International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Experimental Evaluation of Temperature Difference on Needle roller Bearing using Different Loads and Grades of oil Lubricant

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Abstract- Needle roller bearings are mostly used in most of the rotating machines because of their accuracy and proper working operation. The temperature difference of bearing is the most important factor for rotating machines which should be as low as possible. In this paper, the experimental work has been performed on needle roller bearing with different loads (20, 40, 60, 80 and 100 N) applied on it and with six lubricants of different viscosity grades (ISO 10, 32, 46, 68, 100 and 120). It is found that the temperature of test bearing is increased with increasing of applied load in every oil lubricant and the temperature difference is decreased from ISO 10 oil lubricant to ISO120 oil lubricant. It is also found that the speed of shaft maintained constant for the oil lubricants of ISO 10 to ISO100 but the speed of shaft is decreased using oil lubricant of ISO 120 due to high frictional force.

Keywords: Different Loads, Needle Roller Bearing, Temperatures difference

I. INTRODUCTION

Bearings are machine elements that constrain the relative motion between two elements to obtain the desired motion while reducing friction between the moving parts. Various types of lubricants are used to reduce friction and ascertain smooth operation of these bearings. The study is an attempt to understand the thermal properties of a needle bearing experimentally. These are special types of bearings with needle-like long cylindrical rollers. Due to the larger length of the cylinder, the roller bearings have a larger surface area, which substantially enhances their load carrying capacity. Several studies have been carried out to understand the thermal and load bearing capacities of roller bearings. The lubrication of bearings plays the major role in determining its friction reduction capabilities. Several studies have been carried out in order to achieve optimum lubrication of these bearings in order to reduce friction and ensure smooth operation of machine elements. A thorough study of several components of a bearing was performed by R. A. E. Wood (1972). Fangbo Ma et.al (2016) performed the thermal analysis of grease-lubricated roller bearings and developed a mathematical model for calculating the heat generation rate of grease-lubricated spherical roller bearings. G.E. Morales-Espejel et.al (2014) analysed the film thickness in grease lubricated rolling bearings and showed measurements of film thickness in grease lubricated contacts for different reases. They concluded from their experiments that grease produced the film thicknesses at low speeds. Guillermo E. Morales Espejel and Antonio Gabelli, (2016) showed a model for the life of rolling bearing with surface and subsurface survival which was performed to separate the survival probability of the raceway surface during the rolling contact. I. Linares Arregui and B. Alfredsson (2010) analysed the elastic–plastic characterization of roller bearing steel, monotonic and cyclic deformations in bainitic roller bearing steel at different temperature and studied its effect on the working of the bearing. Jafar Takabi and M.M. Khonsari performed the thermal analysis of bearings and analysed the evolution of temperature in a bearing with oil-bath lubrication system both experimentally and analytically. Several tests on bearings were conducted to measure the frictional torque, transient temperature of the outer race, oil and housing. Jafar Takabi and M.M. Khonsari, (2015) studied the dynamic performance of roller bearings operating at high loads and low rotational speeds and different surface roughness values were measured during the test. The numerical results showed the variation of the film thickness, wear rate and heat generation between the rollers and the raceways. Siyuan Ai et.al (2015) studied the temperature variation during the operation of roller bearings using the thermal network method in which double-row tapered roller bearings lubricated with grease were used. The results showed the high temperature rise at roller large end and flange contacts due to large rotating speed. M. Marquart et.al (2013) tried to enhance the life of bearing by the redesigning of the cage using numerical simulation. They investigated several materials, coatings and the transfer of additional lubrication during the primary contact between rolling body and race way. Jing Liu et.al (2018) investigated the friction torque of roller bearing with the roundness error using needle roller bearings. The friction torque of rolling bearings was calculated analytically and hence the efficiency of the rotary machinery was determined.

Jingqiu Wang et.al (2017) investigated the performance of rolling bearings under conditions of starved lubrication and studied the lubricant retaining effect of porous polyimide on the performance of rolling bearings under starved lubrication conditions.

Manuscript published on 30 August 2019.
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They observed that the pore density increases uniformly due to the increase of porosity, which bears a positive correlation with the performance of the bearings. Ke Yan et.al (2017) investigated the effect of sealing condition of high-speed ball bearing and showed the lubrication performance of bearing at high speeds. The results showed that lubricating oil easily accessed the contact region inside the bearing cavity with the help of seal structure. The temperature and pressure distribution of bearing at high rotation speed with dual-nozzle was superior to single-nozzle were also analysed. Konstantinos D. Bakoglidis et.al (2017) analysed the rolling performance of bearing components in different lubrication regimes using carbon nitride coated roller bearings with varying rolling speeds. They found that the presence of coatings was eliminated during operation condition of bearing and the friction coefficients significantly reduced. Philipp Bergmann et.al (2018) performed the modelling of mixed lubrication regime and studied the effects of major aspects of statistical contact modelling. Our work presents an experimental investigation of temperature difference on needle roller bearing using different loads such as 20, 40, 60, 80 and 100 N and oil lubricant of six different grades ISO 10, 32, 46, 68, 100 and 120. The temperature difference must be very less with maintained speed of rotating shaft during running period of bearing.

II. Experimental Setup

Experimental set up as shown in Fig.1 has been used to perform the required tests on the needle roller bearing (202512), loaded with 20, 40, 60, 80 and 100 N. The solid shaft is rotated at constant speed of 920 rpm by using V Belt, two cone pulleys and single phase induction motor of ½ HP shown in Fig.2. Eight rectangular blades are welded on the hub which mounted on the end of solid shaft. Six different viscosity grades (ISO 10, 32, 46, 68, 100 and 120) oil lubricants are used in test bearing to record the temperature during the period of experiment.

Fig.1. Experimental Setup

Fig.2. V Belt, two cone pulleys and single phase induction motor of ½ HP

III. Proposed Methodology

The needle roller bearing (202512) is used in experimental test which loaded with five different loads 20, 40, 60, 80 and 100 N and using six different viscosity grades (ISO 10, 32, 46, 68, 100 and 120) oil lubricants. A block Diagram of experimental test is shown in Fig.3. A flow Chart of experiment of test bearing is shown in Fig.4. The experiment is carried out for 3 hours of running of test bearing with interval of 10 minutes for every load and every oil lubricant.

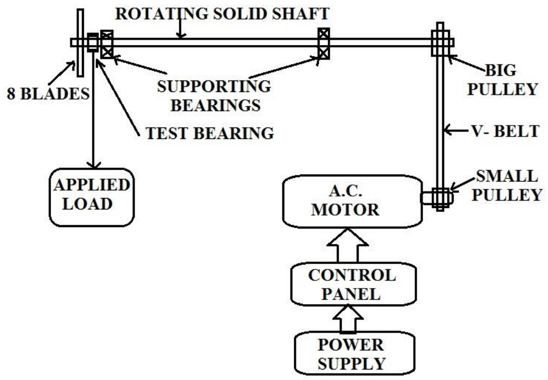

Fig.3 Block Diagram

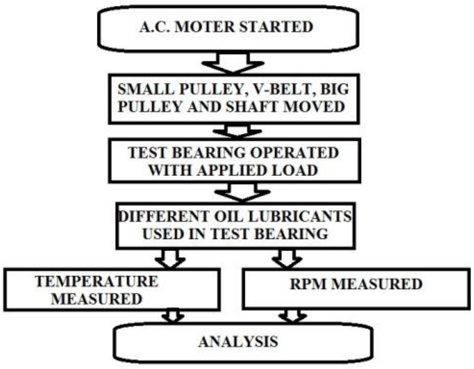

Fig.4. Flow Chart

IV. RESULT ANALYSIS

Oil temperature of test bearing for different loads was recorded during the experimental run at a constant rpm and several interesting results were drawn. The temperature showed a positive correlation with the time elapsed in all loading condition for all grades of oil. A comparative study was performed to understand this variation by plotting the temperature vs time plots for all the grades of oil, as can be seen in Fig.5-10. The plots are linear in all cases up to around 160 minutes after which they reach a saturation point and the temperature becomes constant. Another important observation can be made from the plots that the temperature keeps increasing as we increase the load on the bearing. The main reason for this is that as the load on the bearing increases, the normal force between the shaft and the bearing increases accordingly which in turn results in the increment of the frictional force between the bearing and the shaft. This frictional force is released as a heat loss and hence results in the rise of temperature upon increasing the load, which can be prominently observed in Fig.5-10.

1) Oil lubricants of different viscosity grades

Six different viscosity grades (ISO 10, 32, 46, 68, 100 and 120) oil lubricants are used in our experimental work as described below one after another:

1.1) Viscosity grade (ISO 10)

It is found that minimum temperature of oil lubricant of Viscosity grade (ISO 10) is 28.1 °C at 10 minutes of run of test bearing with applied load of 20 N and maximum temperature of oil lubricant of Viscosity grade (ISO 10) is 44.5°C at 180 minutes of run of test bearing with applied load of 20 N. Therefore, the difference between maximum and minimum temperature is 16.6 °C. Similarly, the difference between the maximum and minimum temperature for five different load on needle roller bearing of 20, 40, 60, 80 and 100 N are 16.4 °C, 17.8 °C, 17.1 °C, 16.1 °C and 16.5 °C respectively.

Table-I: Oil Temperature for viscosity grade (ISO 10) with different loads using needle roller bearing

Observation Nos.	Time (minutes)	Oil Temp. (°C) at 20 N	Oil Temp. (°C) at 40 N	Oil Temp. (°C) at 60 N	Oil Temp. (°C) at 80 N	Oil Temp. (°C) at 100 N
1	10	28.1	29.1	30.8	32.1	33.7
2	20	29.3	30.3	31.5	33.5	34.5
3	30	30.2	31.2	32.6	34.8	35.6
4	40	31.1	32.5	33.7	35.6	36.8
5	50	32.4	33.6	35.9	36.7	37.9
6	60	33.9	34.9	36.8	37.8	38.8
7	70	35.5	36.7	37.4	38.6	39.8
8	80	36.5	37.3	38.4	39.5	40.3
9	90	37.2	38.6	39.5	40.5	41.6
10	100	38.5	39.7	40.2	41.9	42.9
11	110	39.5	40.2	41.5	42.8	43.7
12	120	40.1	41.6	42.9	43.9	44.5
13	130	41.2	42.9	43.5	44.6	45.7
14	140	42.3	43.7	44.2	45.8	46.8
15	150	43.4	44.6	45.6	46.8	47.9
16	160	44.5	45.8	46.8	47.9	48.8
17	170	44.5	46.9	47.9	48.2	50.2
18	180	44.5	46.9	47.9	48.2	50.2

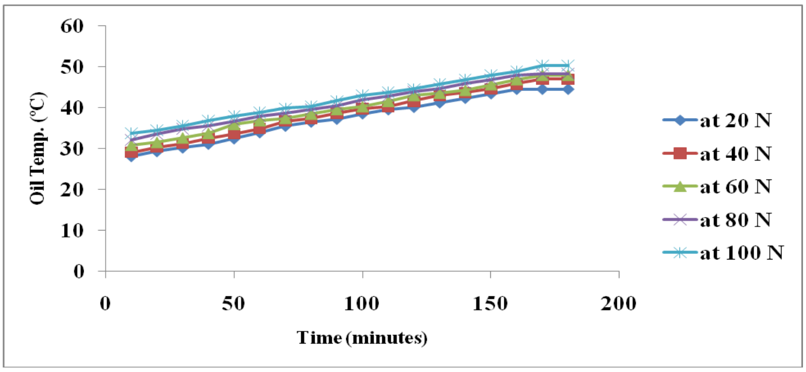

Fig.5. Oil Temperature for viscosity grade (ISO 10) with different loads using needle roller bearing

1.2) Viscosity grade (ISO 32)

It is found that minimum temperature of oil lubricant of Viscosity grade (ISO 32) is 30.4ºC at 10 minutes of run of test bearing with applied load of 20 N and maximum temperature of oil lubricant of Viscosity grade (ISO 32) is 46.2ºC at 180 minutes of run of test bearing with applied load of 20 N. Therefore, the difference between maximum and minimum temperature is 15.8 ºC. Similarly, the difference between the maximum and minimum temperature for five different load on needle roller bearing of 20, 40, 60, 80 and 100 N are 15.8 ºC, 15.8 ºC, 15.8 ºC, 15.8 ºC and 15.8 ºC respectively.

Table-II: Oil Temperature for viscosity grade (ISO 32) with different loads using needle roller bearing

Observation Nos.	Time (minutes)	Oil Temp. (ºC) at 20 N	Oil Temp. (ºC) at 40 N	Oil Temp. (ºC) at 60 N	Oil Temp. (ºC) at 80 N	Oil Temp. (ºC) at 100 N
1	10	30.4	31.8	32.5	34.3	35.9
2	20	31.5	32.6	33.6	35.9	36.9
3	30	32.5	33.5	34.8	36.5	37.5
4	40	33.6	34.8	35.6	37.8	38.6
5	50	34.8	35.6	36.5	38.5	39.5
6	60	35.6	36.6	37.8	39.6	40.3
7	70	37.9	38.9	38.9	40.2	41.6
8	80	38.8	39.1	39.6	41.2	42.8
9	90	39.5	41.2	42.3	43.5	43.8
10	100	41.3	42.1	43.6	44.6	45.2
11	110	42.5	43.6	44.5	45.8	46.3
12	120	43.6	44.5	45.6	46.8	47.8
13	130	44.1	45.1	46.3	47.2	48.9
14	140	44.9	45.9	47.1	48.2	49.1
15	150	45.3	46.3	47.8	49.1	49.9
16	160	45.8	46.8	48.1	49.8	50.3
17	170	46.2	47.6	48.3	50.1	51.7
18	180	46.2	47.6	48.3	50.1	51.7

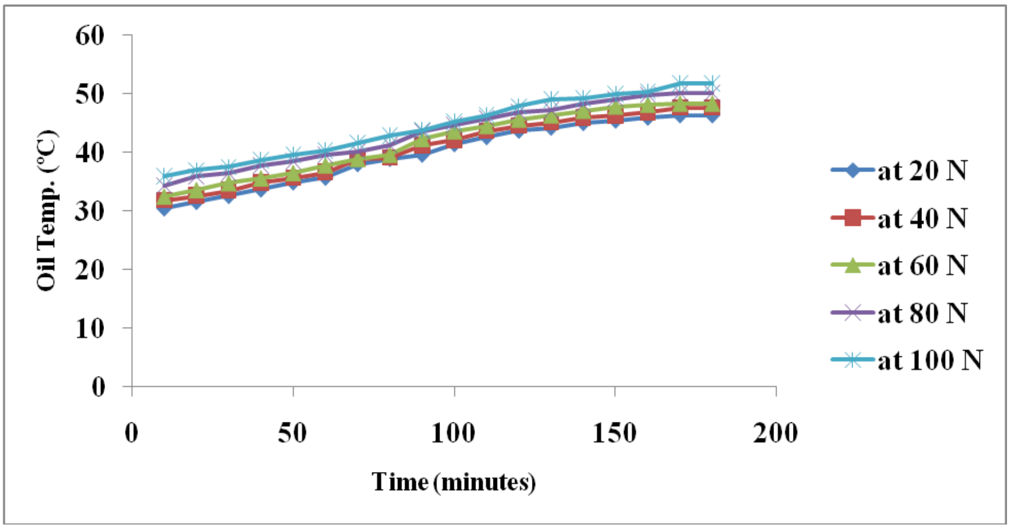

Fig.6. Oil Temperature for viscosity grade (ISO 32) with different loads using needle roller bearing

1.3) Viscosity grade (ISO 46)

It is also found that minimum temperature of oil lubricant of viscosity grade (ISO 46) is 31.9ºC at 10 minutes of run of test bearing with applied load of 20 N and maximum temperature of oil lubricant of viscosity grade (ISO 46) is 47.3ºC at 180 minutes of run of test bearing with applied load of 20 N. Therefore, the difference between maximum and minimum temperature is 15.4 ºC. Similarly, the difference between the maximum and minimum temperature for five different load on needle roller bearing of 20, 40, 60, 80 and 100 N are 15.4 ºC, 15.4 ºC, 15.4 ºC, 15.4 ºC and 15.4 ºC respectively.

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Table-III: Oil Temperature for viscosity grade (ISO 46) with different loads using needle roller bearing

Observation Nos.	Time (minutes)	Oil Temp. (ºC) at 20 N	Oil Temp. (ºC) at 40 N	Oil Temp. (ºC) at 60 N	Oil Temp. (ºC) at 80 N	Oil Temp. (ºC) at 100 N
1	10	31.9	33.7	36.4	36.8	38.2
2	20	32.4	34.9	37.8	37.9	39.6
3	30	33.6	35.8	39.6	39.9	40.2
4	40	34.5	36.5	40.1	40.9	41.2
5	50	35.8	37.9	41.3	41.8	42.3
6	60	36.8	38.9	42.6	42.9	43.5
7	70	37.9	40.1	43.5	43.8	44.6
8	80	38.5	41.3	44.6	44.9	45.9
9	90	39.5	42.5	45.2	45.6	46.3
10	100	40.1	43.6	46.3	46.9	47.8
11	110	41.2	44.5	47.8	48.1	48.6
12	120	42.6	45.8	48.9	49.2	49.8
13	130	43.5	46.9	49.1	49.9	50.1
14	140	44.8	47.8	49.7	50.1	51.2
15	150	45.9	48.1	50.2	50.8	52.1
16	160	46.6	48.7	50.9	51.7	52.8
17	170	47.3	49.1	51.8	52.2	53.6
18	180	47.3	49.1	51.8	52.2	53.6

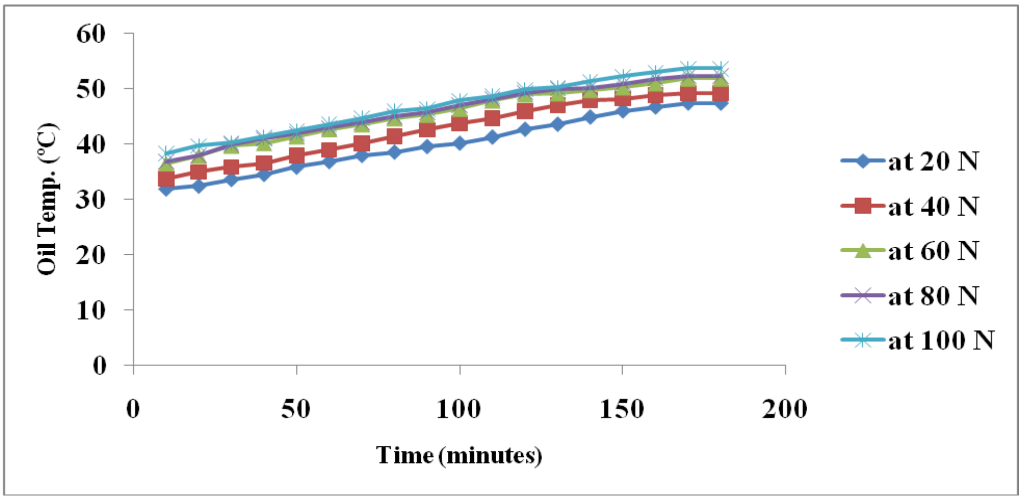

Fig.7. Oil Temperature for viscosity grade (ISO 46) with different loads using needle roller bearing

1.4) Viscosity grade (ISO 68)

It is found that minimum temperature of oil lubricant of viscosity grade (ISO 68) is 33.8ºC at 10 minutes of run of test bearing with applied load of 20 N and maximum temperature of oil lubricant of viscosity grade (ISO 68) is 48.9ºC at 180 minutes of run of test bearing with applied load of 20 N. Therefore, the difference between maximum and minimum temperature is 15.1 ºC. Similarly, the difference between the maximum and minimum temperature for five different load on needle roller bearing of 20, 40, 60, 80 and 100 N are 15.1 ºC, 15.1 ºC, 14.9 ºC, 15.1 ºC and 15.1 ºC respectively.

Table-IV: Oil Temperature for viscosity grade (ISO 68) with different loads using needle roller bearing

Observation Nos.	Time (minutes)	Oil Temp. (ºC) at 20 N	Oil Temp. (ºC) at 40 N	Oil Temp. (ºC) at 60 N	Oil Temp. (ºC) at 80 N	Oil Temp. (ºC) at 100 N
1	10	33.8	35.1	38.2	39.5	40.6
2	20	34.6	36.5	39.6	40.1	41.8

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3	30	35.8	37.8	40.1	41.5	42.3
4	40	36.6	38.5	41.6	42.3	44.5
5	50	37.8	39.8	42.5	44.8	45.8
6	60	38.9	40.1	43.8	45.7	46.7
7	70	39.9	41.6	44.5	45.9	47.9
8	80	40.1	42.8	45.8	46.8	48.7
9	90	41.5	43.6	46.7	47.9	49.7
10	100	42.3	44.5	47.1	48.6	50.1
11	110	43.5	45.6	48.8	49.8	50.9
12	120	44.6	46.8	49.1	50.2	51.6
13	130	45.6	47.6	49.8	51.1	52.8
14	140	46.8	48.9	50.1	51.6	53.9
15	150	47.1	49.1	50.5	52.3	54.1
16	160	47.9	49.8	51.9	53.9	54.9
17	170	48.9	50.2	53.1	54.6	55.7
18	180	48.9	50.2	53.1	54.6	55.7

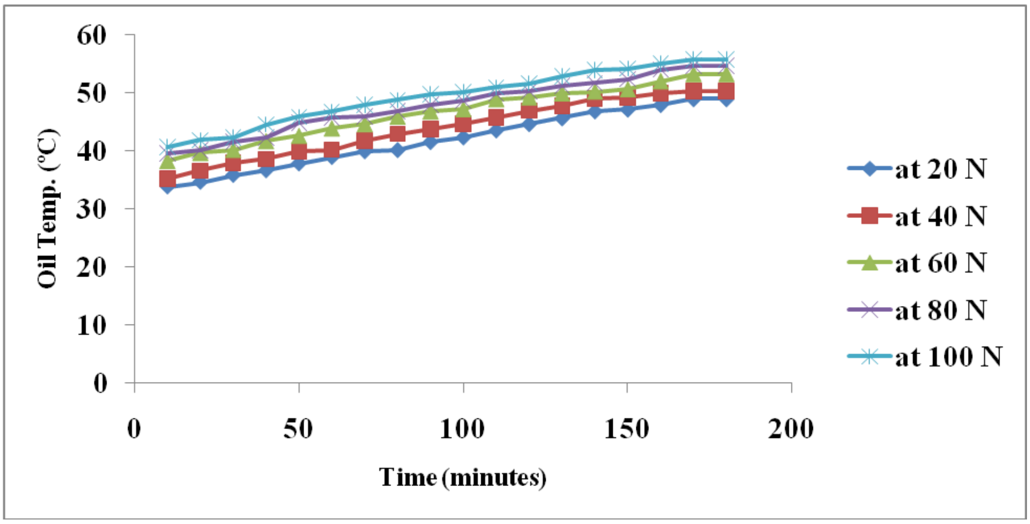

Fig.8. Oil Temperature for viscosity grade (ISO 68) with different loads using needle roller bearing

1.5) Viscosity grade (ISO 100)

It is found that minimum temperature of oil lubricant of viscosity grade (ISO 100) is 37.3°C at 10 minutes of run of test bearing with applied load of 20 N and maximum temperature of oil lubricant of viscosity grade (ISO 100) is 51.3°C at 180 minutes of run of test bearing with applied load of 20 N. Therefore, the difference between maximum and minimum temperature is 14.0 °C. Similarly, the difference between the maximum and minimum temperature for five different load on needle roller bearing of 20, 40, 60, 80 and 100 N are 14.0 °C, 13.5 °C, 14.0 °C, 14.0 °C and 13.9 °C respectively.

Table-V: Oil Temperature for viscosity grade (ISO 100) with different loads using needle roller bearing

Observation Nos.	Time (minutes)	Oil Temp. (°C) at 20 N	Oil Temp. (°C) at 40 N	Oil Temp. (°C) at 60 N	Oil Temp. (°C) at 80 N	Oil Temp. (°C) at 100 N
1	10	37.3	40.1	40.8	42.8	43.4
2	20	38.1	41.3	41.6	43.5	44.6
3	30	39.8	42.6	42.9	44.6	45.8
4	40	40.1	43.8	43.9	45.8	46.7
5	50	41.5	44.9	45.1	46.9	47.8
6	60	42.6	45.8	45.9	47.8	48.9
7	70	43.8	46.8	46.9	48.5	49.2
8	80	44.9	47.9	48.2	49.8	50.1

9	90	45.8	48.5	48.9	50.1	51.6
10	100	46.8	49.6	49.8	51.6	52.9
11	110	47.9	50.1	50.5	52.5	53.8
12	120	48.1	50.9	51.6	53.8	54.8
13	130	48.8	51.6	52.8	54.1	55.1
14	140	49.2	52.9	53.1	54.9	55.9
15	150	49.9	53.1	53.9	55.2	56.2
16	160	50.2	53.4	54.1	55.9	56.8
17	170	51.3	53.6	54.8	56.8	57.3
18	180	51.3	53.6	54.8	56.8	57.3

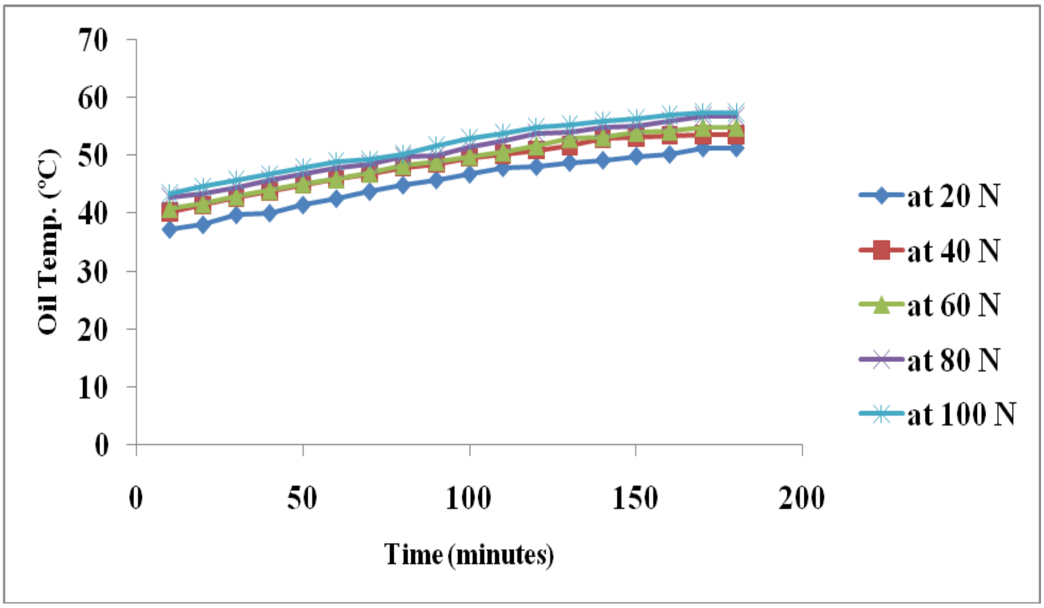

Fig.9. Oil Temperature for viscosity grade (ISO 100) with different loads using needle roller bearing

1.6) Viscosity grade (ISO 120)

It is found that minimum temperature of oil lubricant of viscosity grade (ISO 120) is 40.3°C at 10 minutes of run of test bearing with applied load of 20 N and maximum temperature of oil lubricant of viscosity grade (ISO 120) is 52.3°C at 180 minutes of run of test bearing with applied load of 20 N. Therefore, the difference between maximum and minimum temperature is 12.0 °C. Similarly, the difference between the maximum and minimum temperature for five different load on needle roller bearing of 20, 40, 60, 80 and 100 N are 12.0 °C, 11.8 °C, 11.9 °C, 11.0 °C and 12.0 °C respectively.

Table-VI: Oil Temperature for viscosity grade (ISO 120) with different loads using needle roller bearing

Observation Nos.	Time (minutes)	Oil Temp. (°C) at 20 N	Oil Temp. (°C) at 40 N	Oil Temp. (°C) at 60 N	Oil Temp. (°C) at 80 N	Oil Temp. (°C) at 100 N
1	10	40.3	42.8	43.9	46.4	48.2
2	20	41.3	43.3	44.5	47.1	49.1
3	30	42.5	44.8	45.6	48.2	50.2
4	40	43.5	45.9	46.8	49.1	51.3
5	50	44.8	46.8	47.1	50.1	52.6
6	60	45.9	47.7	48.5	51.2	53.8
7	70	46.8	48.9	49.6	52.2	54.1
8	80	47.8	49.8	50.1	52.9	54.9
9	90	48.5	50.1	51.3	53.2	55.2
10	100	49.6	51.3	52.1	53.8	55.6
11	110	50.1	52.1	52.8	54.2	56.3
12	120	50.3	52.4	53.1	54.9	56.9
13	130	50.8	52.9	53.6	55.4	57.1
14	140	51.1	53.2	54.2	55.9	58.6

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15	150	51.9	53.9	54.8	56.4	59.2
16	160	52.1	54.2	55.1	57.1	59.8
17	170	52.3	54.6	55.8	57.4	60.2
18	180	52.3	54.6	55.8	57.4	60.2

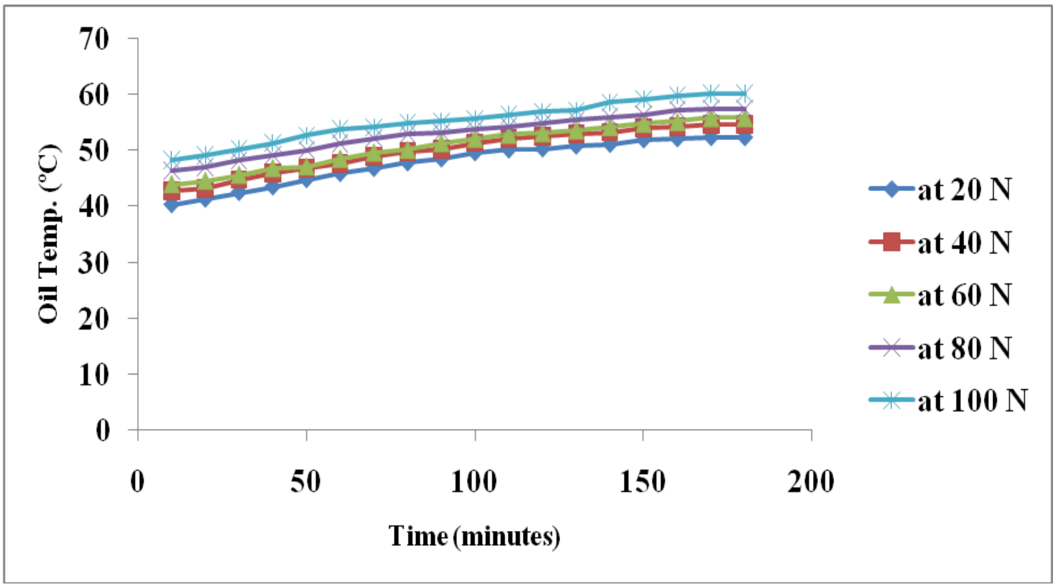

Fig.10. Oil Temperature for viscosity grade (ISO 120) with different loads using needle roller bearing

2) Temperature difference and solid shaft speed

The temperature difference is decreased from ISO 10 oil lubricant to ISO120 oil lubricant. It is found that the speed of shaft maintained constant for the oil lubricants of ISO10 to ISO100 but the speed of shaft is decreased to 860 rpm using oil lubricant of ISO 120 due to high frictional force.

Table-VII: Temperature difference with different loads using needle roller bearing

Sr. No.	Applied Loads (N)	Temp. difference (°C) for viscosity grade (ISO 10)	Temp. difference (°C) for viscosity grade (ISO 32)	Temp. difference (°C) for viscosity grade (ISO 46)	Temp. difference (°C) for viscosity grade (ISO 68)	Temp. difference (°C) for viscosity grade (ISO 100)	Temp. difference (°C) for viscosity grade (ISO 120)
1	20	16.4	15.8	15.4	15.1	14.0	12.0
2	40	17.8	15.8	15.4	15.1	13.5	11.8
3	60	17.1	15.8	15.4	14.9	14.0	11.9
4	80	16.1	15.8	15.4	15.1	14.0	11.0
5	100	16.5	15.8	15.4	15.1	13.9	12.0

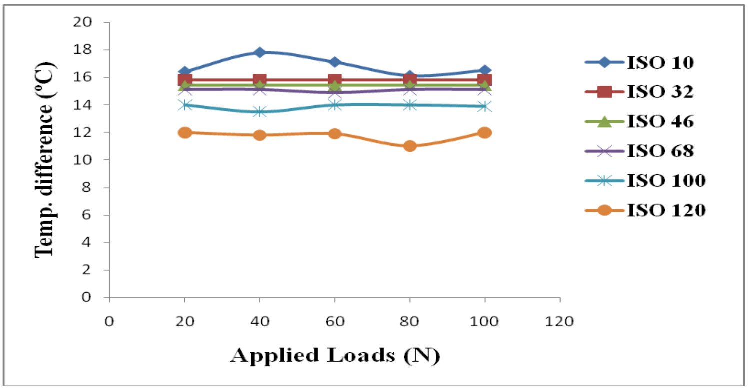

Fig.11. Temperature difference with different loads using needle roller bearing

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Table-VIII: shaft speed using oil lubricants of different viscosity grades with all applied load

Sr. No.	viscosity grades	Speed (R.P.M.) with all applied load
1	ISO 10	920
2	ISO 32	920
3	ISO 46	920
4	ISO 68	920
5	ISO 100	920
6	ISO 120	860

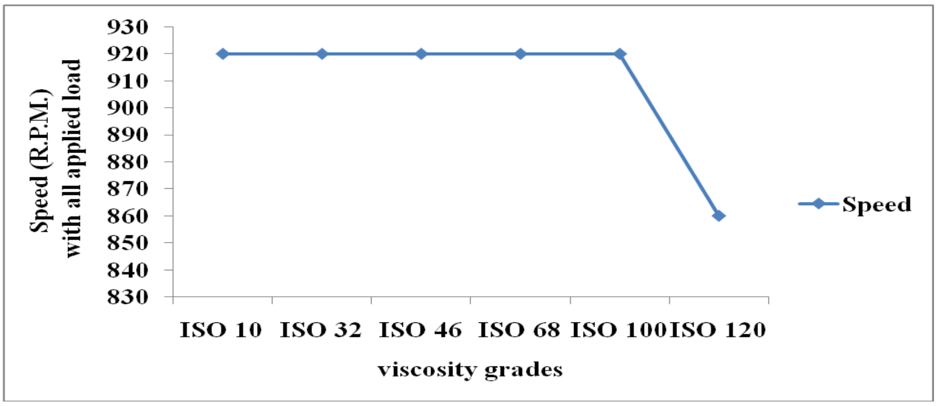

Fig.12. shaft speed using oil lubricants of different viscosity grades

V. Conclusion

The aforementioned research work was carried out to study the thermal properties of a needle bearing and its temperature difference for different lubricating oils and loads at a constant shaft speed. The result showed a positive correlation between the temperature and time elapsed for the bearing until a saturation point was reached. Also, an observation was made that the temperature increases with higher grades of lubricating oil due to the increase in frictional force. The oil temperature is increased with increasing of different five applied loads (20, 40, 60, 80 and 100 N) on test bearing using every oil lubricant viscosity grade. The temperature of oil lubricants is increased from viscosity grade ISO10 to ISO120. It has been found that the temperature difference is decreased from ISO 10 oil lubricant to ISO120 oil lubricant. The speed of rotating shaft maintained constant from oil lubricants of viscosity grade ISO10 to ISO100 but the speed of shaft is decreased to 860 rpm using oil lubricant of ISO 120 due to high frictional force. Therefore, ISO 120 and higher grades oil lubricants are not useful for needle roller bearing (202512).

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Retrieval Number: J11640881019/19©BEIESP
DOI: 10.35940/ijitee.J1164.0881019
Journal Website: www.ijitee.org

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