the acceleration magnitude for 3.5Hz, 7Hz and 11Hz for LAS system. The comparison of the magnitude of the accelerations is plotted in figure 10. From this figure it can be concluded that with the increase in rotational speed the magnitude of vibration increases in both the cases but the increase is 2.5, 2.6 and 3 times for mechanical aligned system compared to laser aligned system at 3.5Hz, 7Hz and 11Hz respectively.



(a) 3.5Hz

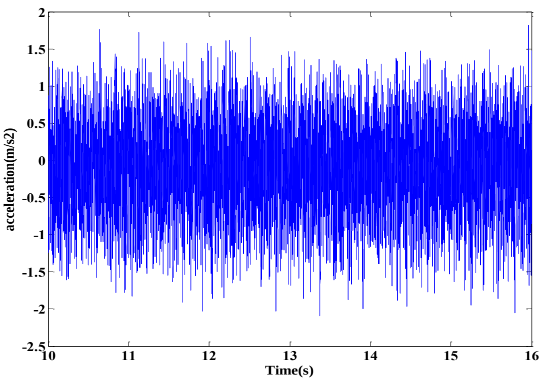


(b) 7Hz

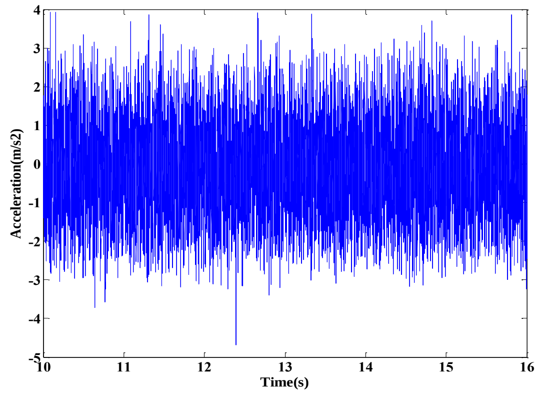


(c)11Hz

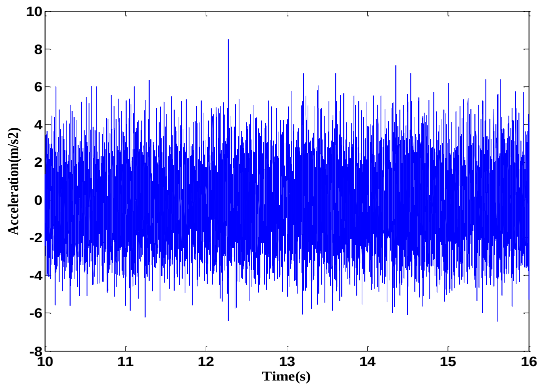
Fig. 8 Magnitude of acceleration of mechanical aligned system



(a) 3.5Hz



(b) 7Hz



(c)11Hz

Fig. 9 Magnitude of acceleration of Laser aligned system

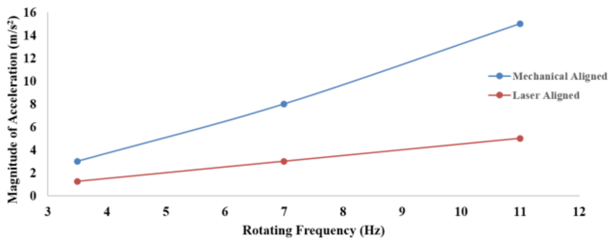
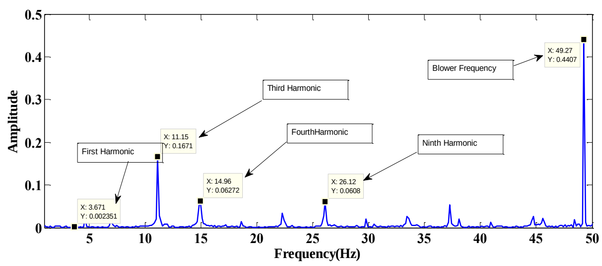
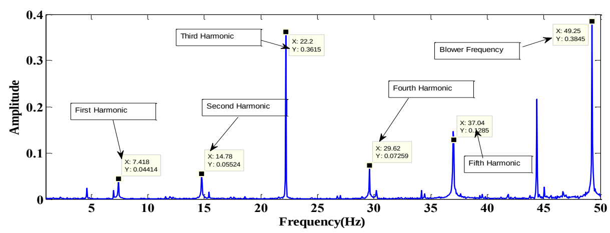


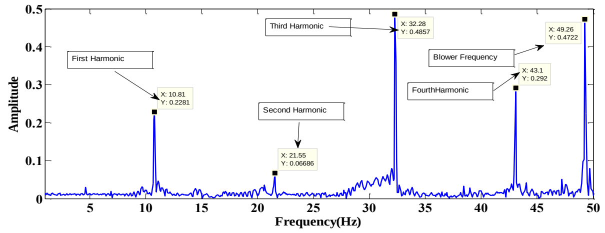
Fig. 10 Magnitude of acceleration for mechanical and laser aligned system



(a) 3.5Hz

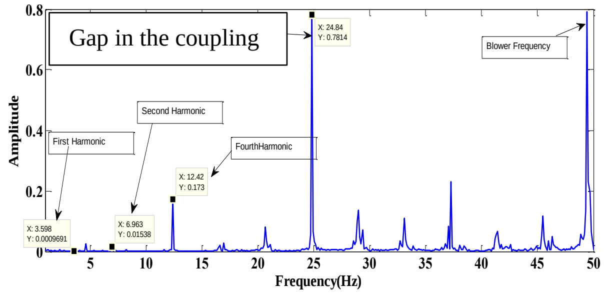


(b) 7 Hz

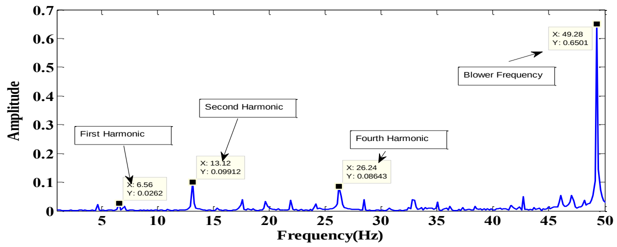


(c) 11 Hz

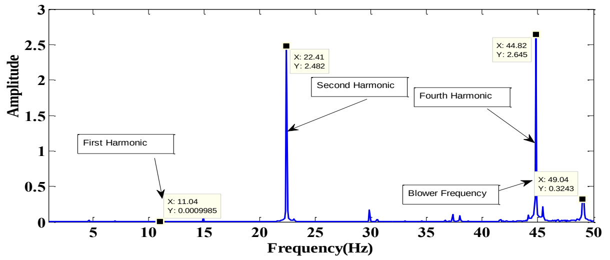
Fig. 11 FFT of mechanical aligned system



(a) 3.5 Hz



(b) 7 Hz



(c) 11 Hz

Fig. 12 FFT of Laser aligned system

The FFT for the acquired acceleration signal at different rotational speeds (3.5, 7, and 11Hz) for aligned systems using mechanical method and LAS are plotted in figure 11 and 12 respectively. Figures 11(a)-(c) show the FFT for 3.5Hz, 7Hz and 11Hz for mechanical aligned system. Figures 12(a)-(c) show the FFT for 3.5Hz, 7Hz and 11Hz for aligned system. For system aligned with mechanical unit the dominant frequency set contain both even and odd number of harmonics of the operating frequency. This indicates the existence of misalignment in both coupling and bearings. The peak of 49Hz in the FFT plot, is the operating frequency of the blower which is used for cooling the motor. In the case of the system aligned with LAS, the presence of only the even numbers of harmonics indicating misalignment only in the coupling. On close investigation of the coupling the deformation of the rubber, used in the jaw type coupling, was observed (as shown in figure 13). This permanent deformation of one side of rubber may have resulted FFT with even number of harmonic signals. Hence it was decided to change the coupling for the future work.

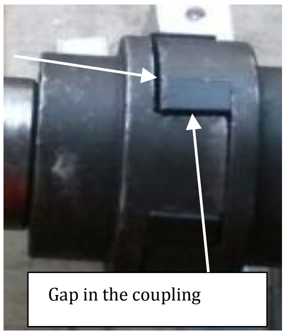


Fig. 13 Gap between the jaw of the coupling due to permanent deformation of rubber

Conclusions

Detailed studies on (i) system using mechanical aligning system and (ii) system using laser aligning system have been carried out. Due to the enormous advantage of Laser aligning system, it was decided to develop an experimental setup and compare its performance with mechanical alignment system. Following conclusion are made:

(i) System aligned by mechanical system resulted in higher vibration compare to system aligned by LAS.

(ii) The system aligned by mechanical system showed both odd and even multiple of peaks indicating misalignment in full system.

(iii) The system aligned by LAS showed even multiple of peaks indicating misalignment in only coupling.

(iv) Visual inspection of coupling indicated permanent deformation of rubber used in lovejoy coupling to absorb the vibration. The the permanent set in rubber, mislaignment occurred in the system. Due to this reason it was decided to change the coupling.

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