CDT Analysis as a Tool for Evaluating Bearing Lubrication and Mechanical Conditions

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Abstract: *Coast Down Time (CDT), which is the exact time elapsed between the power cut off and precise haulting of the rotor can be effectively used to ascertain tribological and mechanical degradation of machineries.*

An experimental investigation has been conducted to evaluate the bearing lubrication for different operating conditions using CDT and also to study the influence of rotor unbalance response on CDT. This paper presents the potential of using CDT as diagnostic monitoring parameter for a horizontal rotor system in relation with steady state vibration monitoring.

Keywords: *Coast down time, vibration, tribology, condition- based maintenance, diagnostic parameter deceleration.*

1. INTRODUCTION

The modern maintenance practices adopted in industries reduce the unwanted failure of rotating machines and thus to achieve the increased productivity. Among the various maintenance strategies, the condition-based maintenance is worthwhile, because here the machinery is maintained just before the actual failure from the knowledge of machine health condition. The machine health information can be assessed by monitoring reliable diagnostic parameters such as vibration, noise and wear particles etc. [5].

Tribo-monitoring through wear / lubricant analysis can detect lubricant contaminants, machine malfunction or lubricant deterioration, particularly when the rotor system is supported with bearings [3]. The bearing operation and maintenance plays a prominent role in machinery reliability, efficiency and safety. Hence, the technique to evaluate the performance of a bearing is significant in assessing the exact tribological process and their mechanical degradation [4]. The tribological process in a bearing is basically related to the mode of lubrication and the most important property of a lubricant for the plain bearing is the viscosity. Therefore, lubricating oil analysis is normally considered to be a successful mean to determine the mechanical wear and the lubricant condition, etc.

Coast down time analysis is one of the monitoring techniques used in condition-based maintenance of machinery and has made its mark for bearing performance evaluation. Coast down phenomena is the inherent behavior of any rotor system during the deceleration period. Coast down time (CDT) can be explained as the exact time elapsed between the power cutoff and precise haulting of the system [1]. The total time taken by the system to dissipate the momentum acquired during sustained operation make the coast down time.

Monitoring of mechanically borne sound and vibration emitted by operating system has probably showed more attention in recent past years than any other type of malfunction detection and therefore the vibration monitoring widely accepted as reliable method of determining the health of rotating machinery. Vibration analysis often involves the extraction of diagnostic vibration signal from the complex machinery. The feature of vibration signal along with their frequency characteristics simplifies the analysis procedure [5]. The vibration analysis technique, therefore, can be effectively used to determine the machine health and sources of incipient mechanical defects.

2.1 CDT AS A TOOL FOR CONDITION MONITORING

The inherent behavior of any rotating system after the supply cut off is called the coast down phenomena and the CDT is the total time taken by the system to dissipate the momentum acquired during sustained operation time. The CDT in many instances depends upon the inertia of the system component and the tribological effects of elements like bearings, seal etc and other malfunctions [2]

CDT in any rotating system is dependent on:

- Inertia of the system components;
- The tribological behavior of the machine elements;
- Operating conditions, and
- Environmental effects such as fluid drag.

The experimental investigation conducted on a journal has revealed that CDT can be used as an important machine condition parameter, to detect the mechanical problems and it is the most economical and easy to implement in comparison with vibration analysis, [8].

Further, the CDT reveals the feasible performance of bearing with respect to the lubrication conditions and selection of lubricant under a given operating conditions [1]. The effect of misalignment in CDT was investigated and found that the results are comparable with the vibration and orbit analysis [2]. Coast down time reveals the feasible performance of bearings with respect to the lubrication conditions and the lubricants used at a given operating conditions, if other mechanical conditions are isolated [6]. Most of the experimental investigation has been done by ensuring that the entire rotor system is completely free from the power source during coast down period in order to minimize the effect of external disturbing parameters due to the fact that the fluctuation in power source voltage, frequency etc can have appreciable effect on CDT. However, in the present work, the Coast down analysis is done with the power drive connected to the rotor via a positive coupling [7].

2.2 EXPERIMENATAL DETAILS

A horizontal rotor system exhibited in Figure 1 has been fabricated. It essentially consists of a shaft with a rotor at the centre, supported on antifriction bearings at the both ends. The lubricating oil is supplied to the non-drive end bearing by gravity feed. The rotor is driven through a disc coupling by a variable speed AC motor.

A Non-contact photo tachometer of Extech instruments, having auto ranging with Built-in RS-232 PC interface is used for speed measurement and PC based data acquisition of speed.

The Bal Pac 1200 vibration data collector is used for measuring the vibration amplitude displacement at steady state operation. With its tunable filter, the instrument automatically measures amplitude and plot a vibration frequency spectrum over an operator-selected range of frequencies.

The system is made to run at constant speeds (say1500, 2200 and 3000 rpm) for a rotor state of moderate unbalance till the system attains sufficient momentum for a given lubricant (SAE 140). During this sustained running of rotor, vibration data is obtained from both drive end non drive end bearing in vertical, horizontal and axial directions [9]. The stored vibration data is further processed using a software. The power supply is cut off and the speed change is recorded using non contact digital tachometer during the deceleration period of the rotor till it comes to the complete stop. The experiment is repeated for other lubricants (SAE 20W/50 & SAE 90 oil).

Further, CDT data and vibration characteristics were extracted after introducing an unbalance of 20 grams at a radius of 17.5mm in the rotor. The purpose was to understand the influence of unbalance on CDT and to compare the CDT information with respect to vibration reading.

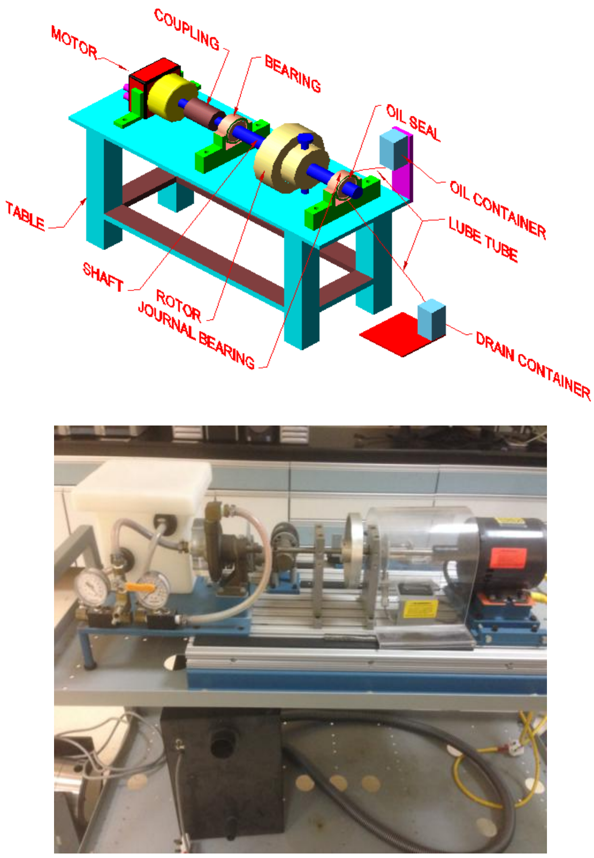

Figure 1: *Test Rig schematic*

2.3 RESULT AND DISCUSSION

The table 1 exhibits the maximum vibration amplitude (non drive end) and CDT data obtained at different cut off speed for the three types of oil used, with a moderate balance status of the rotor.

Table 1: *Vibration & CDT data for different cut off speeds*

	OIL SAE20W/50		OIL SAE140		OIL SAE90	
Cut off Speed	CDT	Vibration in In/Sec	CDT	Vibration in In/Sec	CDT	Vibration in In/Sec
1500	3.5	0.518	3	0.467	4	0.464
2200	5.10	0.841	3.81	0.829	5	0.946
3000	7.3	1.26	6.96	1.19	7	1.42

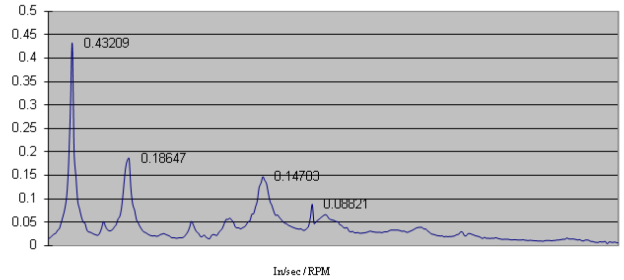

Figure 2: *Typical Vibration Spectrum at 1500 RPM with SAE 90 lubricant.*

A typical vibration signature (Figure 2) taken form non drive end bearing at a rotor speed of 1500 rpm for the oil SAE 90 reveals peaks prominently at 1XRPM and 2xRPMand sub harmonics. The CDT plots for different oil at various cut off speeds of 1500 rpm, 2200 rpm and 3000 rpm are shown in shown in Figure 3-5.

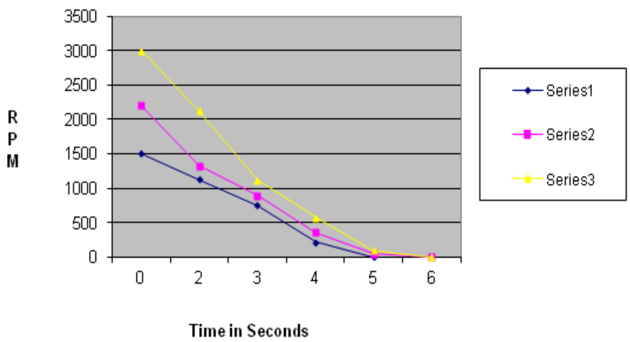

Figure 3: *CDT for SAE20W/50*

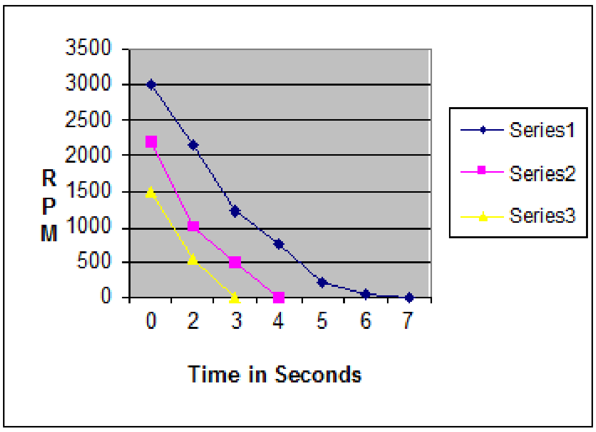

Figure 4: *CDT for SAE 140*

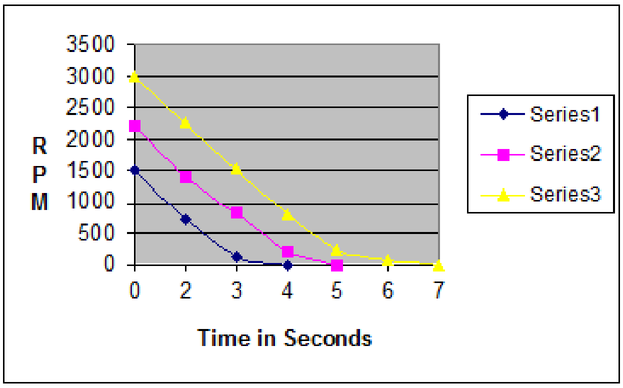

Figure 5: *CDT for SAE 90*

Table 2: *Vibration & CDT data for different cut off speeds (Unbalance)*

	SAE 20W/50		SAE 140		SAE90	
Cut off Speed	CDT	In/Sec	CDT	In/Sec	CDT	In/Sec
1500	4	2.23	2.99	1.18	4.2	1.78
2200	5.865	2.42	4	2.86	4	2.29
3000	5	4.21	6	4.32	6	3.58

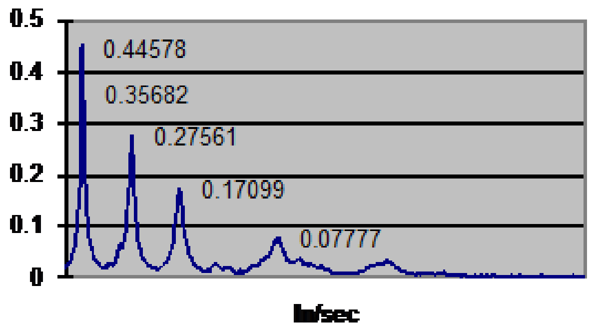

Figure 6: *Vibration Signature at 1500-RPM using lubricant SAE 90 (Drive end) Unbalance*

The vibration signature (Figure 6) taken at unbalance condition reveals for the oil SAE 90 at 1500 rpm reveals the high amplitude peaks at 1XRPM. CDT plots with unbalance condition of rotor are also exhibited in Figure (7-9).

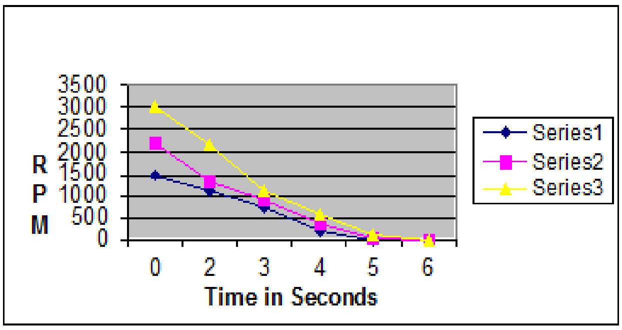

Figure 7: *CDT for SAE 20W/50 (Unbalance)*

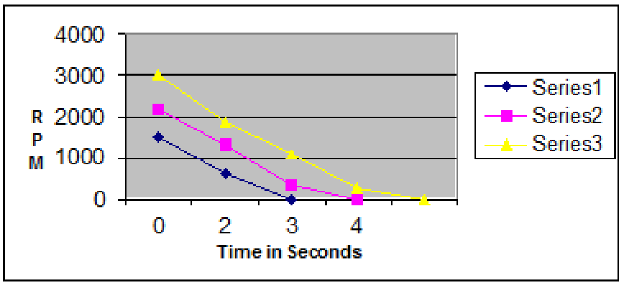

Figure 8: *CDT for SAE 140 (Unbalance)*

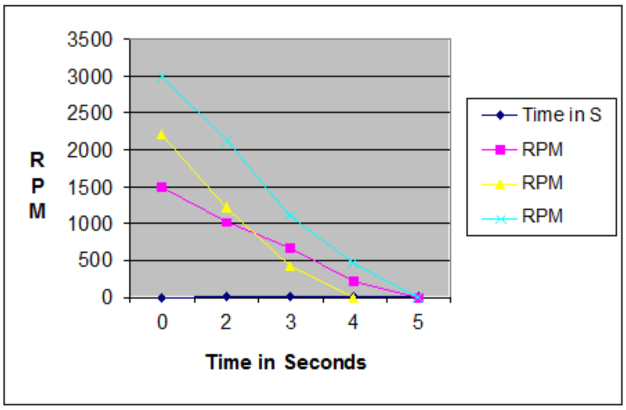

Figure 9: *CDT for SAE 90 (Unbalance)*

Cut Off Speed - 1500 RPM:

The maximum and minimum vibration of 0.518 and 0.464 in/sec are observed for SAE 20W/50 and SAE 90 respectively and the vibration spectrums are characterized by 1x RPM and 2xRPM harmonics, obviously attributed to the inherent problem of residual unbalance in the rotor and the mechanical looseness. The CDT plots at cut off speed for different lubricants are exhibited in Fig. 3 shows clearly that the CDT time for SAE 90 oil is more than the CDT for other oils. The least vibration is recorded for SAE 90 oil. Therefore, the CDT obtained at 1500 RPM for different lubricants are comparable with the steady state vibration.

Cut Off Speed - 2200 RPM:

The maximum overall vibration amplitude at non-drive is 0.946 for the SAE 90 oil and vibration amplitudes for SAE 140 and SAE 20W/50 almost remain same. The CDT plots for different lubricant is exhibited in Fig. 4 clearly indicates that the CDT for the SAE 20W/50 is maximum.

Cut Off Speed - 3000 RPM:

The maximum vibration amplitude noted was for the SAE 90 and CDT plots at 3000 RPM shows almost similar trend for all lubricants. The CDT at higher cut off speed is higher than the other two lower cut off speeds, resulting a proportional change. The higher vibration amplitude at 3000 RPM is attributed to the prominence of unbalance response of the rotor at higher speeds.

Effect of Unbalance:

The effect of unbalance on CDT at different cut off speed is evident from Table (2). The graphs indicates that the CDT at various cut off speed remains almost same due to the fact the unbalance effect is dominating the mechanical behaviors of the rotor system, and the effect of tribological condition is suppressed. However, the higher-grade oil SAE 140 has significant contribution to CDT time in comparison with the steady state vibration. The SAE 140 oil provides minimum CDT, compare when to the other two oil. The same trend has been noticed at higher cut off speed. The steady state vibration amplitude with unbalance mass is much higher than the amplitude without rotor imbalance for SAE 20W/50.The vibration has increased from 0.518 in/sec to 2.23 in/sec with the imbalance mass added to the rotor. The spectrums here are dominated with peak at 1Xrpm amplitude at 1xRPM clearly suggesting the effect of unbalance in the spectrum.

The results of experiment conducted are summarized as below:

- The CDT at higher cut off speed found to be more in comparison with lower cut off speeds. It also suggests that CDT has an effect on cut off speed and found to be changing in relation with the cut off speed.
- The thicker oil is (SAE 140) at lower speed is exhibiting reduced value of CDT due to the effect of operating speed in lubrication, particularly the fluid friction. However, the CDT of thicker oil found particularly the fluid friction to improving substantially at higher cut off speed.
- The steady state vibration at different cut off speeds and corresponding CDTs are comparable i.e. when the CDT is increased, the steady state vibration amplitude is reducing. However, the changes are not very much significant.
- The CDT with unbalance at higher cut off speed, exhibiting almost same behavior for all lubricants. It is observed that the unbalance introduced in the rotor has not provided a substantial change in CDT but for the vibration amplitude and prominence of peak at 1X rpm

2. CONCLUSION

The CDT can be used an effective diagnostic parameter when the mechanical problems (unbalance, effect of power supply etc) are isolated and can provide pertinent information regarding the tribological behavior, degradation and the effectiveness of lubrication. The CDT together with the other monitoring parameters could play a prominent method for machine monitoring if one or more mechanical problems such as unbalance looseness are present in the rotor system

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