

EXPERIMENTAL INVESTIGATION OF BALL BEARING LUBRICATION CONDITIONS BY SHOCK PULSE METHOD

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ABSTRACT

Lubricant (grease) is a vital requirement of ball bearing system. Grease not only protects ball bearing from wear and tear but performs various other functions that are essential for proper functioning of ball bearings. The lubricant (grease) under different conditions attains different properties which in turn affect the performance of the ball bearings. The effect of the condition of the lubricants on the performance of the ball bearings is well documented. The work reports about the investigation of ball bearing using shock pulse method by using two different instruments (Tester T2000 Model and Shock Pulse Meter 43A) of different operating conditions of ball bearing the condition such as used the quantity of grease as different percentage (0%, 25%, 50%, 75%, 100%) and bad quality grease (burn grease) at different rpm at a fixed load (10kg) and compare the normalized shock pulse value (dB) at different operating conditions. This method uses a piezo-electric accelerometer superimposed electrically as well as mechanically to about 32 kHz of resonant frequency. The result will help in bearing related to quantity as well as quality condition based maintenance choosing the optimum conditions for detecting the lubricant problem in ball bearing.

Keywords: Ball bearing, lubrication, shock pulse, grease.

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INTRODUCTION

Ball bearings are considered to be most critical components of household applications to heavy machineries like locomotives and turbines. Grease is the mostly used lubricant for ball bearings mainly because they are comparatively convenient to handle and needs the easiest of sealing devices. Greases are applied in areas where a continuous supply of oil cannot be done, like open bearing or gears. Factor like type of grease, in fact depends upon operating temperatures, oxidation stability, water resistance, etc. The other factors include characteristics like viscosity and consistency. There are many routes to check and measure the intensity of lubrication in ball bearing problems. Vibration analysis, acoustic emission, and shock pulse are just a few of the

methods used today, to detect the ball bearing lubrication condition measurement. Most lubrication practices are often performed on a time basis, which can result in over lubrication causing premature bearing failure. For the monitoring of the ball bearing lubrication condition have been used the most affective measurement method like shock pulse [1]. In industrial application, a critical role is played by rolling element bearings. There may be significant economic losses due to unexpected bearing failures. An effective way to prevent the bearing failures is condition monitoring. For bearing condition monitoring, Tandon and Choudhary have set up a detailed review in the area of vibration and acoustic methods [2]. As a quantitative method for detecting the defects of rolling element bearings, the shock pulse method (SPM) is widely accepted. In the SPM,

the maximum normalized shock value is used as a measure of bearing condition [3]. By this method, a single value indicating the bearing condition is achieved and there is no need for elaborate data interpretation as required in some other methods (e.g. traditional spectral analysis, cepstrum analysis [4], cyclic statistics [5], empirical mode decomposition (EMD) [6], wavelet transform [7], etc). However, the shock value in the SPM may be mistakenly estimated by direct demodulation. To overcome this deficiency, wavelet transform which is based on lifting scheme is applied to pre-process the vibration signals of rolling bearing [8].

Shock pulse measurement

The Shock Pulse Method (SPM) [9] was developed by SPM Instrument AB, Sweden in 1970s. It is based on the fact that an impulse of vibration is generated when a ball or roller in the bearing touches with a scratched area of raceway or with debris. Sign of bearing condition is given by maximum normalized shock value (dB).

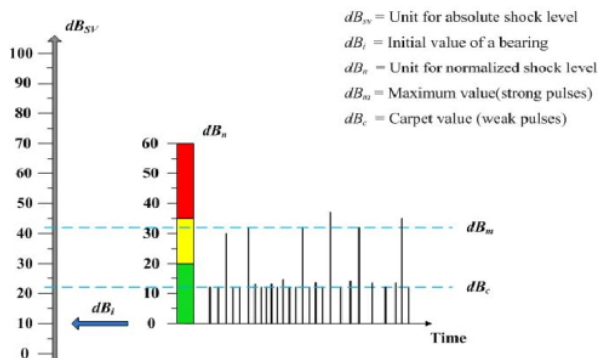


Fig.1 Various values of SPM and their range [9].

It is given by $dB = 20 \log_{10} 2000SVND0.6$ where N is the bearing rotational speed, and D represents the inner diameter of the bearing. SV denotes the shock value, which is computed by demodulation of signals of bearing vibration. The bearing operation conditions can be approximated with dB value as [10]. Table 1 represents the various values of dB for different bearing conditions.

Table 1.

Normalized shock pulse value (dB)	Bearing condition
0 – 20	Good
20 – 35	Caution (Bearing to be damaged)
> 35	Bearing damaged

The limits of the three condition regions were set empirically through the testing of bearings under variable operating conditions in the 1970s. Among all three regions, SPM has been most successfully established to get reliable identification of the working conditions of rolling element bearings and lubrication conditions. Moreover, these limits have been widely accepted in industries because of their successful application Figure 2 shows the various types of lubrication failure shock pulse range.

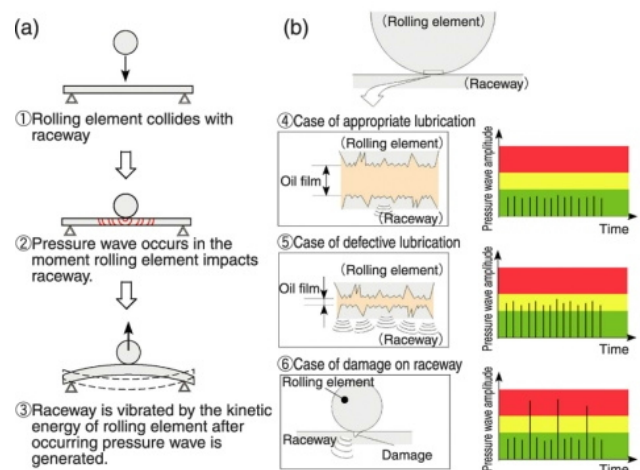


Fig. 2 Various type of lubrication failure shock pulse range [11].

REQUIRED INSTRUMENTS AND MATERIALS

The experimentation has been performed Shock Pulse Meter T-2000 tester with accelerometer and Shock Pulse Meter 43A instruments available in noise & vibration lab in Industrial Tribology and Maintenance Centre at Indian Institute of Technology, Delhi. The detailed information regarding the aforesaid instruments are as under:

Shock Pulse Meter T – 2000 tester with accelerometer

The T – 2000 is switched on by pressing any of the five function keys. Power down function is automatic and happens approx 30 seconds after a function key is pressed. If the instrument fails to power down within one minute, press the unmarked master reset key. The TNC connector SPM(9) is used for shock pulse transducers (hand held probe, transducer with quick connector or measuring cable connecting to a measuring terminal).

The BNC connector VI B(11) is used for the vibration transducer. SPM and VI B transducer may be connected simultaneously. The key SPM /VI B switches between shock pulse meter and vibration measuring mode. The connector TAC (10) receives both the tachometer probe and the earphone. The tachometer mode is active while the tachometer probe is connected the ear phone mode is active while the earphone is connected.

Memory

When the T – 2000 powers down or is switched to other measuring mode the following reading is remembered.

- The last shock pulse reading (dBm , dBc and dBi setting)
- The last vibration reading (vibration severity and machine class setting)
- The last rpm reading

In addition, changing instrument settings after pressing the key will not change the last reading.

Shock pulse measurements

Normalized shock pulse readings show the bearing condition. These require the input of the bearing's initial value dB_i the measuring unit is dB_n (normalized shock value). The T – 2000 accepts dB_i value from -9 to $+40$. Un-normalized reading shows the magnitude of the shock signal in absolute

terms. The measuring unit is $dBsv$ (decibel shock value). The dB_i is set to (two, hyphen which is the setting below -9). Setting the initial dB_i - the initial value dB_i can be changed in three different ways, illustrated with direct change of the dB_i , setting RPM and shaft diameter. Measure parameter:-carpet value of shock pulse (dBc), maximum value of shock pulse (dBm).

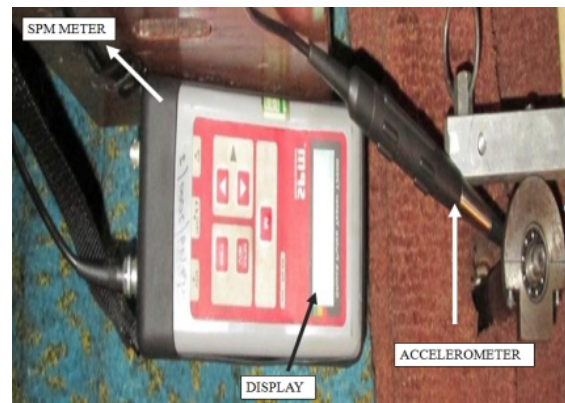


Fig. 3 Shock Pulse Meter T – 2000 with accelerometer.

Shock Pulse Meter (43A)

Shock pulse measurements begin at the lowest reference level, the thumb wheel is turned clockwise to dB_n . The shock pulse meter registers now the large number of minor shock pulses which occur in every rotating ball and roller bearing. Their minor shock pulse constitutes the noise carpet of the bearing. These are generated in very rapid sequence. The sound pulse from the instrument follows each other so closely that they form an even continuous tone.

When the bell of the strength indicator is placed higher, fewer people are able to make it ring. When the thumb wheel on the shock pulse meter is turned further counter clockwise, the number of sound pulses decreases. The range b/w noise carpet and peak value is of minor interest for shock pulse measurements. By turning the thumb wheel from the starting point ($0\ dB_n$) counter clockwise, it tries to find the level where the sound just changes from a

continuous tone to an intermittent tone. This change makes the upper limit of the noise carpet. The corresponding shock pulse value dBc (decibel carpet value) is the reading of the instruments dial.

The carpet value dBc is a measure of the normal surface roughness which exists even in perfect bearing. A bearing is of good operating condition normally has a carpet value below 10 dBn . This shock pulse meter consists of transducer with probe type 10777 max 60 $dBsv$ (made in Sweden) and a microphone.

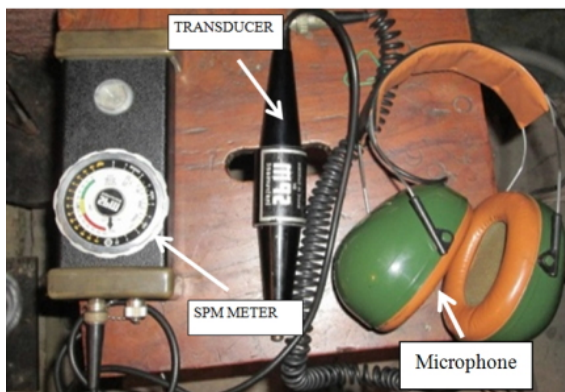


Fig. 4 shock pulse meter 43A with transducer and microphone.

SKF ball bearing

For calculating the data at different operation ball bearing conditions, skf ball bearing 6002 was used. Figure 5 shows the photographic view of the ball bearing with fresh and burnt grease. The details of the same are as under:

skf ball bearing 6002 new

without lubrication

(both end opened and dry),

Bore dia – 15 mm; Outer dia (D)

– 32 mm; Thickness(B)

– 9 mm

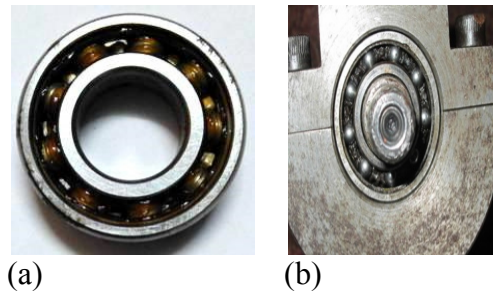


Fig. 5 SKF – 6002 ball bearing (a) fresh grease and (b) burnt grease.

Grease

Li based grease, fresh and burnt type grease, has been used for the experimentation. Figure 6 shows the pictorial view of fresh and burnt grease.

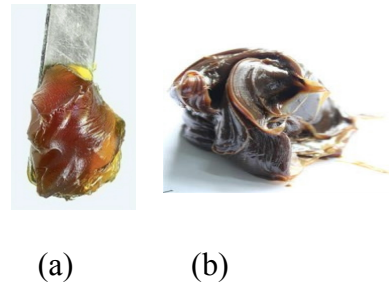


Fig. 6 Li based (a) fresh and (b) burnt grease.

EXPERIMENTAL SETUP

Experimentation was performed with different percentage values of fresh grease and burnt grease used in the ball bearing on both Shock Pulse (SP) Meter $T - 2000$ and 43A. At first, the data was collected with the help of SP meter model no. $T - 2000$ and it was further followed by verifying it with SP meter 43A along with microphone where human skill also plays an important role. Figures 7 and 8 represent the schematic and pictorial views of the experimental set-up.

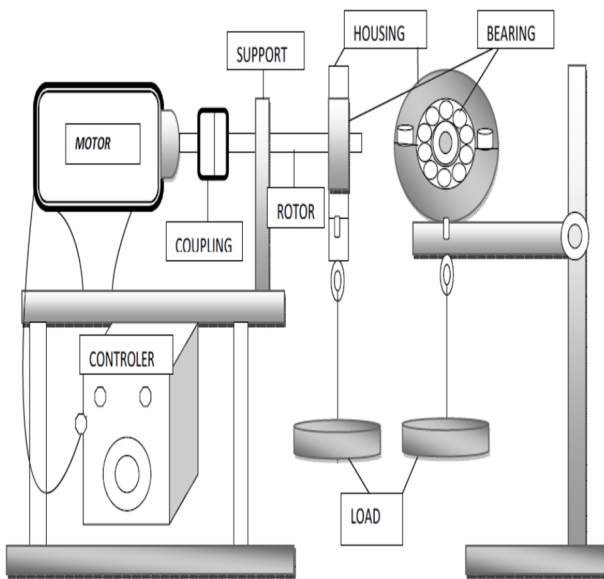


Fig. 7 Experimental set-up for testing of ball bearing with SPM.

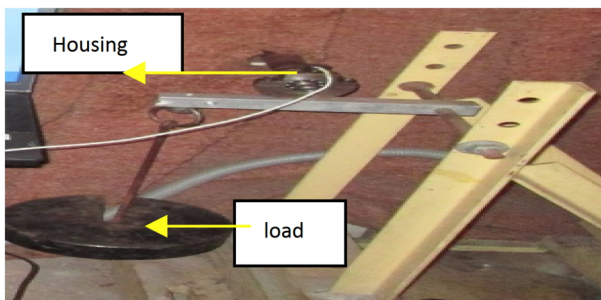


Fig. 8 Test rig set-up with loading system.

EXPERIMENTATION

The test samples have been prepared for the experiment. At first, the quantity of the fresh grease was measured with the help of ball bearing formula which is given below –
 Quantity of grease (gm) = $.005 \times D \times B$, D- Outer dia (mm), B-Thickness of bearing (mm).

In this experiment:

Outer diameter = 32 mm, Thickness of bearing = 9 mm

Qty of grease = $.005 \times 32 \times 9 = 1.44 \text{ gm.} = 1440 \text{ mg.}$

Table 2.

S. No.	% Quantity of grease	Qty (mg)	Load applied (kg)	rpm of Bearing
1.	0%	Dry running	10	300,500,1000, 1200,1500
2.	25%	360mg	10	300,500,1000, 1200,1500
3.	50%	720mg	10	300,500,1000, 1200,1500
4.	75%	1080mg	10	300,500,1000, 1200,1500
5.	100%	1440mg	10	300,500,1000, 1200,1500
6.	100% (Burnt grease)	1440mg	10	300,500,1000, 1200,1500

Table 2 represents the different quantities of the grease taken for the experimentation. Then, a load of 10 kg was applied on the running state of the bearing. The rpm of the ball bearing were kept at 300, 500, 1000, 1200 and 1500 respectively. The rpm of the bearing was obtained with the SP meter instrument and consequently the speed of the rotor shaft was confirmed with the help of laser type speedometer.

EXPERIMENTAL RESULTS

Table 3 and Table 4 show the experimental results for each type of test samples, as discussed in Table 2. These tables also include the shock pulse value dBc (carpet value) and dBm (maximum value). Figure 9 and 10 show the relative graphs of effect of dBc and dBm on Qty of grease and speed (rpm). The load was fixed at 10 kg for both the cases.

Effect of Shock pulse carpet value (dBc) on Qty of grease and Speed (rpm)

Shock pulse carpet value (dBc) was taken from the SP meter $T - 2000$ at different samples.

Table 3.

Speed (rpm)	300	500	1000	1200	1500
Grease 0%	17	19	17	18	19
Grease 25%	16	16	15.5	15	15
Grease 50%	10	11	8	9	9
Grease 75%	9	7.5	7.5	8	7
Grease 100%	8	7	7	7.5	7

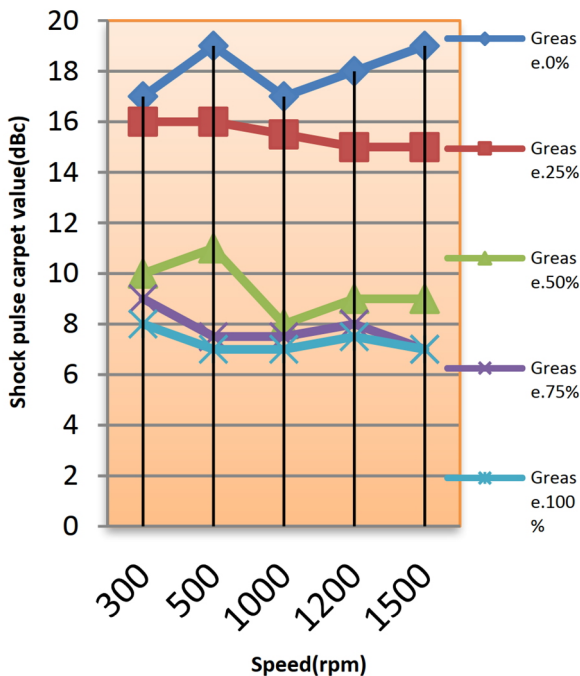


Fig. 10 Effect of qty of grease on shock pulse carpet value (dBc) and rpm.

Shock pulse maximum value (dBm)

Shock pulse maximum value (dBm) was taken from the SP meter T – 2000 at different samples.

Table 4.

Speed (rpm)	300	500	1000	1200	1500
Grease 0%	35	35	36	35	35
Grease 25%	30	34	33.5	31	32
Grease 50%	28	26	26.5	27	27
Grease 75%	28	25.5	23	23.5	24.5
Grease 100%	24	25	22	24	24

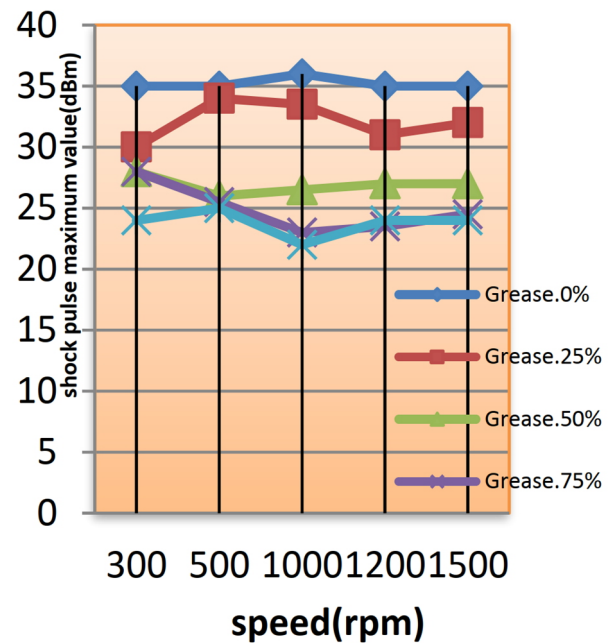


Fig. 11 Effect of qty of grease on shock pulse maximum (dBm) and rpm.

Table 5 shows the shock pulse carpet values was taken at the speed of 1000 rpm at different samples and plot the graph among these values. The value of dBc was taken on the different % of grease with fixed speed 1000 rpm.

Table 5.

Lubricant %Applied(mg)	0%	25%	50%	75%	100%
dBc	17	15.5	8	7.5	7

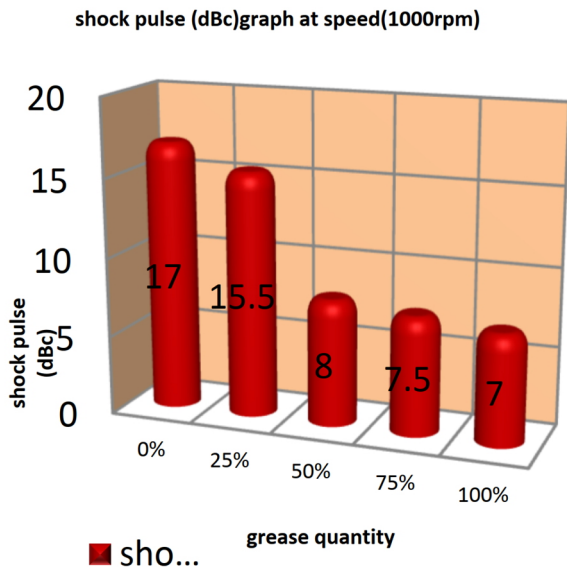


Fig. 12 graph between shock pulse (dBc) and increasing % of lubricant (grease) on 1000rpm.

Table 6 shows the shock pulse maximum was taken at the speed of 1000 rpm at different samples and plot the graph among these values. The value of dBm was taken on the different % of grease with fixed speed 1000 rpm.

Table 6.

Lubricant %Applied(mg)	0%	25%	50%	75%	100%
dBm	36	33.5	26.5	23	22

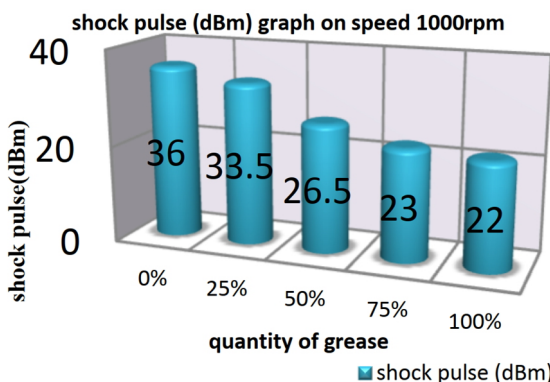


Fig. 13 graph between shock dBm and increasing % of lubricant (grease) on 1000 rpm.

The value of shock pulse dBc and dBm of heated grease (brunt) has been taken for 100% applied required grease in to the test bearing, at different rpm at fixed load 10kg.

Table 7.

Speed (rpm)	300	500	1000	1200	1500
dBc	23	24	23	23	21
dBm	34	36	34	35	26

Figure 14–17 show the comparative graphs between fresh grease & burnt grease on 100% lubricated condition with varying operative speed of 300, 500, 1000, 1200, 1500 rpm on SPM parameter dBc.

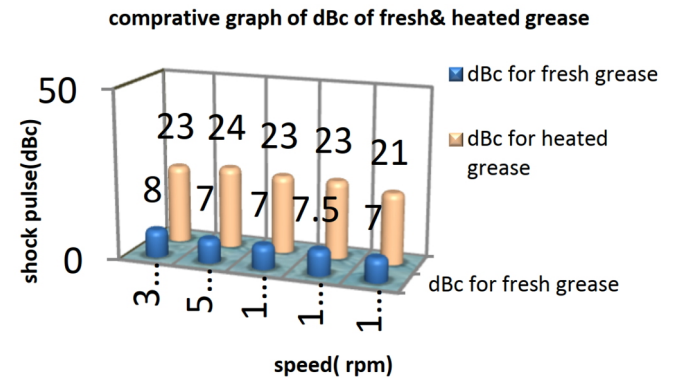


Fig. 14 comparative graph of dBc between fresh & heated grease.

Comparative graph between fresh grease & heated grease on 100% lubricated condition with varying operative speed of 300, 500, 1000, 1200, 1500 rpm on SPM parameter dBm.

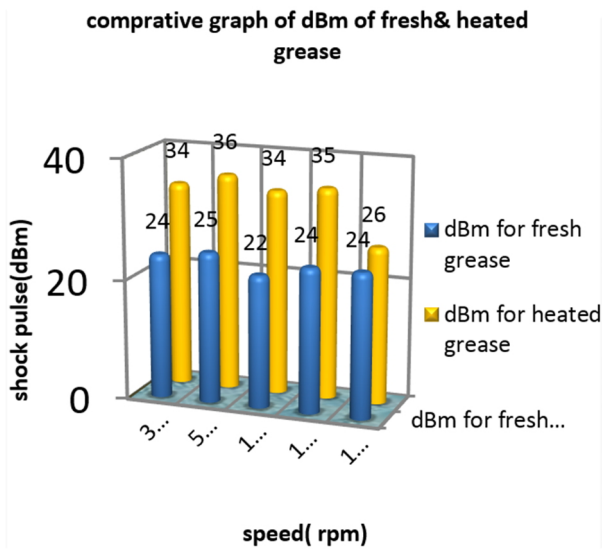


Fig. 15 comparative graph of dBm between fresh & heated grease.

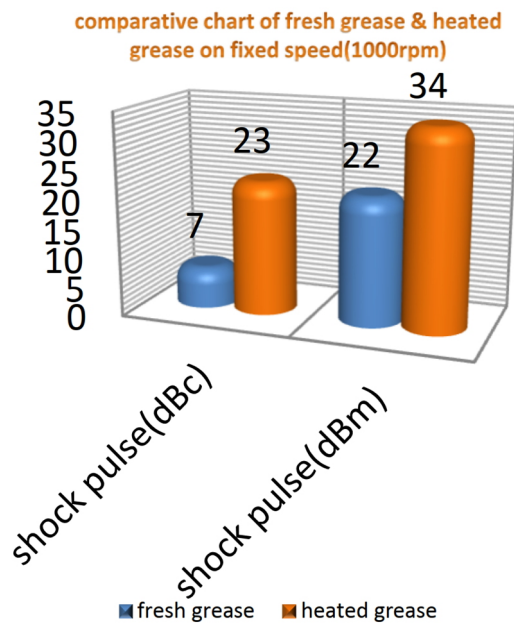


Fig. 16 comparative graph of dBc & dBm between fresh & heated grease on 1000 rpm.

RESULTS & DISCUSSION

With increasing the % of required quantity of grease from 0% – 100% reducing the shock pulse carpet value (*dBc*) from 19 – 7 and shock pulse maximum value (*dBm*) from 35 – 24 at the 1500 rpm at a fixed load 10 kg that mean if the bearing running without sufficient quantity of grease then the value of both shock pulse (*dBm* & *dBc*) getting more

comparative graph and the value see Table 5–6 and Fig 10–11.

Type of grease and condition of grease also play important role, here we see the value of shock pulse carpet value (*dBc*) from 7.5 – 23 and shock pulse maximum value (*dBm*) from 24 – 35 at the 1000 rpm at a fixed load 10 kg the value is min when we using fresh grease see Table 7 and graph Fig. 14–16.

So, we can say the shock pulse methods also play very important role for condition monitoring of grease quality.

CONCLUSIONS

From this research work, the following conclusions can be drawn –

1. It is found that when the bearing is running at 1000 rpm speed and the quantity of applied grease is increased from 25% to 50%, the value of *dBc* changes from 15.8 to 8).
2. The value of *dBm* changes from 33.5 to 26.5. After that the values of shock pulse (*dBc* & *dBm*) for the fresh grease applied 100 % of total required amount and for the bad quality (burnt) grease (100% of total amount) at the speed of 1000 rpm have been compared.
3. It is found that the values of *dBc* and *dBm*, when the fresh grease was used, are 7 and 22 respectively. The values of *dBc* and *dBm* are 23 and 34 respectively, when the burnt grease is applied.
4. The shock pulse methods are effective for the detection of insufficient quantity of grease as well as the quality of grease .

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